US Army Corps of Engineers ®
Portland District

Major Rehabilitation Evaluation Report

Columbia River at the Mouth, Oregon and Washington

Major Rehabilitation of the Jetty System at the Mouth of the Columbia River

Brubaker Aerial Survey, *Mouth of the Columbia River from Pacific Ocean* (1929).
Collection: National Archives, Pacific Alaska Region.

June 2012 Final

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Executive Summary

The mouth of the Columbia River (MCR) jetty system is in a state of structural decay. Continued deterioration, ongoing storm activity and the continued loss of sand shoal material—the foundation of each of the three MCR jetties—has positioned the jetty system for a series of frequent, costly emergency repairs. Consequently, significant modifications and repairs to the MCR jetties are necessary for the continued safe entry of ships into the Columbia River navigation channel.

Functioning jetties at the MCR support the following:

- $20 billion in international trade
- 42 million tons of cargo
- 3,500 Cargo Vessel crossings per year
- 1,400 crossings requiring more 30-foot draft or greater
- More than 40,000 jobs dependent on this trade

According to the Center for Economic Development and Research, the Columbia/Snake River navigation system is the number one export gateway for the Nation's wheat and barley exports. It is also the number one export gateway for west coast wood and mineral bulk exports and number one for automobile imports. Marine traffic passing the entrance of the Columbia River has increased by 34% from 32 million tons in 2003 to 42 million tons in 2010. All of this translates into significant benefits for not only the Pacific Northwest, but also for the national economy. The Columbia River comprises the M-84 Corridor for the Marine Highway Program. It is noted by the US Department of Transportation as a truck bottleneck resulting in up to 750,000 truck delay hours and an area of major rail congestion. The marine highway serves to reduce the congestion

The primary function of the MCR project is to maintain the navigation channel for deep draft shipping. The secondary function evaluated in the structure rehabilitation effort is to significantly extend the life and reliability of the jetties in order to ensure the primary function.

The MCR jetty system consists of three rubble-mound jetties, with a total originally authorized length of 10.2 miles, constructed from 1885-1939 on massive tidal shoals to secure consistent navigation through the coastal inlet. The inlet morphology has been changing ever since. After decades of storm activity, the tidal shoals of each jetty's foundation have been modified due to erosion.

An analysis was completed that evaluated the causes and problems associated with the current structural instability of the MCR jetty system. This analysis resulted in a recommendation to improve structural reliability, to extend functional life, and most significantly, to maintain deep-draft navigation. Each of the three jetties was analyzed independently in order to define the scope of this major rehabilitation effort. The evaluation report outlines the coastal processes affecting jetty reliability, summarizes the sequence of events leading to the present condition of the jetties, and describes their structural condition. A risk-based, life-cycle analysis was used to examine jetty performance (past and future) and develop jetty modification alternatives through a phased strategy for jetty repair.

Beaches on the ocean sides of the North and South jetties, formed originally as a result of jetty construction, have been receding and thus exposing previously protected jetty sections to storm waves at the beach line. In the absence of specific and immediate repair actions, the jetties and sand shoals upon which they rest will further deteriorate, increasing the likelihood of a jetty breach and immediate impact to the navigation channel and commercial deep draft access to the Columbia River port facilities. Recent interim jetty repairs have addressed some of the immediate critical needs. For example, in 2007 approximately $19M was expended on repairs to the South Jetty. Additional jetty repairs will be necessary to address critical near- and long-term maintenance needs and to reduce the potential need for emergency repairs and/or emergency dredging and the impacts that result to navigation.

Development of this report applied the recent *Lessons Learned* resulting from Hurricanes Katrina and Rita. They are as follows:

Point 1 – Employ Integrated, Comprehensive and Systems-Based Approach
Point 2 – Employ Risk-Based Concepts in Planning, Design, Construction, Operations and Maintenance
Point 3 – Continuously Reassess and Update Policy for Program Development, Planning Guidance, Design and Construction Standards
Point 4 – Dynamic Independent Review
Point 5 – Employ Adaptive Planning and Engineering Systems
Point 6 – Focus on Sustainability
Point 7 – Review and Inspect Completed Works
Point 8 – Assess and Modify Organizational Behavior
Point 9 – Effectively Communicate Risk
Point 10 – Establish Public Involvement Risk Reduction Strategies
Point 11 – Manage and Enhance Technical Expertise and Professionalism
Point 12 – Invest in Research

The major rehabilitation approach for the MCR jetty system is focused on defining the larger processes affecting the jetty system and then describing the jetty system degradation and reliability over time. Frequency and consequences of future jetty repairs, as well as potential impacts to dredging and navigation, were evaluated using a planning model.

Initially, the base condition involved a "fix-as-fails" approach where each jetty was allowed to degrade to as low as 20 percent of the originally authorized cross section and therefore breaches were forecasted. An Independent External Peer Review (IEPR) comment stated that this was an unrealistic assumption. Upon further consideration, the Portland District changed the base condition to reflect the most likely future jetty maintenance strategy of interim repair.

Due to the level of construction and the high mobilization costs, the revised base condition described in this report does not include any jetty head re-construction. Only the trunk and the root of the jetty are maintained, and the jetty head is allowed to recede landward. The base condition is identified as an interim repair approach because the upper portion of the cross section is allowed to be damaged to approximately 35 percent of the remaining cross-section above -5 MLLW prior to repair actions being taken. In this way, the jetty is maintained close to the margin of functional loss without breaching.

The South Jetty dune augmentation at the root of the South Jetty is part of the base condition and will be implemented regardless of the outcome of the MCR Jetties Major Rehabilitation project. Within a broad assessment it was determined that consequences of a breach would be high enough to warrant preventive measures now, independent of any jetty repair activity. In addition, the FY 11 *Major Maintenance Report* (MMR) actions are part of the *Major Rehabilitation Report* (MRR) base condition: North Jetty lagoon fill between stations (STA) 20 to 60; and North Jetty critical repairs between STA 86 to 99.

In this report, the MRR, three basic with-project implementation alternatives were developed and considered for the MCR jetties: scheduled repair, immediate rehabilitation, and scheduled rehabilitation. Alternatives for each jetty were considered to occur either through scheduled, predetermined time and place, or on a monitor-and-repair basis for locations where a stochastic model predicted jetty repair or breach locations or both.

For the North and South jetties, the repair alternative included repair combined with and without engineering features (head capping and spur groins). For the repair alternative, stone placement is generally limited to the above-water jetty sections and remains within the limits of the existing jetty and relic stone structures.

Rehabilitation alternatives generally incorporated engineering components necessary to increase the reliability of the current structure and jetty system, and could include features that extend beyond the current footprint of existing jetty and relic stone structures and include both above- and below-water fill. Engineering features were incorporated as common components in all rehabilitation alternatives and included head capping, and adding spur groins. Rehabilitation strategies were evaluated as both immediate and scheduled. Scheduled rehabilitation included construction at specific locations along a jetty during specific times in order to optimize the federal investment. For example, based on modeling results, construction on Jetty A will be completed years before work concludes on the South Jetty.

A common set of descriptive life-cycle statistics were used to assess the performance for each jetty within a historical and future context. The statistics used to assess historical performance included jetty repair aspects, life-cycle repair cost, jetty geometry (crest profile, cross-section, head location), and jetty reliability. The statistics used to assess future jetty performance and compare alternatives included:

- Average annual cost (AAC)
    - Initial construction cost
    - Repair costs and their timing
- Reliability or the probability of a project feature to perform satisfactorily
- Constructability and access
- Potential impacts to larger inlet system
- Environmental effects of jetty rehabilitation, repair, or function loss
- Jetty lengths were evaluated based on AAC and functional reliability of their performance, the jetties will not be re-constructed to their authorized length at this time.

Alternatives were formulated based on jetty cross-section resilience, maintenance options, and construction scheduling. Estimates of future life-cycle outcomes were made for a range of maintenance strategies and rehabilitation alternatives. Selection of a least cost plan to manage the future life-cycle of each jetty was based on the optimization of the above metric considerations.

The metric used to portray future life-cycle cost is expressed in terms of average annual cost, which is based on a 50-year period beginning with the on-line year of alternative implementation.

Based on the tonnages produced by the Stochastic Risk-Based life-cycle simulation (SRB) model, head capping and spur groins are not part of the least cost—National Economic Development

(NED)—plan for any of the three jetties. However, this does not preclude the addition of either of these engineering features in the future. If biennial photogrammetric surveys and best adaptive management practices indicate the necessity of head stabilization or spur groins or both, such actions will be reconsidered. Furthermore, during the detailed design report (DDR) phase alternatives to optimize head stabilization will be assessed.

Beyond the initial rehabilitation period, the jetties will be aggressively monitored and maintained. The future costs have been estimated as a series of predicted repairs continuing for the next 50 years. Although the predicted repairs for the entire 50 year life-cycle was utilized to select the most economical plan, only the initial rehabilitation period consisting of the first seven years are itemized below.

For all three jetties, the NED plan was selected and their benefit to cost ratios (BCR) are listed below:

- **North Jetty** (BCR: 1.09) – Scheduled repair with head stabilization at or near STA 101, (less extensive than the previously proposed capping). These repairs will be conducted after the base condition maintenance repairs to stations 86-99 and lagoon fill to stop erosion of the jetty root. It does not include spur groin construction.

- **South Jetty** (BCR: 1.00) – Base condition (interim repairs) allowing head recession. It does not include spur groin construction. Dune augmentation near the jetty root will be implemented in FY 13 as a separate action and not included in the cost estimate. Although the base condition is the NED plan, the interim repair, hold head alternative is very close in AAC, differing by 0.9 percent. When conditions are appropriate (i.e., repairs of the South Jetty allow for a haul road to be established to the end of the jetty approximately FY 2019), head stabilization could be re-evaluated—using parameters such as least cost, environmental acceptability and engineering feasibility.

- **Jetty A** (BCR: 1.42) – scheduled repair and head stabilization at approximately STA 89. It does not include spur groin construction. The modeling performed to assess the project alternatives assumes that Jetty A is in place and fully functioning. This is because Jetty A, as originally constructed, protects the North Jetty and helps to train the Columbia River main stem. In addition, Jetty A is believed to play an important function for the Columbia River plume. The plume is an important food source for the 13 Columbia River salmonid evolutionarily significant units (ESUs) listed under the Endangered Species Act (ESA).

The project has a combined BCR of 1.1 for the system (all three jetties).

The initial construction schedule is projected to be from 2014 through 2020. Based on the 100% federally fully funded, feasibility level design in 2012 dollars, project first cost at an effective price level of 01 October 2012 is $238,547,000 and a total project cost fully funded of $257,201,000**.** Total project costs fully funded are estimated as follows per jetty: North Jetty at $79,797,000; South Jetty at $146,884,000; and Jetty A at $30,520,000.

The scheduled jetty repairs plan will reduce ongoing erosion to the surrounding shoals. Stabilizing the North Jetty and Jetty A lengths will have positive effects on the adjacent shorelines as well as the configuration and evolution of the ebb tidal shoal. Scheduled repairs will also help to stabilize both the above and below water morphology at the project.

Chapter 1 of this report provides a general introduction to the MCR jetties system and surrounding area, including:

- The purpose and importance of the jetty system;
- A detailed history of the construction, past repairs, and morphologic changes;
- The technical, as well as budget challenges; and
- A description of the current conditions.

Chapter 2 provides the economic rationale for the federal interest, a summary of how costs are calculated, and the benefit-to-cost ratios of the various repair/rehabilitation alternatives.

Chapter 3 provides the engineering basis for the development and analysis of the alternatives. This chapter includes:

- A characterization of the wave climate and morphologic processes at the MCR;
- The current issues/risks of deterioration or failure for each of the jetties and associated consequences;
- A characterization of the design of each jetty and the relevant performance modes;
- The description of the methodology and model used for assessing the reliability and life-cycle performance of the jetties, including alternatives;
- A summary of how the model was calibrated using historical and hindcast data; and
- A description of each of the repair/rehabilitation alternatives, including the model analysis results related to projected future long-term maintenance actions and reliability.

Chapter 4 builds upon the previous two chapters to provide a comparison of the alternatives based on initial and life-cycle costs, reliability, and environmental considerations. Based on these comparisons, a recommended plan for each jetty is given.

Chapter 5 summarizes the anticipated environmental effects of the proposed rehabilitation of the MCR jetty system, and the coordination undertaken related to environmental compliance issues. The associated EA provides a full evaluation of the project and associated environmental compliance considerations. Additional discussion and pertinent correspondence is included in Appendix D, *Environmental Documentation.* Any citations in this chapter can be found in the References section of the EA. The discussion is pulled directly from the EA which evaluates the effects of the Major Rehabilitation actions, the Major Maintenance Report actions, and South Jetty dune augmentation actions.

Chapter 6 provides an overview of the construction methods (both land-based and water-based) and estimated production rates and schedule for the recommended plan. The associated cost estimates are provided.

Chapter 7 is the recommendation signed by the USACE District Commander.

The first six appendices provide further technical details of the information summarized in Chapters 3 and 4 of the report. Appendices C, D, E, F, and G provide detailed information related to the economic, environmental, and programmatic discussions of Chapters 2, 5, and 6. Appendix H is a summary of key project events and provides an audit trail for all report reviews.

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Acronyms and Abbreviations

AAC	average annual cost(s)
AMT	Adaptive Management Team
ATR	Agency Technical Review
ATV	All-Terrain Vehicle
BA	Biological Assessment
BCR	benefit-to-cost ratio
BMP	best management practice(s)
CAU	concrete armor unit(s)
CE/ICA	Cost Effectiveness/Incremental Cost Analysis
CL	Center Line
CWA	Clean Water Act
cy	cubic yard(s)
DDN-PCX	Deep Draft Navigation Center of Expertise
DDR	Detailed Design Report
DQC	District Quality Control
EIS	Environmental Impact Statement
ESA	Endangered Species Act
EA	Environmental Assessment
EC	Engineer Circular
EFH	Essential Fish Habitat
EO	Executive Order
EP	Engineer Pamphlet
ER	Engineer Regulation
ESA	Endangered Species Act
ERDC	Engineer Research and Development Center
ESU	Evolutionarily Significant Unit
FONSI	Finding of No Significant Impact
FS	safety factor
ft	foot or feet
FY	fiscal year
GRP	Geographic Response Plan
HCP	Habitat Conservation Plan
HGM	Hydrogeomorphic
HQUSACE	Headquarters, U.S. Army Corps of Engineers
HTRW	hazardous, toxic and radioactive waste
IDC	Interest During Construction
IEPR	Independent External Peer Review
IFO	Intermediate Fuel Oil
IHA	Incidental \Harassment Authorization
LIDAR	Light Detection and Ranging
MCACES	Microcomputer Aided Cost Estimating System
MCR	Mouth of the Columbia River
MCY	million cubic yard(s)
MHHW	mean higher high water
MLLW	mean lower low water
MRR	Major Rehabilitation Report

NED	National Economic Development
NEPA	National Environmental Policy Act of 1969, as amended
NGVD	National Geodetic Vertical Datum
NM	Nautical mile
NMFS	National Marine Fisheries Service
NOS	National Ocean Survey
NPV	net present value
NWD	Northwest Division, U.S. Army Corps of Engineers
NWP	Portland District, U.S. Army Corps of Engineers
ODEQ	Oregon Department of Environmental Quality
ODFW	Oregon Department of Fish and Wildlife
ODMDS	Ocean Dredged Material Disposal Sites
ODOT	Oregon Department of Transportation
OMRR&R	Operation, Maintenance, Repair, Rehabilitation, and Replacement
O&M	Operations and Maintenance
OPRD	Oregon Parks and Recreation Department
PDT	Project Delivery Team
RM	river mile(s)
SHPO	Oregon State Historic Preservation Offices
SONCC	Southern Oregon/Northern California Coast
SRB	stochastic risk-based life-cycle simulation (model)
STA	Station
STWAVE	Steady-State spectral WAVE
SWL	storm-induced water level
TPCS	total project cost
USACE	U.S. Army Corps of Engineers
USEPA	U.S. Environmental Protection Agency
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
WQC	Water Quality Certification
WRIA	Water Resource Inventory Area

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1. INTRODUCTION

1.1. GENERAL

This chapter of the report provides a general introduction to the MCR jetties system and surrounding area, including:

- The purpose and importance of the jetty system;
- A detailed history of the construction, past repairs, and morphologic changes;
- The technical, as well as budget challenges; and
- A description of the current conditions

1.2. PROJECT AUTHORIZATION - MCR PROJECT FEATURES

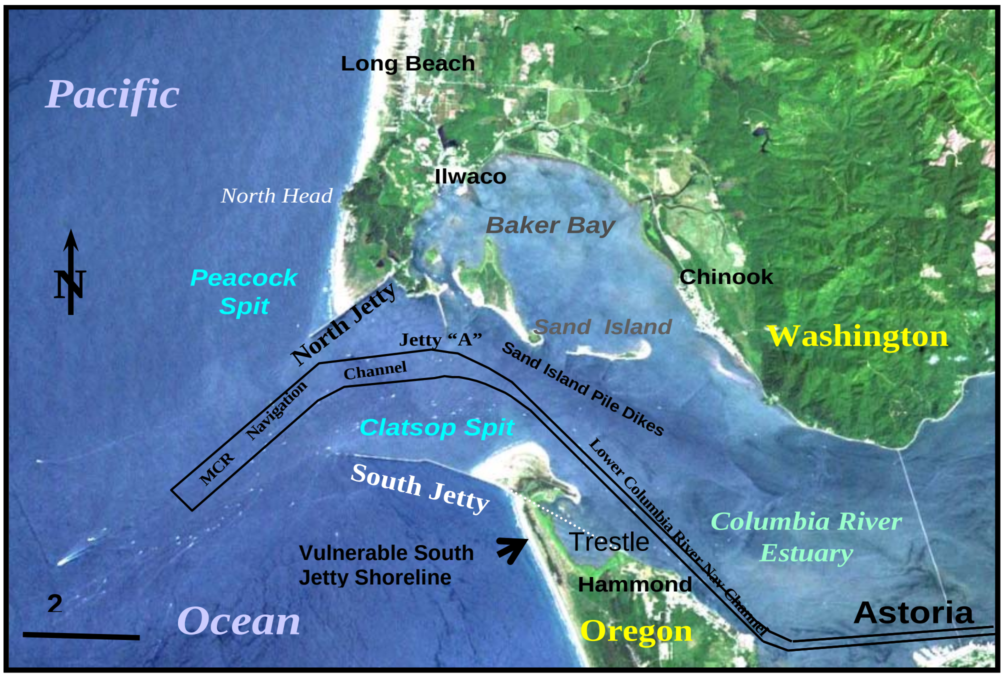
At the mouth of the Columbia River (MCR), three rubble-mound jetties with a total authorized length of 10.2 miles were constructed by the U.S. Army Corps of Engineers (USACE) to secure consistent navigation through the coastal inlet. The Rivers and Harbor Act of 5 July 1884 authorized construction of the South Jetty (first 4.5 miles) to attain a 30-foot channel across the MCR bar. The Rivers and Harbor Act of 3 March 1905 authorized the extension of the South Jetty to 6.6 miles and construction of the North Jetty (2.5-miles long) to attain a 40-foot bar channel (0.5-mile wide)—including spur groins. The Rivers and Harbor Act of 3 September 1954 authorized a bar channel at a depth of 48 feet below mean lower low water (MLLW; all elevations are in this datum unless otherwise noted) and Spur Jetty B on the north shore of the inlet; however, funds for Spur Jetty B were not appropriated. Public Law 98-63, 30 July 1983, authorized deepening the northern most 2,000 feet of the MCR channel to 55 feet below MLLW. Jetty A was authorized and constructed to 1.1 miles in length in connection with rehabilitation of the North Jetty for the purpose of channel stabilization. Its purpose was to assist in controlling the location and direction of the ebb tidal flow through the navigation entrance.

1.3. LOCATION AND PROJECT AREA DESCRIPTION

The MCR navigation project is located at the confluence of the Columbia River with the Pacific Ocean on the border between Washington and Oregon. Figure 1-1 illustrates the navigation project and the three primary navigation structures, the North Jetty, South Jetty, and Jetty A. Those structures are shown in more detail in Figure 1-2. The North Jetty and Jetty A are located in Pacific County, Washington, near Ilwaco and Long Beach on the Long Beach Peninsula. The North Jetty was completed in 1917. Jetty A, positioned on the south side of the North Jetty, was constructed in 1939 to a length of 1.1 miles. Jetty A was constructed to direct river and tidal currents away from the North Jetty foundation. The South Jetty is located in Clatsop County, Oregon near Warrenton/Hammond and Astoria. The initial 4.5-mile section of the South Jetty was completed in 1895, with a 2.5-mile extension completed in 1913. Jetty construction realigned the ocean entrance to the Columbia River, established a consistent navigation channel that was 40 feet below MLLW across the bar, and significantly improved navigation through the MCR. Improvements made from 1930 to 1942 (including addition of Jetty A and Sand Island pile dikes) produced the present entrance configuration. Figure 1-3 illustrates the MCR inlet and bathymetry changes from 1866 to 2003. Plates 1 through 3, located at the end of this chapter, show the layout and stationing of each of the MCR jetties.

Prior to improvement in 1885, the tidal channels through the MCR shifted north and south between Fort Stevens and Cape Disappointment, a distance of about 5.5 miles. The controlling depth of dominant channel through the ebb tidal delta varied between 18 to 25 feet deep below MLLW. The ebb and flood tidal deltas at MCR entrance were distributed over a large area immediately seaward and upstream of the river mouth. Ships often had trouble traversing the Columbia River bar, the area in which the flow of the estuary rushes headlong into towering ocean waves. On many occasions, outbound ships had to wait a month or more until bar conditions were favorable for crossing. To make navigating through the MCR even worse, sailing ships had to approach either of the two natural channels abeam to the wind and waves. The natural channels often shifted widely within the course of several tidal cycles. At best, crossing the bar was dangerous. At worst, it was not possible.

Figure 1-1. MCR Jetty Locations



Offshore of the MCR lays the vast expanse of the northeast Pacific Ocean. Inshore of the MCR lies the Columbia River and estuary, the coastal outlet for a drainage basin of 250,000 square miles where the headwaters emanate from the western slope of the Rocky Mountains. The course of the Columbia River is 1,210 miles long, dropping over 2,600 feet from its Canadian headwaters to the sea. The Columbia River accounts for 60% (winter) to 90% (summer) of the total fresh water that discharges into the Pacific Ocean from the Canadian border to San Francisco, California. The Columbia River estuary is the largest fluvially dominated estuary in the Pacific Northwest. Its upriver limit, defined in terms of salt water intrusion, varies from river mile (RM) 28 to 38 and is a function of fluvial flow and sequencing of the tidal cycle. Current reversal due to tide can occur as far inland as RM 70. Tidal effects (fluctuation of water surface elevation) extend upriver to Bonneville Dam (RM 145).

The 6-mile long deep-draft navigation channel at the MCR has become the ocean gateway for navigation access to and from the 500-mile long Columbia/Snake River inland navigation system. It is a critical regional and national gateway linking agricultural, mineral and goods production across the Northwest, Mountain, Midwest, and East Coast states to growing markets in the Pacific Rim. The economies of many states rely on the trade and commerce that flows up and down the system. Each year, ocean-going vessels on the Columbia River carry about 42 million tons of cargo with an estimated value of $20 billion on an annual basis (more than 40,000 local jobs are dependent on this trade).

Figure 1-2 shows the rubble-mound structures that make up the MCR jetty system. Top left photo shows the South Jetty looking east. The remnant feature shown disconnected from the primary structure is the concrete monolith that was constructed in 1941. The top right photo shows Jetty A. The bottom photo illustrates the North Jetty and the shoreline north of the MCR. The North Jetty also realized significant head recession shown in the photo. As each of the three jetties deteriorates, the MCR entrance and navigation channel is exposed to increased wave energy and sediment movement.

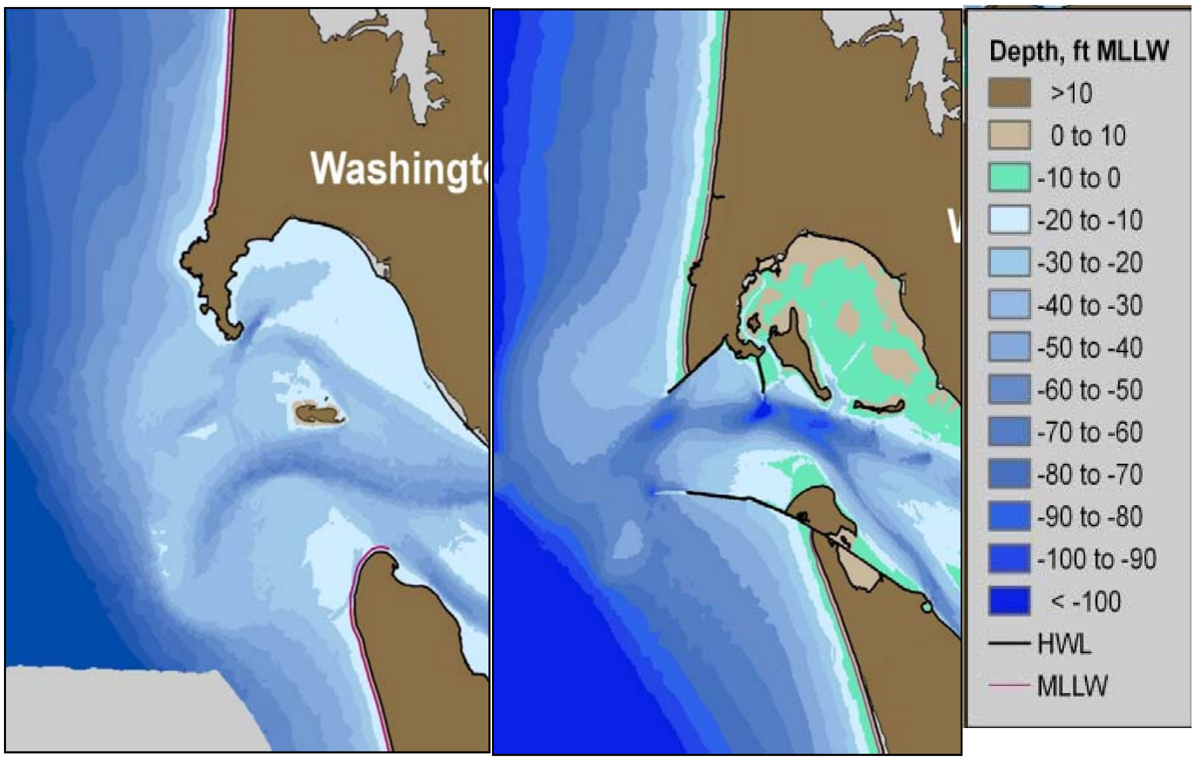
Figure 1-2. Detailed Structural Views of Jetties at the MCR

South Jetty

Jetty A

North Jetty

Figure 1-3. MCR Inlet and Bathymetry Change from 1866 to 2003



Source: Byrnes, 2006.

According to the Center for Economic Development and Research, the Columbia/Snake River navigation system is the number one export gateway for the Nation's wheat and barley exports. It is also the number one export gateway for west coast wood and mineral bulk exports and number two for automobile imports. Marine traffic passing the entrance of the Columbia River has increased by 34% from 32 million tons in 2003 to 42 million tons in 2010. Additional economic information about the Columbia/Snake River navigation system can be found in Appendix C, *Economic Analysis*.

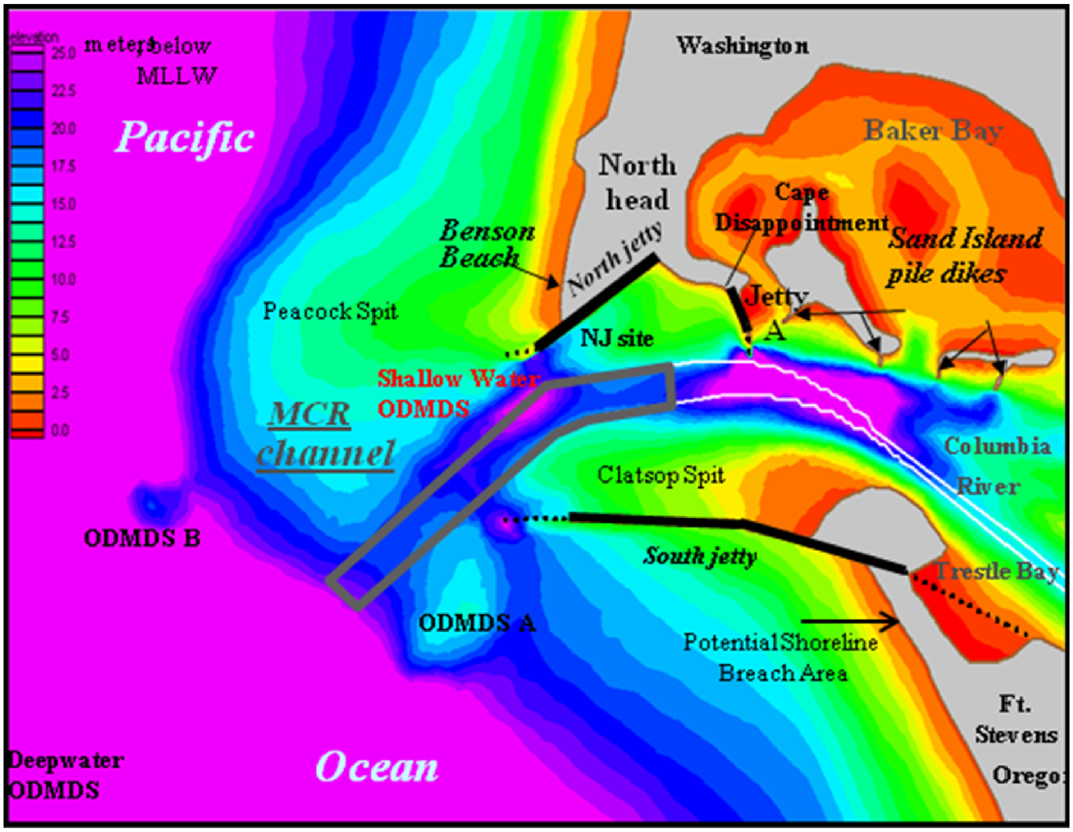
1.4. IDENTIFICATION OF PROBLEMS AND OPPORTUNITIES

Budget guidance [Budget Engineer Circular (EC) 11-2-201, dated 3 March 12] defines major rehabilitation based on these thresholds: "The work will extend over at least two full construction seasons and will require at least $6.6 million in outlays. For inland waterways projects, the reliability threshold will be $14 million." The work on all three of the MCR jetties fits the definition of major rehabilitation and therefore, this report is prepared using that guidance.

This evaluation was undertaken to address problems related to the structural stability of the MCR Jetties to extend their functional life to maintain deep-draft navigation. The jetties are integral to maintaining a reliable deep-draft channel at the mouth of Columbia River due to the inherent relationship between the channel and the jetties. The purpose of this report is to assess the most efficient means of maintaining deep-draft navigation in a least-cost manner. The jetties were constructed on massive tidal shoals and these shoals have been changing since initial jetty construction. The longevity of the jetties is tied to the stability of the shoals on which the jetties were built, and the stability of the shoals is now a function of the jetties. The jetties and shoals act as integrated units to confine tidally driven circulation through the MCR and maintain the present channel configuration. Figure 1-4 illustrates the extensive underwater shoaling at the MCR.

Figure 1-4. Bathymetry and Underwater Shoaling at the MCR

(the color scale indicates depth from shallow to deep, 0.0 meters in red to 25.0 meters in magenta)



Through phased jetty construction (1885-1939) and the associated response of MCR morphology, each project feature at the MCR now is dependent on the other, both in terms of structural integrity and project feature functional performance. Severe deterioration of any of these features can jeopardize the MCR federal navigation channel and adversely affect the other structures. Should the North Jetty experience substantial deterioration from its present condition, the navigation channel, South Jetty, Jetty A, and ultimately the Sand Island pile dikes would be negatively affected. A similar scenario would likely occur if the South Jetty experienced substantial deterioration from its present condition. In this regard, the project features at the MCR are interrelated and perform as a system.

Structural degradation of the jetties has accelerated in recent years because of increased storm activity and loss of sand shoal material upon which the jetties are constructed (Figure 1-5 shows waves attacking the South Jetty). Both the frequency and intensity of extreme cyclones in the Pacific Northwest have increased markedly (Graham and Diaz 2001, Moritz and Moritz 2006). In addition, extremal analyses of Pacific Northwest buoy data from the National Data Buoy Center have shown a gradual increase of the predicted 100-year wave height (Komar and Allan 2000; Moritz 2001; Moritz and Moritz 2006; Ruggiero et al., 2010).

Figure 1-5. Wave Attack on the South Jetty

Beaches on the ocean sides of the North and South jetties, which formed as a result of jetty construction, have been receding gradually over the years, exposing previously protected jetty sections at the beach line to storm waves (Figure 1-6 shows Benson Beach recession at the North Jetty). This recession is in direct proportion with jetty length. As jetty length is shortened, beach front is lost.

The orientation of the shoals/spits at the MCR has arisen due to waves and currents; the morphology and coastal processes at the MCR are linked. Eddies that form within the MCR arise due to the interaction of flow with the jetties and the morphology greatly influences flow and shoaling within the federal navigation channel. The littoral dynamics north and south of the MCR are drastically different from “open coast” areas away from the entrance. Depending on the regional wind field, the “coastal current” up-drift and down-drift from the MCR can attain speeds of 3 feet/second. As the tidal shoals continue to recede (erode), the MCR jetties will be exposed to larger waves and more vigorous currents.

Figure 1-7 illustrates the Ocean Dredged Material Disposal Sites (ODMDS) located at the MCR that are a key element to the project’s channel maintenance program used by ocean dredges that operate there.

Figure 1-6. Shoreline Response North of the North Jetty

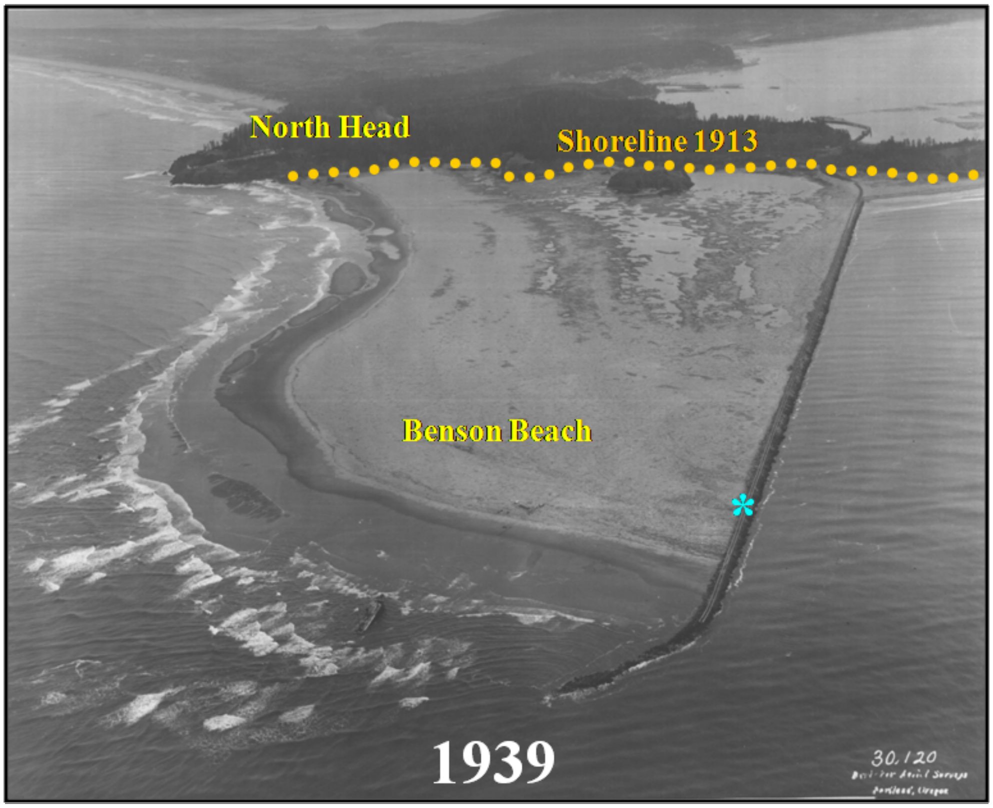
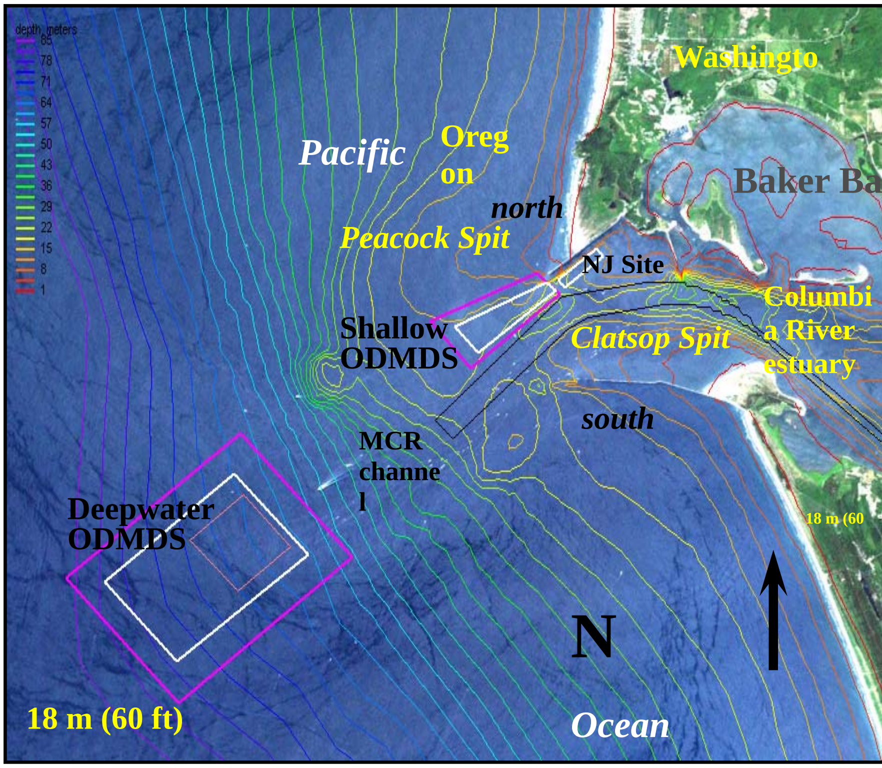


Figure 1-7. Ocean Dredged Material Disposal Sites



Despite intermittent repair and partial rehabilitation efforts, all of the MCR jetties are currently in a significantly deteriorated condition (Figure 1-8 and Figure 1-9). Intermittent repairs were conducted in 2005 on the North Jetty and in 2006 and 2007 on the South Jetty. The last partial rehabilitation on the North Jetty was conducted in 1964 and addressed 17% of its length, on the South Jetty was conducted in 1982 and addressed 25% of its length, and on Jetty A was conducted in 1961 and addressed 56% of its length. The jetty heads of the North and South jetties have not been repaired since their original construction and are severely deteriorated. The South Jetty head is no longer connected to the trunk by a continuous above water jetty reach. The jetty heads continue to recede landward from their original locations. The above water lengths for the South and North jetties and Jetty A are currently shorter than their authorized lengths by 6,200 feet, 2,120 feet, and 900 feet, respectively. Due to the interaction of wave patterns and currents with the jetty configuration, the shorter jetty lengths can increase underwater shoal erosion, influence shoreline position adjacent to the jetties, and can increase the loading on the structures landward of the jetty head.

Progressive damage to one of the jetties could result in a significant breach which can trigger an emergency repair to the jetty, rapid infill into the navigation channel, and emergency dredging activities. The current rehabilitation approach for the MCR Jetties focuses on adequately defining the larger processes affecting the jetties, and then describing their reliability over time. Some of the larger physical processes have been already mentioned including erosion and re-orientation of the ebb tidal shoal, shoreline erosion adjacent to the structures, increased depths along the jetties due to inlet and channel changes and increasing wave height trends. Consequences evaluated include frequency and consequences of future jetty repairs, as well as potential impacts to dredging and navigation. Each alternative adds additional elements of either process stabilization or above or below water cross section stabilization, as well as varying degrees of cross section reliability improvement.

Figure 1-8. South Jetty Damage Areas

Figure 1-9. North Jetty Damage Areas

In summary, taking no action to rehabilitate the MCR jetties to extend the functional life would result in further deterioration of the structures and would result in a jetty breach. A jetty breach results in accelerated jetty damages adjacent to the breach area, sediment infill through the hole in the jetty, and increased jetty repair and dredging costs. Recent interim jetty repairs have addressed immediate critical needs. However, additional modifications and repairs to the jetties are necessary to address critical near- and long-term needs and to reduce the potential for emergency repairs, emergency dredging, and impacts to the Columbia-Snake River inland navigation system. Further discussion concerning the problems and opportunities of the MCR Jetties can be found in Appendix A1, *Coastal Engineering*.

1.5. PROJECT HISTORY

1.5.1. Construction and Repair History

Table 1-1 provides a description of the construction and repair history for the MCR jetties. The function of the MCR jetties has evolved since initial construction. Improvement of the MCR navigation entrance was conducted incrementally with subsequent stages being initiated as a physical need was recognized. The South Jetty was constructed first as a mid-tide jetty to a moderate length (1885-1895). Instability of the South Jetty and continued migration of the navigation channel led to recommendations to extend the South Jetty and raise it to a high tide jetty. During improvement of the South Jetty (1905-1913), it became apparent that a North Jetty would be needed to maintain a stable navigation channel.

Table 1-1. Construction and Repair History for the MCR Jetties

1881: Proposed project to build a strong pile-dike, 3 feet high about at low tide, 8,000 feet long and 20 feet wide along a line previously established on the south side. The structure to start near the northeast corner of Fort Stevens, following the 12-foot curve, dike will be directed a little westward of the outer part of headland of Cape Hancock. It was stated that work commence soon (during summer and autumn) because channel maintenance is dependent upon building up Clatsop Spit.

1883: A jetty plan approved by the Board of Engineers from the south cape of the entrance on the spit. A survey was conducted in October-November of the south cape, Point Adams, to extreme low water. The jetty extends from Point Adams and makes the distance between the outer end of the jetty and Cape Disappointment the same as the distance between Chinook Point and Point Adams. The Board stated that any structures placed in-river should not harm the river and should keep the channel open using the tide; therefore, the jetty should not obstruct the entry of the flood tide. The jetty design called for a crest elevation at low water level. Estimated depths of various jetty sections from the landward end are: 5,000 feet - less than +6 feet; 7,500 feet – +6 to +11 feet; 4,000 feet – +11 to +16 feet; and 7,500 feet – +16 to +21 feet. Jetty crest elevation was designed to be at low water level because of wave violence that could harm a higher jetty. The logic was that a higher jetty could be built, if needed later, by placing more stone on the existing jetty. A jetty height to mid-tide level was suggested but not recommended because the lower jetty would be quite effective in directing the ebb tide and would interfere less with the flood tide. A higher jetty would result in higher maintenance costs due to the jetty being more exposed to wave action.

1884: The improvement plan for MCR was approved by the Rivers and Harbors Act of July 5, 1884 to maintain a channel 30 feet deep at mean low tide by constructing a low-tide jetty, about 4.5 miles long, from near Fort Stevens on the South Cape to a point about 3 miles south of Cape Disappointment.

1886-1896: Original construction South Jetty from Fort Stevens (station 25+80) across Trestle Bay and Clatsop Spit to station 250+20. Rock placed with a natural slope to an elevation from 4 to 12 feet, crest width roughly 10 feet. "The jetty, of a brush-mattress and stone ballast, was built for 1,020 feet from ordinary highest tide-line, and minor constructions added." Material has filled along the jetty's south side, moving the shoreline seaward. Highest tide-line is located at tramway station 30+50. A 115 feet long spur was built landward of the jetty for shore protection. A 510 feet long sand-catch, consisting of heavy beach drift and loose brush, was built on the south side of landward end of the jetty to continue filling the old outlet of a lagoon at extreme end of Point Adams. Jetty stone was originally dumped in ridges, but waves flattened and compacted the rocks to a width of 50 feet. The report indicated urgency to extend the jetty to prevent further deterioration of the bar channel.

1889: The South Jetty now under construction for 1.5 miles. Clatsop Spit has more material visible at low water and the river channel has a tendency towards a straight course out to sea. Tillamook Chute being closed. Sand building up south of the jetty adjacent to and in front of the mattresses as they are constructed.

1890: South Jetty construction is 3.25 miles underway. Jetty elevation at MLLW for about 3 miles. 1.25 miles of tramway to be constructed. Clatsop Spit building up, the outflowing waters being concentrated over the channel bar. Station 25+80 considered the beginning of the jetty. The jetty mattress has advanced from stations 99+04 to 194+08. The jetty elevation is at MLLW to station 170+00. From Station 170+00 to the end of mattress work, there is about 9 feet of rock on top of the mattress. At station 65+00, there were signs of sinking and a large amount of rock was dumped in place.

1903-1913: Extension of South Jetty. Crest elevation of jetty raised to 10 feet MLLW from stations 210+35 to 250+20, and rock placed from stations 250+20 to 375+52, elevation increasing in steps to 24 feet MLLW. Crest width is 25 feet and side slopes are natural slope of rock. Seaward bend in the jetty is added and called the "knuckle."

1913-1917: Original construction of North Jetty from stations 0+00 to 122+00. Side slopes are 1 vertical by 1.5 horizontal (1:1.5) and crest width is 25 feet. Crest elevation varies from 15 to 32 feet.

1931-1932: Repair South Jetty from stations 175+00 to 257+68.7 (shoreline to knuckle), side slopes 1:1.5, crest elevation 24 feet MLLW, and crest width 24 feet. This is first maintenance for South Jetty. The jetty had been flattened to about low water level. 2.2 million tons of stone placed in super-structure. The work completed in 1936. The end of jetty would unravel 300 feet or more, so a solid concrete terminal was constructed above low water level. The terminal was located 3,900 feet shoreward of the original jetty end that was completed in 1913.

1933-1934: Repair of South Jetty from stations 257+68.7 to 305+05 (knuckle to middle of outer segment). Two level cross section with crest elevations of 17 and 26 feet. Crest width of each level is 24 feet. Side slopes are 1:1.5 on channel side and vary from 1:1 to 1:1.75 to 1:2 on ocean side.

1935-1936: Repair South Jetty from stations 305+05 to 353+05 (middle of outer segment to existing end). Similar design to 1933-1934 repair.

Table 1-1 (continued). Construction and Repair History for the MCR Jetties

1936: Stone/asphalt cone-shaped terminal constructed on South Jetty from stations 340+30 to 344+30. Crest width of approximately 50 feet and elevation varied from 23 to 26 feet. Side slopes are 1:2.

1937-1939: Repair of North Jetty from stations 68+35 to 110+35. Crest elevation 26 feet and crest width 30 feet. Side slope 1:1.25 on ocean side and 1:1.5 on channel side.

1939: Original construction of Jetty A from stations 40+93.89 to 96+83. Crest width is 10 feet from beginning to station 53+00, 30 feet in width, and elevation at 20 feet from this point on. Four pile dikes completed at Sand Island.

1940: Repair of South Jetty with replacement rock in locations as needed.

1940-1942: South Jetty repair from stations 332+00 to 343+30. Concrete terminal/stone foundation added. Crest elevation from 8-20 feet and crest width from 50-75 feet, 10 inches. Side slopes determined by concrete terminal shape.

1945-1947: Repair Jetty A from stations 78+00 to 96+00. Crest elevation to 20 feet with crest width of 40 feet.

1948-1949: Repair 300 feet of Jetty A from stations 92+35 to 95+35 with a crest elevation of 20 feet, a crest width of 30 feet, and side slopes of 1:1.25.

1951: Repair Jetty A from stations 91+50 to 93+00 with a crest elevation of 20 feet MLLW, a crest width of 30 feet, and side slopes of 1:1.5.

1952: Repair of Jetty A from stations 90+00 to 94+00 with a crest elevation of 20 feet, a crest width of 30 feet, and side slopes of 1:1.5.

1958: Repair of Jetty A from Stations 41+00 to 79+00. Crest elevation raised to 20 feet and a crest width of 20 feet from Stations 41+00 to 56+00. Crest width is 30 feet from Stations 61+00 to 79+00.

1961-1962: Repair Jetty A from stations 50+00 to 90+50, with no repairs from Stations 68+00 to 76+50. Crest elevation built with a 10% grade from 20 feet to 24 feet from stations 50+00 to 68+00. The crest elevation was raised to 24 feet from stations 76+50 to 90+50.

1961: South Jetty repair from stations 194+00 to 249+00 (before knuckle, current stationing). Crest elevation varies from 24 to 28 feet and crest width is 30 feet. Channel side slope 1:1.25 and ocean side slope 1:1.5. Repairs from stations 38+00 to 93+00 (old stationing). Elevation at station 38+00 is +24 feet and then increased with a 0.5% grade up to +28 feet for the remainder of repair section. The repair centerline is located 13 feet north of the centerline of the original jetty design. The design crest width 30 feet. North slope 1:1.25 and south slope 1:1.5.

1962-1965: South Jetty repair from stations 249+00 to 314+05 (beyond knuckle). Crest elevation begins at 28 feet and transitions to 25 feet for most of section. Side slopes vary from 1:1.5 to 1:2 and crest width is 40 feet (this appears to be the furthest seaward intact portion of current jetty). Repairs made from stations 93+00 to 157+50 (old stationing). The crest elevation is +28 feet at station 93+00, then decreases to +25 feet at station 95+00, and then continues with this elevation to end of the repairs. The crest width is 40 feet and has a slope of 1:1.5 from stations 93+00 to 152+00. Slope then transitions to 1:2 from stations 152+00 to 154+00. The centerline of the repair is 15 feet south of the trestle centerline.

1965: Repair North Jetty from stations 89+47 to 109+67 with a crest elevation of 24 feet and crest width is 30 feet. Side slopes vary from 1:1.5 to 1:2.

1982: Repair South Jetty from stations 194+00 to 249+00 (segment before knuckle). Crest elevation varies from 22 to 25 feet MLLW. Crest width varies from 25-30 feet and side slopes 1:1.5. Crest elevation varies from +22 feet at station 38+00 to +25 feet at station 80+35 (old stationing). From stations 44+50 to 80+35, crest width is 30 feet and slope is 1:1.5. Centerline of repairs has 10 feet maximum variance to the north for the South Jetty control line. From stations 80+35 to 93+00, centerline of repairs is the same as South Jetty control. Crest elevation +25 feet, width varies from 25-30 feet, side slope is 1:1.5.

2005: Interim repair of North Jetty (stations 55+00 to 86+00). Crest elevation +25 feet with side slope of 1:1.5.

2006: Interim repair of South Jetty (stations 223+00 to 245+00). Crest elevation +25 feet with side slope of 1:2.

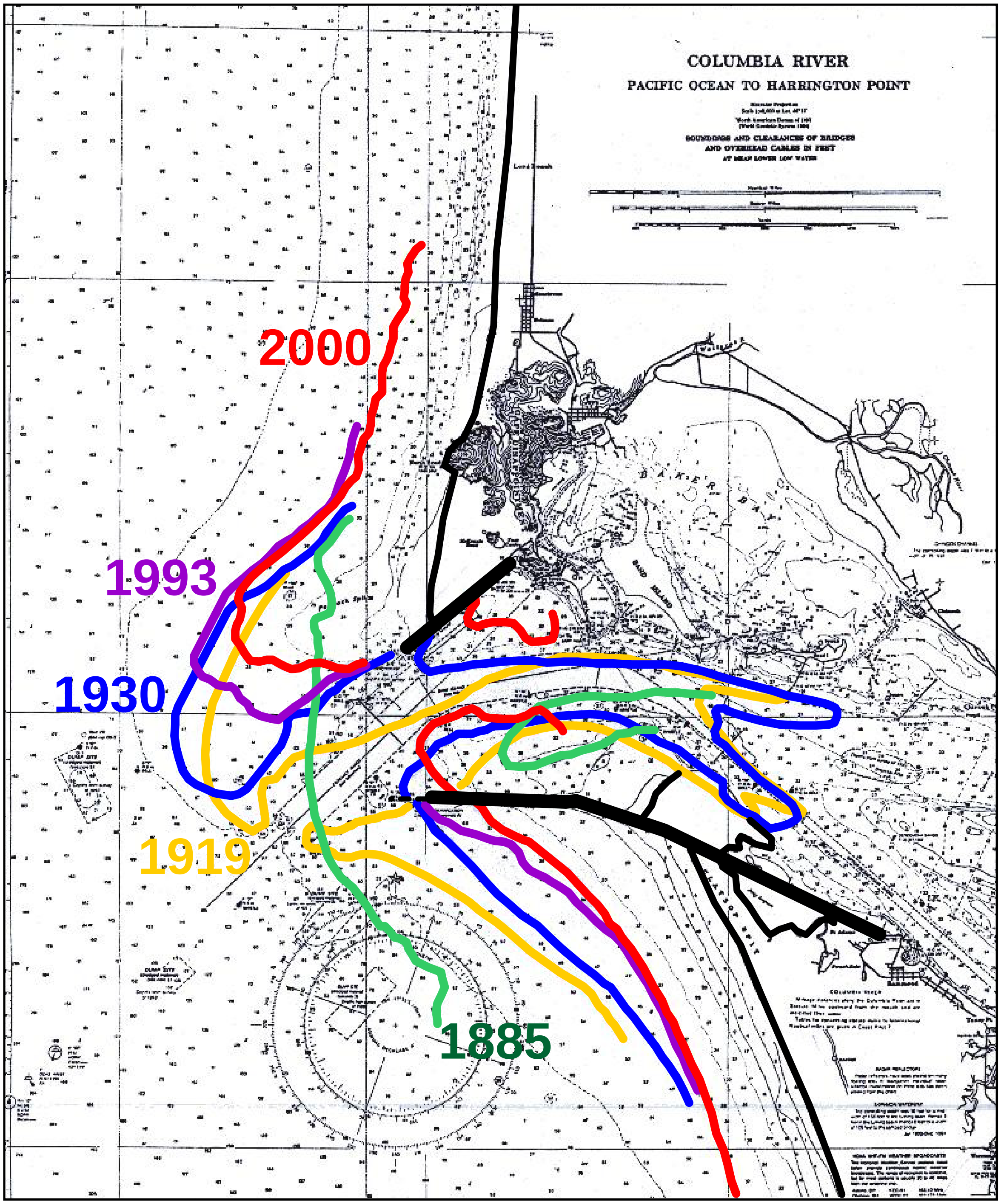
2007: Interim repair of South Jetty (stations 255+00 to 285+00). Crest elevation +25 feet with side slope of 1:2.

The sequential improvements were conducted during 1885 to 1917. During the early 1930s (after both North and South jetties had been in place and significant modification of the inlet's morphology had occurred), the North Jetty became threatened by high velocity ebb tide flow that threatened to undermine the structure's channel side foundation. Concurrently, the south side of Sand Island was being eroded by increased current action. Loss of either the North Jetty or Sand Island would have rendered the inlet unsuitable for navigation. The adverse circulation affecting the North Jetty and Sand Island was motivated by the northward migration of the estuary thalweg toward Cape Disappointment. In the late 1930s, the Sand Island pile dikes and Jetty A were constructed by the USACE to stabilize the evolving inlet. The pile dikes stabilized Sand Island, preventing detrimental effects on Baker Bay and inlet navigation. Jetty A prevented the northward migration of the inlet's thalweg while deflecting ebb away from the North Jetty and flood current away from Sand Island. Collectively, all three jetties and the Sand Island pile dikes now function in concert to balance the large scale ocean processes affecting the entrance. Through the evolution of the inlet and its morphology, Jetty A now also serves as a breakwater to protect Sand Island and the Ilwaco entrance into Baker Bay from large ocean waves.

Since the original jetty construction, several large-scale physical process changes have altered the current and projected future reliability of the jetties. These large-scale process changes gradually impact the stability of the structures and their reliability. It has been shown that as increased depths are secured in the improved navigation channel, larger waves are able to enter the channel and attack the jetties, in addition to undermining the sandy foundation upon which they rest. These increased depths primarily affect the channel-side of the jetties, particularly the North Jetty which is closer to the navigation channel. Along the landward half of the North Jetty, another de-stabilizing flow path has developed through the structure as tidal flow moves through the structure to the eroded lagoon behind the structure.

Another apparent large-scale process change has been a gradual increase in the wave climate both in terms of storm wave height as well as number of large storms occurring in a given year. Concurrent with the increase in storm climate and the larger interior waves and currents, foundation erosion has accelerated both seaward and adjacent to the jetties. During 1993 to 2000, the 40-foot contour on the ebb tidal shoal receded landward at a rate seven times faster than during 1930 to 1993, as shown in Figure 1-10. As the ebb tidal shoal recedes, the wave and current regime at the entrance and along the jetties changes.

Figure 1-10. Map of 40-foot Contours near the MCR Over Time, 1885 to 2000

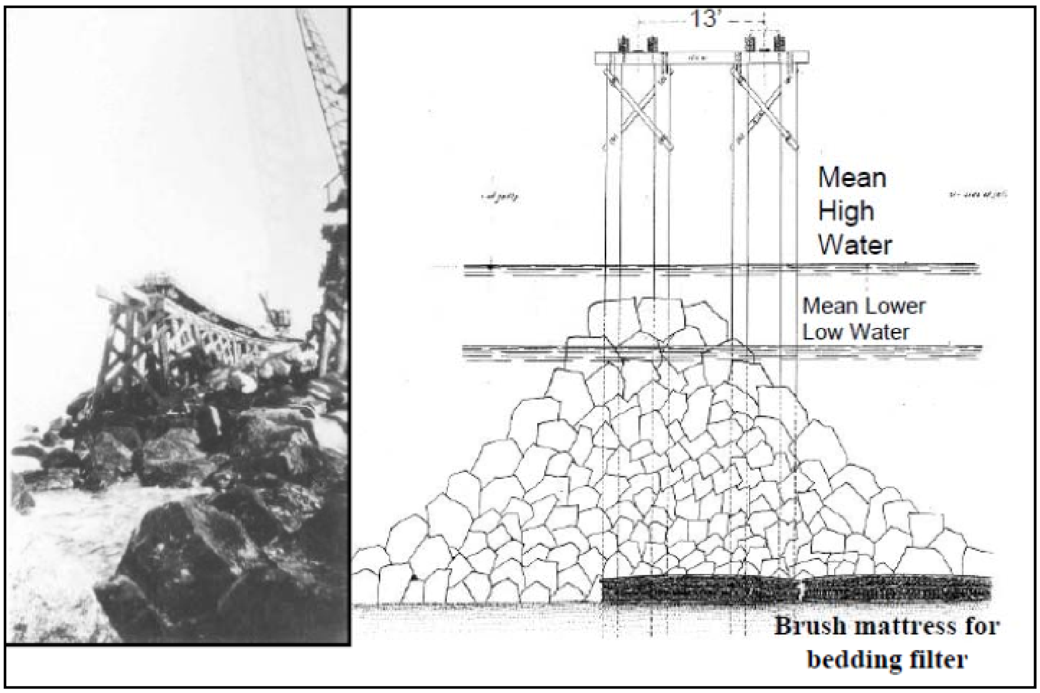


1.5.1.1. South Jetty

In 1884, Congress authorized the USACE to construct a 4.5-mile-long South Jetty for the purpose of attaining a 30-foot-deep channel across the MCR bar. The jetty was to extend northwesterly from Fort Stevens (on Point Adams) in a slightly convex manner along Clatsop Spit to a point about 3 miles south of Cape Disappointment. A jetty with a crest elevation at mid-tide was originally considered due to the assumption that it would control currents, as well as a high-tide jetty, but would cost less and contain sand better than a low-tide jetty. Table 1-2 summarizes the construction and repair efforts for the South Jetty over the project life.

The original crest elevation of the South Jetty was constructed to a mid-tide elevation (3 to 5 feet above M LLW) and a crest width of 10 feet. Figure 1-11 shows the design cross-section and construction method used to construct the South Jetty. Emphasis was given to ensure a proper "bedding" layer underneath the jetty to establish a stable foundation. The maximum size of armor stone was 7 tons, based on professional judgment and limitation of the tramway equipment. The finished side slope of the jetty was approximately 1 vertical by 1.5 horizontal (natural slope).

Figure 1-11. Design Section for Original South Jetty Construction



Improvements during South Jetty construction included the addition of four rock spur-groins (100-1,000 feet long) on the jetty's north side (at stations 52, 88, 156, and 228) to prevent scour and undermining, and increasing the jetty crest elevation. From shore to station 120, the jetty crest elevation was increased to 12 feet to reduce wave overtopping, prevent shoal migration, and protect the tramway. The crest elevation was sloped down from +12 feet (station 120) to +4 feet at station 250+20. Construction of the 4.5-mile-long South Jetty started in 1885 (station 25+80) and was completed in 1895 (station 250+20, known as the "knuckle").

Table 1-2. Construction and Maintenance Activities for the MCR South Jetty

Design Parameter	**1886-1896 (original)**	**1903-1913 (ext.)**	**1931-1932**	**1933-1934**	**1935-1936**	**1936 (stone/ asph. term)**	**1940**	**1940-1941**	**1941-1942**	**1961**	**1962-1965**	**1982**	**2006-2007**
Stone Density (pcf)	~180 (varied)	~180/ 171.2	171.2	171.2	171.2	171.2	171.2	171.2	148	186/ 171.9	167.6	167.6	167-180
Side slope (V:H)													
North Side	natural slope	natural slope	1:1.5	1:1.5	1:1.5	1:2	-	w/in conc	-	1:1.25	1:1.5, 1:2	1:1.5	1:1.5
South Side	natural slope	natural slope	1:1.5	1:1, 1:1.75, 1.2	1:1.75, 1:2	1:2	-	w/in conc	-	1:1.5	1:1.5, 1:2	1:1.5	1:2
Crest Elevation (ft)	4 to 12	10 to 24	24	17 and 26	17 and 26	23 to 26	-	16	8 to 20	24 to 28	25 to 28	22 to 25	25
Crest Width (ft)	10	25	24	24	24	50	-	50 to 75'10"	50 to 75'10"	30	40	25-30	30
Armor Quantity	945,923	4,837,311	729,647	355,371	1,151,768	10,635/ 12,787	21,391	76,614	27,960	213,461	308,101	77,000	78,000 / 73,000
Select A (tons)											15		
Class A (tons)	7 (max)		9	10	10		10	10	Comp Str: 2200 psi min	10	10	13	15, 22
Class B (tons)			1 to 6	1 to 6	1 to 6		1 to 6	2.5-3 (avg)		5	4	8.6	
Class C (tons)			<1	<1	<1			<1		<3			
Stone Source	Willamette River	Bugby/ Fisher	Fisher	Fisher	Fisher	Fisher	Fisher	Fisher	-	Youngs River Falls/ Fisher	Fisher	Fisher	Beaver Lake, Youngs River Falls
Stone Type	Basalt	Basalt/ Andesitic	Andesitic Basalt	Andesitic Basalt	Andesitic Basalt	Andesitic Basalt	Andesitic Basalt	Andesitic Basalt	-	Basalt/ Andesitic	Andesitic Basalt	Andesitic Basalt	Andesitic Basalt
Beginning Station	25+80	250+20	175+00	257+68.7	305+05	340+30	where needed	339+60	332+00	194+00	249+00	194+00	223+00, 255+00
Ending Station	250+20	375+52	257+68.7	305+05	353+05	344+30		341+60	343+30	249+00	314+05	249+00	245+00, 285+00

Additional Structures	Year Complete	Location	Length	Elevation
Groin 1	1893	228+00	500	DL to bottom
Groin 2	1893	156+00	600	DL to bottom
Groin 3	1895	88+00	1000	DL to bottom
Groin 4	1895	52+00	1000	DL to bottom
Shore Revetment	1896	25+80	3955	16.5 to 12
Groin 6	1913	309+33	~110?	8
Groin 7	1913	333+46	~90?	9

A rock revetment was constructed east of the South Jetty root (along stations 0-25) to prevent erosion flanking of the jetty by waves and currents. Construction of the original jetty required 946,000 tons of stone, which was placed using a trestle-supported tramway with locomotives, side-casting cars, and crane. Stone was delivered to the tramway by barge. Before construction of the South Jetty, there was no dominant channel though the MCR and controlling depth was about -20 feet below MLLW.

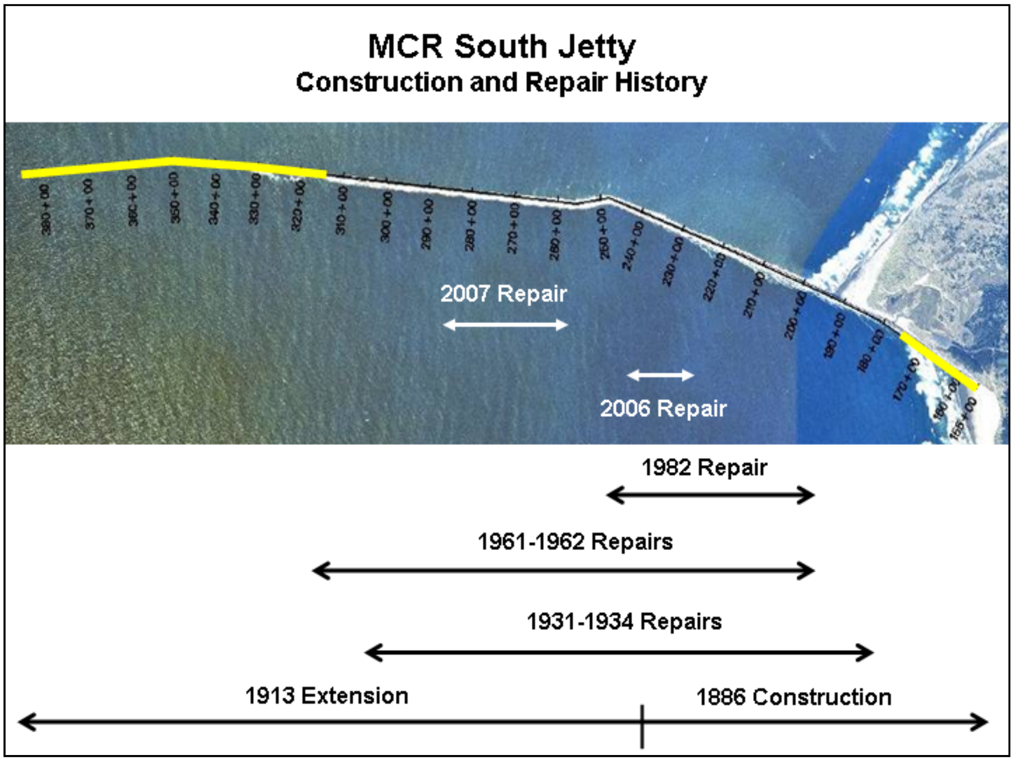
Upon completion of the original South Jetty, a well-defined channel had developed through the MCR with controlling depth of 30 feet below MLLW. The jetty length was still insufficient to continue funneling sediment into deep water and by 1902 all traces of a channel had disappeared and the governing depth reverted to 20-22 feet below MLLW. In 1903, the Board of Engineers recommended that Congress authorize the USACE to enact the following: (1) the South Jetty be extended 2.5 miles in length toward the west and the jetty crest raised to 10 feet MLLW or higher; (2) a 2.5-mile-long North Jetty be constructed on Peacock Spit (after completion of South Jetty extension); and (3) commence dredging at the bar, if needed. It was specified that the North and South jetties be 2 miles apart at their ends. The purpose of the recommended improvements was to obtain a 0.5-mile-wide channel through the MCR with controlling depth of -40 feet below MLLW.

In 1905, Congress authorized the implementation of the 1903 recommendations for the purpose of attaining a channel 40 feet below MLLW and 0.5-miles wide across the bar. Repairs were made to the original 4.5-mile-long South Jetty (stations 175-250) using 410,000 tons of stone. Construction of the 2.1-mile-long extension (stations 250-375) required 4.48 million tons of stone. Work on the South Jetty was completed in 1913. The alignment of the extension was intended to extend the seaward location of the channel by following the shallow waters of Clatsop Spit as far as possible without making significant changes in the direction of the structure. It was thought that if the 2.1-mile-long extension were constructed in continuation of the straight-line direction of the original jetty, the velocities of the ebb and flood tides would be significant enough to undermine the jetty foundation, unless groins were incorporated. The extension was expected to prevent the ebb flow from losing energy and dissipating over Clatsop Spit, but instead to be guided toward the existing channel and help maintain its depth. It was expected that the extension would hold Clatsop Spit in position and allow it to build up by impeding the entrance of sand into the channel. The curvature of the jetty at the "knuckle" was intended to encourage deposition of sand along the channel side of the jetty, so that the installation of groins would not be necessary.

As completed in 1913, the South Jetty had an average crest width of 10 feet and an elevation of +10 feet along the inner 2.65 miles (stations 25-165) of the jetty. The outer 4 miles of the jetty (stations 165-375) had an average crest width of 25 feet and elevation of +24 feet. The finished side slope was approximately 1 vertical by 1.5 horizontal (natural slope). An increased jetty crest elevation was needed to prevent wave overtopping damage to the lee side of the jetty, reduce sediment transport over the jetty, and protect the construction tramway from wave action. Stone size was the same as used for the original jetty (maximum size 7 tons). Two submerged rock groins (extending northward 200 feet from the jetty centerline) were constructed at the outer area at stations 309 and 333 to prevent scour along the north side of the jetty toe. These two rock groins have been instrumental in stabilizing the outer end of the jetty toe since time of construction. Figure 1-12 shows the construction and repair history for the South Jetty over the project life. The yellow line on the figure indicates the area along the jetty that has never been repaired since original construction.

Figure 1-12. South Jetty Construction and Repair History

(yellow represents portions of the jetty that have never been repaired)



1931-1942 South Jetty Rehabilitation

Due to the high cost of tramway construction and maintenance, jetty repair work was deferred during 1917-1931. By 1920, the outer 2.5 miles of the South Jetty crest had been beaten down by wave action and scour to an elevation of 4 feet. By 1931, the elevation of the crest was at approximately MLLW from Clatsop Spit (station 170) seaward to the jetty head (station 375). The degradation of the South Jetty allowed significant re-distribution of Clatsop Spit along the north side of the South Jetty. Much of the sediment emanating from Clatsop Spit was transported northward and eventually deposited within the southern flank of the navigation channel. By 1931, the outer 1,500 feet of the North Jetty had been beaten down to an elevation of about 3 feet and some settlement had occurred along its entire length. Except at the outer end, the North Jetty had stood up rather well due to the accretion of sand along its northern side, which by 1932 had extended to the head of the jetty (see Figure 1-6).

The first and most significant effort to rehabilitate the South Jetty was undertaken by three separate contract actions during 1931-1936. The total length of reconstructed jetty was 3.4 miles, beginning at station 175 and ending at station 353. As rehabilitated in 1936, the above-waterline part of the South Jetty extended to within 3,300 feet of the end of the jetty as completed in 1913. During 1931-1936, a total of 2.21 million tons of stone was placed. The stone was placed using tramway, dump cars, and a 25-ton crane. Stone was delivered to the tramway by barge. Average production of stone placement was 75,000 to 100,000 tons/month. To prevent future wave damage, the larger armor stone that was placed on the south jetty during the 1931-1936 rehabilitation ranged between 6 and 25 tons. Average armor stone size was 9 tons. The armor stone size was chosen based on professional judgment and equipment limitations. Rehab crest width ranged between 24 to 70 feet and crest elevation was 26 feet. Even before repairs could be completed, it was realized that the outer 3,000 feet of the South Jetty could not be maintained due to continual stone loss from the jetty. In 1937, station 350-353 was rebuilt using 10,600 tons of armor stone infused with 12,800 ton of asphalt-sand mix. The asphalt-bound jetty head performed poorly.

By 1941, the end of the rehabilitated South Jetty (station 338-353) had been reduced to 0 feet elevation by wave action and toe scour/undermining. In an effort to form a stable jetty head, a massive concrete terminal was constructed during 1941-1942. The terminal was 50-75 feet wide by 300 feet long with an elevation of 8 to 20 feet, requiring 14,000 cubic yards (cy) of concrete and 76,000 tons of stone, and was constructed at station 331 to form an armored cap. At present, most of the concrete terminal has been displaced by scour and wave action. Only the outer 100 feet of the concrete terminal remains today, secured by relic stone (from previous repairs) and the rock groins along the north side of the jetty. The 1931-1942 rehabilitation sequence was the last time that the tramway method of repairs was used on the South Jetty. A remnant of the concrete terminal presently forms the seaward-most extent (above water line) of the South Jetty at station 331, which is 4,400 feet shoreward of the 1913 maximum offshore extent (station 375). This feature can be seen in Figure 1-13.

Figure 1-13. Remnant of Concrete Terminal at End of South Jetty

1960-1982 South Jetty Rehabilitation

The South Jetty was repaired during 1961-1965 and in 1982. During 1961-1965, approximately 521,000 tons of stone were used for repair between stations 194-314. This was the first time that an empirical design approach (Hudson equation) was used to define armor stone size for the South Jetty in terms of incident wave height and jetty side slope. In 1961, jetty repairs occurred along stations 194-249 and addressed the most severe damage, which had been sustained along stations 232-242 where the South Jetty crest had been reduced to 3-10 feet above MLLW. Within this area, the jetty had been damaged by wave action to a degree such that the north side of the jetty had sustained damage by wave overtopping. Other areas along stations 194-249 had experienced a general damage trend due to wave action and scour/undermining along the south side of the jetty. Between stations 194-249, the jetty was rebuilt with a crest width of 24 feet and elevation of 24 feet. Jetty side slope for the repair was 1.5 horizontal by 1 vertical on south side and 1:25 horizontal by 1 vertical on the north side. During 1961, a total of 213,461 tons of stone was placed. During 1962, repairs occurred along stations 249-314 using a crest width of 40 feet and elevation of 25 feet MLLW using 308,000 tons of stone. Most of the stone was placed along the southern side of the jetty. Stone was placed using land-based crane and jetty haul road. The size of armor stone averaged 25 tons.

In 1982, the South Jetty was repaired and 77,000 tons of stone was placed along stations 194-249 (same as in the 1962 repair). Most of the stone was placed along the southern side of the jetty to address wave damage. The amount of stone placed per unit length of jetty in 1982 (at 14 tons/feet) was less than one-third of any repair effort previously conducted on the jetties. Armor stone size averaged 13 tons (maximum 25 tons/minimum 8 tons). The repair cross-section had a crest elevation of 25 feet, crest width of 30 feet, and side slope of 1.5 horizontal to 1 vertical. Stone placement was by land-based crane and jetty haul road. Stone was delivered to the job site by barge.

2006-2007 South Jetty Interim Repairs

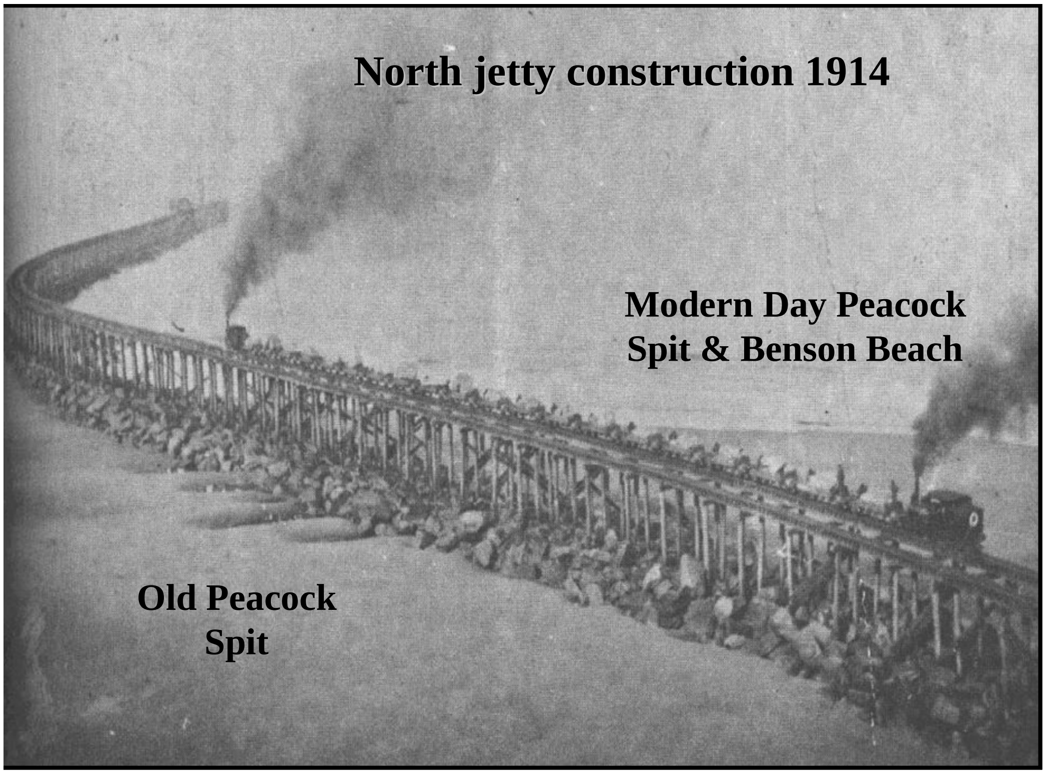
During 2006 and 2007, interim repairs were conducted along the South Jetty. These repairs were short-term efforts intended to stabilize the jetty until a longer term action could be taken. In 2006, interim repairs were conducted from stations 223 to 245. Crest elevation used was 25 feet with a side slope of 1 vertical to 2 horizontal. The stone sized ranged from 15 tons to 22 tons. In 2007, interim repairs were conducted from stations 255 to 285. Crest elevation used was 25 feet with a side slope of 1 vertical to 2 horizontal.

1.5.1.2. North Jetty

Congress authorized construction of the North Jetty through the Rivers and Harbors Act of 1905. Construction of the jetty was needed to limit the northward migration of the navigation channel, in response to South Jetty construction during 1885-1913. The direction of the jetty was to follow approximately the shallow waters southwesterly across Peacock Spit without a sudden change in direction to a point roughly 2 miles north of the end of the South Jetty. Heavy scour along the jetty toe was expected and taken into account during design by incorporating additional bedding stone.

North Jetty construction began in 1913 after completion of the South Jetty, and was completed in 1917. The North Jetty extended southwest from Cape Disappointment (station 0+00) along Peacock Spit for about 2 miles (station 107), then turned westward for about 1,700 feet and terminated at station 122. The 2.35-mile-long North Jetty required 2.95 million tons of stone. The stone was placed using a trestle-supported tramway with locomotives, side-casting cars, and crane. Stone was delivered to the tramway by barge. The same cross-section as shown in Figure 1-11 was used for original North Jetty construction, except that crest elevation was at 28 to 32 feet MLLW. Crest elevation along the landward 3,000 feet of the jetty was 15 feet MLLW. Jetty crest width was 25 feet. Maximum armor stone size was 7 tons. The finished side slope was approximately 1 vertical by 1.5 horizontal (natural slope). Figure 1-14 illustrates the trestle-based original construction of the North Jetty.

Figure 1-14. Trestle-based Original Construction of the North Jetty



Upon completion of the North Jetty in 1917, the two MCR jetties would work together to: (1) constrict the width of the MCR entrance to 2 miles at the terminal ends of the jetties, at which point the velocity of tidal flow would minimize the formation of shoals in the MCR entrance channel; and (2) "hold" and prevent channel-ward encroachment of existing entrance shoals - Peacock Spit along the north side of the MCR entrance channel and Clatsop Spit along the south side of the channel. By 1917, the navigation channel had attained a controlling depth of 40 feet and channel width was 1,000 feet. By 1937, the controlling depth was 46 feet and the distance between 40-foot depth contours along the channel centerline was 8,000 feet. The two jetties stabilized the inlet and enabled maintenance of an engineered entrance with nominal dredging. Figure 1-15 and Table 1-3 summarize the construction and repair efforts for the North Jetty over the project life. The yellow line on the figure indicates the area along the jetty that has never been repaired since original construction.

Figure 1-15. North Jetty Construction and Repair History (yellow represents portions of the jetty that have never been repaired)

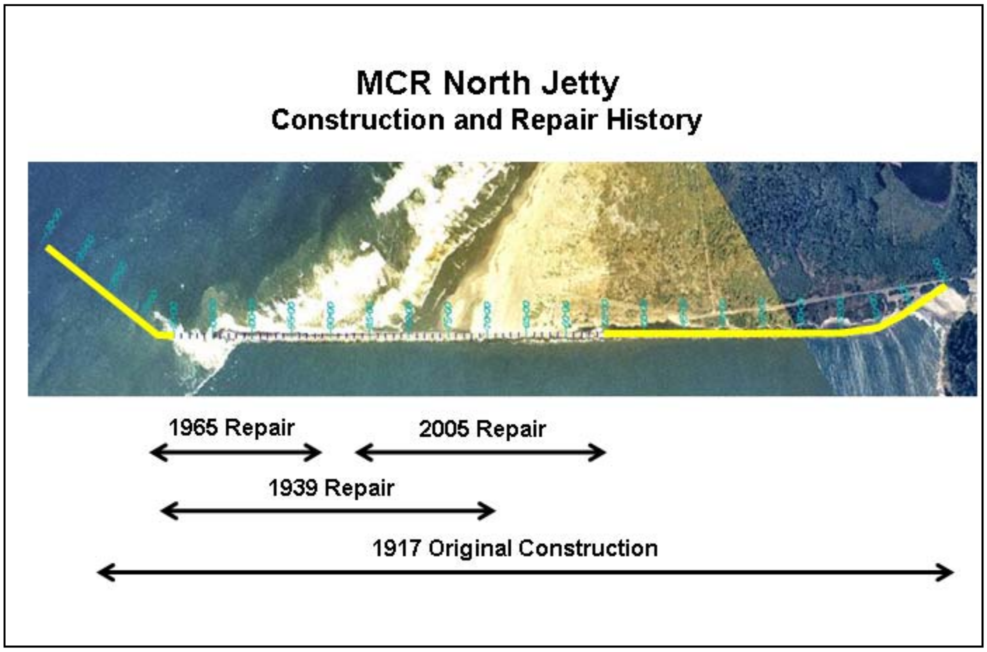


Table 1-3. Construction and Maintenance Activities for the MCR North Jetty

Design Parameter	1917	1939	1965	2005
Stone Density (pcf)	167	167	167	167-180
Structure Side slope (V:H)				
North Side	1:1.5	1:1.25	1:1.5 to 1:2	1:1.5
South Side	1:1.5	1:1.5	1:1.5 to 1.2	1:1.5
Crest Elevation (ft MLLW)	15 to 32	26	24	25
Crest Width (ft)	25	30	30	30
Armor Stone Quantity (tons)	2,946,449	247,233	136,935	
Select A Size (tons)			24	
Class A Size (tons)	50 lbs to 7 tons*	10	15.1	10
Class B Size (tons)		3.5	8	
Stone Source	Fisher	Skookumchuck	Fisher	Young's River Falls, Abe Creek, Phipps, Fisher, Turner, Washougal, Columbia Granite
Stone Type	Andesitic Basalt	Diorite	Andesitic Basalt	Multiple
Beginning Station	0+00	68+35	89+47	55+60
Ending Station	122+00	110+35	109+67	86+00

The first effort to rehabilitate the North Jetty was undertaken during 1938-1940. The total length of jetty reconstruction was 4,200 feet from stations 68-110 using 243,833 tons of stone. Along most of this reach, the north side of the jetty had resisted wave action due to the accumulation of sand (Benson Beach, see Figure 1-6). However, the south side of the jetty was damaged due to undermining from current action and direct exposure to waves. All of the stone placed on the jetty trunk during the 1938-1940 rehabilitation was along the northern side to maximize the effectiveness of establishing a rebuilt cross-section by placing stone on the more stable slope as opposed to the undermined slope on the south side of the jetty. Each side of the jetty head received equal amounts of stone (stations 108-110). The stone was placed using tramway, dump cars, and a 25-ton crane. Stone was delivered to the tramway by barge. Armor stone size ranged between 6-25 tons. Average armor stone size was 9 tons. The armor stone size was chosen based on professional judgment and equipment limitations. Rehabilitated crest width was 30 feet and crest elevation was 26 feet above MLLW.A concrete terminal (width of 70 feet and elevation 17 feet using 3,280 cy of concrete) was constructed from about stations 118-120 to establish a secure jetty head. The seaward-most 1,400 feet of the North Jetty (stations 120-124) was not rehabilitated. By 1964, the North Jetty concrete terminal had been reduced to 0 feet MLLW or less. The 1938-1940 rehabilitation sequence was the last time that the tramway method of repairs was used on the North Jetty. By 1964, the concrete terminal had broken into several pieces and settled to – 6 feet. At present, the remnants of the concrete terminal have been beaten down to below –10 feet.

The North Jetty was repaired in 1965 and 132,000 tons of stone was placed along stations 89-110. In 1964, the head of the North Jetty had been beaten back by wave action and undermining to station 103 from the original jetty head location at station 124. Along much of the southern side of the jetty, the outer armor stone had sloughed into the river exposing smaller core stone. The 1965 repair was needed to address damage along the southern side of the jetty caused by undermining of the jetty toe and to re-establish a stable jetty head. This was the first time that an empirical design approach (Hudson equation) was used to define armor stone size for the North Jetty in terms of incident wave height and jetty side slope. Model studies conducted by the Waterways Experiment Station in 1963 indicated that rehabilitation of the North Jetty to its outer end would improve flow patterns around the jetty, such that less shoal material would deposit in the MCR navigation channel. Much of the repair effort was dedicated to re-establishing a secure jetty head.

Most of the stone placed along the jetty trunk was placed along the northern side to efficiently re-establish a jetty cross-section. The exposed core stone along the south side was not believed to be vulnerable to wave attack, and significant water depth along the southern side of the jetty precluded an efficient cross-section renewal. Armor stone size ranged between 15-25 tons. The repair cross-section had a crest elevation of 24 feet and crest width of 30 feet. Stone placement was by land-based crane and jetty haul road. Stone was delivered to Ilwaco by barge and transported 2 miles by truck to the job site.

Early in this investigation, it was determined that portions of the North Jetty were close to failure. Interim repairs of the North Jetty in 2005 addressed only the upper part of the cross-section damage (stations 55 to 85) and were expected to last 10 to 15 years. The intent of this interim repair was to address the loss of jetty cross section above elevation -10 feet due to slope failure and direct wave action, in order to address short term stability problems.

1.5.1.3. Jetty A

During the early 1930s, after both the North and South jetties had been in place and significant modification of the inlet's morphology had occurred, the North Jetty became threatened by high velocity ebb tide flow, which threatened to undermine the structure's channel side foundation. Concurrently, the south side of Sand Island was being eroded by increased current action. In the late 1930s, the Sand Island pile dikes and Jetty A were constructed to stabilize the evolving inlet. Original construction was conducted with diorite rock from stations 40+93.89 to 97+36. From the beginning of the structure to station 53, the jetty was just a small armament feature with a crest width of 10 feet. The jetty from stations 53 to 92+86 was 30-feet wide at an elevation of 20 feet. The centerline of the jetty was centered along the railroad trestle. At station 92+86, the railroad trestle diverges into two trestles. The centerline of the jetty appears to be the center of the two trestles. Figure 1-16 and Table 1-4 summarize the construction and repair efforts for Jetty A.

Multiple partial repairs to Jetty A were made during the 1940s to 1960s. In 1958, approximately 3,800 feet of the inner end was repaired (stations 41 to 79). The structure had degraded to an elevation of 15 to 20 feet and was rebuilt to 20 feet (stations 41 to 56) with the baseline on the centerline of the old trestle. From stations 56 to 61 a transition occurs where the centerline of the repair changes from 25 feet to the right of the baseline to 10 feet left. From stations 61 to 79, the crest width was 30 feet.

Figure 1-16. Jetty A Construction and Repair History

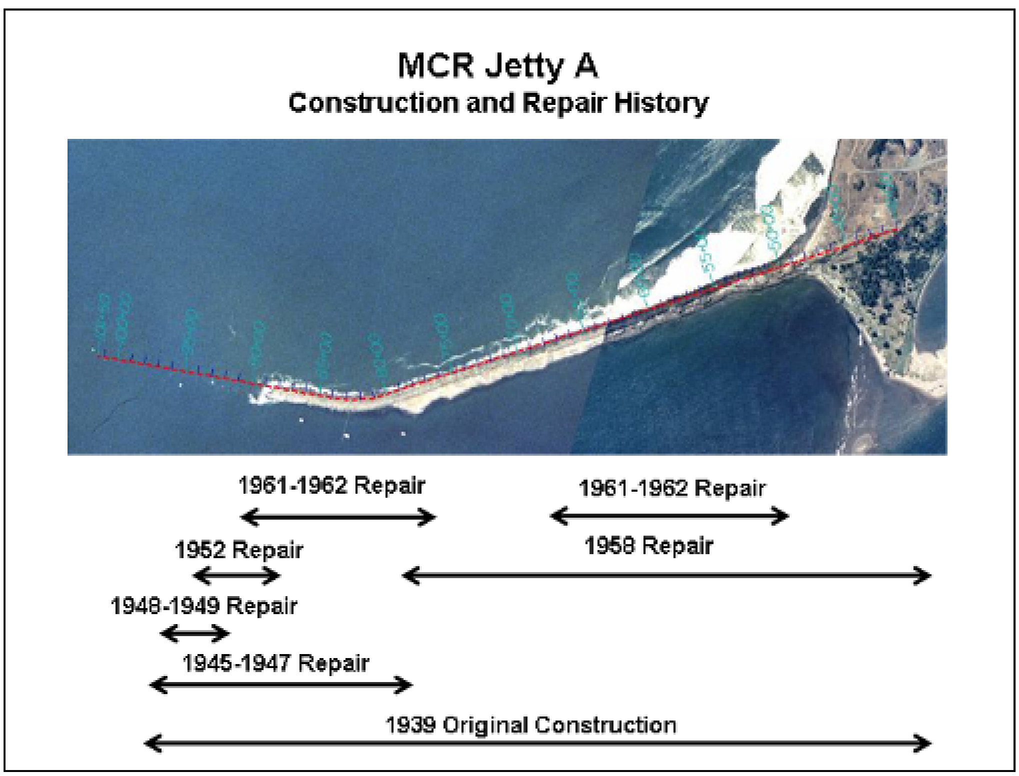


Table 1-4. Construction and Repair History for MCR Jetty A

Design Parameter	1939	1945-47	1948-49	1951	1952	1958	1961-62
Stone Density (pcf)	160	160	160	145	145	145	145
Structure Side slope (V:H)							
East Side	1:1.5	1:1.5	1:1.25	1:1.5	1:1.5	1:1.5	1:1.5
West Side	1:1.5	1:1.5	1:1.25	1:1.5	1:1.5	1:1.5	1:2
Crest Elevation (ft MLLW)	16-20	20	20	20	20	20	20-24
Crest Width (ft)	10-90	40	30	30	30	20-30	30
Armor Stone Quantity (tons)	233,708	63,125	30,000	6,994	25,005	92,399	161,098
Class A Size (tons)	10	6	5	500lbs to > 5 tons	5*	10	10
Class B Size (tons)	1 to 6	1 to 4	1 to 4	25lbs to 1 ton	100lbs to 4 tons	3	4
Class C Size (tons)	< 1	100lbs to 1 ton	100lbs to 1 ton			100lbs to 1 ton	< 2
Stone Source	Skoo.	Naselle	Skoo.	Cape Disappointment	Cape Disappointment	Cape Disappointment	Cape Disappointment
Stone Type	Diorite	Basalt	Diorite	Basalt Breccia	Basalt Breccia	Basalt Breccia	Basalt Breccia
Beginning Station	40+93.89	78+00	92+35	91+50	90+00	41+00	50+00
Ending Station	96+83	96+00	95+35	93+00	94+00	79+00	90+50**

*Change order increased average weight of Class A to 8 tons.
**No repairs from sta. 68+00 to sta. 76+50.

In 1960, approximately 3,150 feet of the outer end of Jetty A was repaired. The section was rebuilt to +24 feet in elevation from degraded elevations of +10 to 15 feet. A memorandum established a cap stone weight of 17.6 tons based on a wave height of 15.5 feet and a specific gravity of 2.4. The stone size considered for the 1960-1961 repair was a 6-ton minimum and at least an average weight of 10 tons. The armor layer was designed to have class A stone placed along the westerly/ocean slope and over the crest of the jetty. Class A and class B stone would then be placed along the easterly/Baker Bay slope. Select class A stone, weighing more than 15 tons, was placed between jetty stations 90+00 and 90+50.

A 1960 Design Memorandum stated that the history of repairs at Jetty A, "suggests major deficiencies in past construction." This design report stated that since the jetty, "is principally serving as directional current training and not as wave protection, the structure would adequately fulfill all requirements if the repairs were to end at station 91+00 rather than 95+50. For the same reason, the height of jetty repair between stations 78+00 and 91+00 should be held to elevation +20." Rock in the armor layer was individually placed with a crane, as opposed to being dumped onto the jetty from the trestle and tramway. Stations 41 to 79, repaired in 1958, received considerable damage due to overtopping waves. Breaks in the jetty exposed the jetty to further damage. The design report stated that it was believed that the first damage to the jetty was due to subsidence caused by scouring of sand from around the jetty base resulting in armor stone displacement. Smaller rock was then exposed to waves, which resulted in further displacement.

A small armament was built from stations 49+93.89 to 53+00 on Jetty A according to plan drawings and the 1960 Design Memorandum. The jetty was then built to an elevation of 20 feet MLLW out to station 92+86. From stations 92+86 to 97+36, a second trestle was built and the jetty crest width was built wider, with a crest width at the end of 90 feet. There have been six repairs since original construction. The centerline of the jetty has not remained the same throughout the repairs.

Jetty A, as originally constructed, protects the North Jetty and helps to train the Columbia River mainstem. In addition, Jetty A is believed to play an important function for the Columbia River plume. The plume is an important food source for the 13 Columbia River salmonid evolutionarily significant units (ESUs) listed under the Endangered Species Act (ESA).

1.5.1.4. Forensic Analysis of Historical Jetty Stability

A forensic analysis of historical construction and repair efforts at the MCR project incorporates both the capacity of the structure to resist damage as well as the degree of loading the structure undergoes. Both of these categories have evolved over time for all of the jetties being analyzed. The location and capacity of the historical construction efforts are shown in Figure 1-2 through Figure 1-16 and Tables 1-2 to 1-4. For the purposes of defining the failure history, the jetty lengths can be divided into general zones of exposure. Table 1-5 summarizes the primary loading factors for the range of zones of each jetty. Zone 1 is closest to shore and typically has the lowest loading forces while zones 3 and 4 are the furthest offshore and have the highest and most complex loading. Additional information on construction history can be found in Appendix A1, Section 5. The last column summarizes the identified failure modes associated with that construction effort and point in time.

The key capacity features that influence the performance of the MCR structures include stone size, sideslope, stability coefficient, and crest elevation. All of these factors have been influenced somewhat by construction method. Pacific Northwest jetties have historically been constructed from the top of the jetty downward with limited reach length equipment. In the case of the initial construction, this involved the construction of a railroad trestle that extended the length of the structure from which the rock was dumped. The initial construction and subsequent repairs evolved over time from the initial low crest, small stone size construction of the South Jetty first construction to the more substantial cross sections of the later efforts. For subsequent repair efforts, minimum crest width and crest elevation were often associated with providing a safe and viable construction platform for the equipment. A rigorous and analytical approach to sizing the stone for the construction and expected wave loading did not occur until the 1950’s and 1960’s.

At the MCR and for most Pacific Northwest coastal projects, wave attack is the primary loading factor, both front slope attack as well as backslope instability due to overtopping. Other related damaging forces are related to the scour and morphology change around the project. In some cases morphology/shoreline change can have a positive effect on the stability of the structure, e.g. the shoreline accretion along the north side of the North Jetty has functioned to protect the landward half of that structure from oceanside loading. However, in other cases, toe scour or shoreline recession has the combined effect of destabilizing the structure toe as well as allowing larger waves to impact the structure. Increasing wave heights over time at the entrance can also be attributed to sequential channel deepening actions. While the original authorized depth was 30 ft in 1882, the actual depth over time achieved was variable during the construction of the three jetties. Once all three jetties were constructed, more stability was achievable in the maintained channel. The gradual increase in channel depths occurred in 1895 (30 ft), 1918 (40 ft), 1957 (48 ft), and 1984 (55 ft).

Shortly after the construction of the North Jetty, it became threatened by high velocity ebb tide flow which threatened to undermine the structure's channelside foundation. In contrast to the South Jetty original construction, the North Jetty construction plan did not include any channelside spur groins to assist in controlling the flow along the foundation of the structure. Concurrently, the south side of Sand Island was being eroded by increased current action. Loss of either the North Jetty or Sand Island would have rendered the inlet unsuitable for navigation. The adverse circulation affecting the North Jetty and Sand Island was motivated by the northward migration of the estuary thalweg toward Cape Disappointment. In the late 1930s, the Sand Island Pile Dikes and Jetty A were constructed by USACE to stabilize the evolving inlet. At the same time the scour was occurring on the channelside of the North Jetty, the ocean side of the structure was being protected by a large accretion fillet. Along the landward half of the North Jetty, another de-stabilizing flow path had developed through the structure as tidal flow moved through the structure to the eroded lagoon behind the structure.

By 1919, the 40 foot contour had been displaced more than 6560 feet seaward in response to the phased jetty construction and the morphology had been thrown out of equilibrium due to increased tidal flow velocity in and around MCR. On the south side of MCR, there was no seaward displacement of the 40-foot contour. Rather, the 40-foot contour south of MCR had been receding landward since jetty construction in 1885. By 1930, waves and currents were acting on the displaced morphology to bring the region to equilibrium. The displaced tidal shoals on the north side of MCR were being eroded and the 40-foot contour was receding landward. The offshore extent of the 40-foot contour on the south side of MCR has been receding landward of its 1885 position, toward the South Jetty, since jetty construction.

Appendix A1, Figures A1-19 to A1-24 and Appendix A5 show morphological change to the inlet over time since original construction. Specific changes to be noted which relate to project loading include shoreline or underwater shoal accretion or erosion, reorientation of the ebb tidal flow path through the mouth, and deepening of the contours which allows greater wave penetration into the inlet. Continued jetty length loss preceded additional erosion of the underwater shoals and greater wave loading of the landward portions of those structures as well as adjacent structures. All of these loading and stability processes have been simulated in the life cycle performance model for this project through the hindcast mode of the event tree simulation.

Table 1-5. Historical Failure Modes for the MCR Jetties

Failure Mode (STA (zone))	Channel-side Wave Height	Oceanside Wave Height	Channel-side Scour	Oceanside/ Backside Scour	Overtopping Forces	Deficient Design Section
North Jetty						
20 to 50 (1)	X		X	X		X
50 to 90 (2)	X	X	X		X	X
90 to 122 (3)	X	X	X	X	X	X
South Jetty						
150 to 200 (1)		X			X	X
200 to 250 (2)	X	X			X	X
250 to 300 (3)	X	X		X	X	X
300 to 375 (4)	X	X	X	X	X	X
Jetty A						
40 to 60 (1)					X	X
60 to 80 (2)		X			X	X
80 to 97 (3)		X	X	X	X	X

1.5.2. Historical Morphology Change at the MCR Inlet

An extensive bathymetric analysis was conducted of the MCR by Applied Coastal Research and Engineering in 2006 in order to document evolution of the morphology spanning the time frame prior to jetty construction to the present day. (Byrne and Griffee, 2006) The report built on a preliminary study completed for the Portland District in 1998 (Byrnes and Li, 1998). The study was designed to compile and analyze existing surveys over shorter time intervals to address dredged-material management issues and regional sediment management at and adjacent to the MCR. Detailed bathymetric change maps from this study can be found in Appendix A5.

Between 1868/77 and 1926, massive adjustments in sediment volume occurred at the entrance where the ebb-tidal shoal moved seaward about 2 mi, depositing approximately 252 million cubic yards (MCY) of sediment in 90-ft water depth. Approximately 70% of this deposition occurred between 1899 and 1926, after the entrance jetties were constructed. The ebb-shoal that formed is strongly skewed to the north, even though the channel exits the coast to the south-southwest. Deposition of northward directed sand from the ebb-shoal created Peacock Beach, just north of the north jetty and south of Cape Disappointment. Clatsop Spit evolved in association with construction of the south jetty, creating a 3.5 mi long beach and filling the 1868 entrance channel as the new channel shifted north and displaced Sand Island. Sediment deposition north of the channel and in Bakers Bay (158 MCY), east of Cape Disappointment, appears to be the result of decreased flow in the area resulting from jetty placement and channel realignment. Conversely, seafloor erosion south of the south jetty is the result of decreased sediment supply to the area when the entrance channel shifted to the north, jetting much of its sediment load seaward to the ebb shoal. Sediment erosion associated with channel realignment and erosion south of the south jetty (543 MCY) controlled the sediment budget in the entrance area.

Bathymetric changes recorded for the period 1926 to 1958 illustrate similar depositional trends as the previous surface comparison, but many differences are documented as well. A number of trends emerge from the comparison. First, net northward transport of sediment is illustrated by the north-oriented ebb shoal. The center of the shoal has again moved seaward in response to flow from the increasingly-deeper channel (-40 to -48 ft during this time period); sediment deposition on the ebb shoal during this time was 181.8 MCY. A substantial zone of erosion exists just landward of the ebb shoal, marking the position of the 1926 ebb-tidal delta. The magnitude of erosion for this feature (81.4 MCY) is a little less than half of the deposition recorded for the ebb shoal. Another indication of northward sand transport is the apparent streaming of sand north from the ebb-tidal delta to the beaches along the coast of Long Beach Peninsula. During this time, beaches were accreting along this entire stretch of coast. Approximately 94.1 MCY of sand deposited along the coast during this period.

The interior entrance area illustrates zones of erosion and deposition associated with channel migration, dredging, and deposition at the north end of Clatsop Spit. Overall, erosion (155.2 MCY) is greater than deposition (67.4 MCY) in the entrance area, creating a net sediment loss of 87.8 MCY. To the south of the south jetty, sediment erosion is occurring along the beach (12.4 MCY) and on the shelf (38.4 MCY). The sediment deficit is related to jetty placement and blocking of sand from the entrance that used to supply sediment to the northern Oregon coast. Shoreline change data from Byrnes and Li (1998) suggest that this is a local phenomenon (with 3.5 mi of the jetty), with net shoreline advance indicated south of this point. Komar and Li (1986) discuss this spatial variability in shoreline response and state that in recent years, shoreline retreat south of the jetty has diminished and stabilized.

A number of bathymetric surveys conducted by the USACE – Portland District were employed to evaluate geomorphic changes at the Columbia River mouth up to 2003. Surface comparisons were made for two time periods: 1958 to 2003 and 1994 to 2003. The 1958 to 2003 seafloor change map illustrates the same general trends as those presented for the 1926 to 1958 comparison, except the magnitude of accretion and erosion has increased. The centroid of deposition on the ebb shoal (minus the impact of dredged material placement at Site B) has shifted to the north. Sediment accretion north of the entrance along Long Beach Peninsula continues to occur as the shoreline moves seaward. In addition, erosion associated with the 1926 ebb-tidal delta has increased, and the magnitude of sediment deficit south of the south jetty has been enhanced. One major difference for the 1958 to 2003 surface comparison is the presence of two well-developed mound areas representing dredged material disposal Sites A and B. These areas have been accumulating dredged material since 1956.

The final surface comparison is for the 1994 and 2003 survey dates. Largest changes are associated with offshore dredged material placement, erosion on the ebb shoal, and nearshore and beach erosion just north of the north jetty. Erosion on the ebb shoal and the nearshore area north of the north jetty is consistent with the 1958 to 2003 bathymetric comparison. These two areas indicate net losses of 20.1 MCY and 23.7 MCY, respectively. At ocean disposal sites A and B, erosion on the disposal mound is prevalent; however, sediment deposition occurs to the north of each mound as well, indicating the dominant direction of net drift for dispersed sediment. Site A has had no new material deposited since 1995 and Site B has been inactive since 1998. This information provides direct evidence of net transport pathways at and adjacent to these disposal sites, and throughout the study area. The general trend of deposition north of the entrance is still evident, but the magnitude of change is relatively small due to the short period of time between surveys. A net deficit of about 21 MCY of sediment is calculated for the entire surface. (Byrne and Griffee, 2006)

1.5.3. Service Disruptions, Repairs, and History of Project Costs

A discussion of the construction and repair history for the MCR jetties is provided in Section 1.4.1. Construction of the North and South jetties significantly altered the natural inlet at MCR and secured a stable deep draft navigation channel, although there is risk of jetty destabilization due to scour. A more detailed discussion is provided in Appendix A1. Historically, breaches have occurred in the MCR jetties.

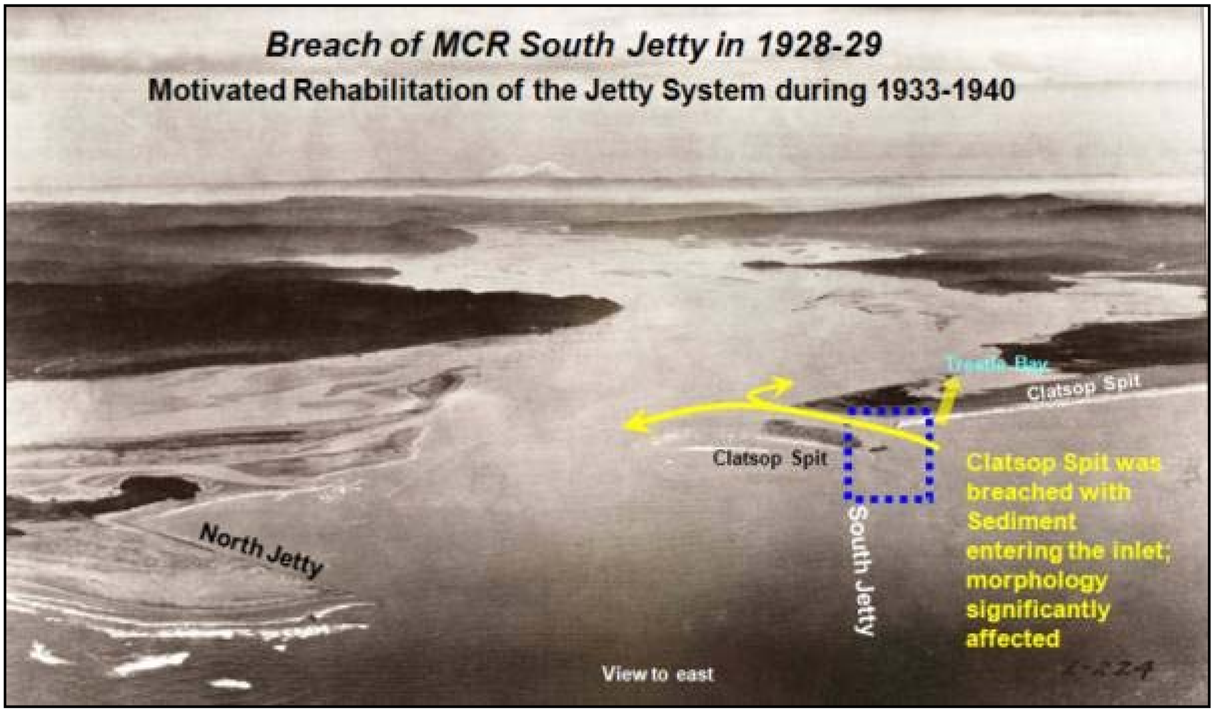
In a historical context, the South Jetty root breached extensively during the late 1920s. This event modified the configuration of the MCR inlet and affected navigation, motivating a significant rehabilitation campaign of the South and North jetties during the 1930s. Figure 1-17 illustrates this event. In 1928, a breach through the jetty cross section occurred near the shore connection (jetty root). The consequences of the breached jetty were significant. A large volume of sediment passed through the breach (from south to north) and deposited in the inlet, which changed the inlet's morphology. Much of the sediment along the ocean shore south of the inlet was transported by flow through the breached jetty (narrowing the margin between the ocean and Trestle Bay). Storm surge overtopped the shore and passed into Trestle Bay, threatening the stability of the entire inlet. Tidal circulation through the breach promoted the northward migration of Clatsop Spit, which adversely impacted navigation through the MCR. The breach event motivated a 9-year jetty rehabilitation program for the North and South jetties and included the construction of Jetty A.

The outer end of the North Jetty was rehabilitated from 1938-1940; however, by 1958 the jetty was again in need of rehabilitation because a 300-foot breach had developed immediately shoreward of the terminal block, and the river side of the outer half of the jetty had been damaged by undercutting. During the late 1950s, Jetty A had become breached, resulting in a concerted effort to rehabilitate the structure. Jetty A has not been repaired since 1962. Figure 1-18 shows the Jetty A breach, as well as an imminent breach developing along the North Jetty in 2002.

During 1999-2004, reaches of the North and South jetty became partially breached, motivating "interim repairs" to both jetties, performed "just-in-time" during 2005-2007. Before completion of the North Jetty interim repairs in 2005, approximately 300,000 cy of sand (from Benson Beach) had passed through the damaged section of the North Jetty. This volume was estimated based on bathymetric surveys conducted during 1999 and 2006. The sand deposited along the channel side of the North Jetty, not being transported toward the navigation channel due to lack of hydraulic forcing. Interim repairs addressed the most critical areas of the North and South jetties in a cost-effective manner. The interim repairs were intended to last 10 to 15 years (from 2006), until the jetties could be rehabilitated.

Major disruptions to the MCR navigation channel have been avoided through several large rehabilitation efforts throughout the extended project life of the MCR structures. Figure 1-19 and Figure 1-20 illustrate damage to the South Jetty and the attempt to stabilize the structure. Each of those efforts served to re-establish the robustness and reliability of the structures.

Figure 1-17. Historical Breaching of the South Jetty



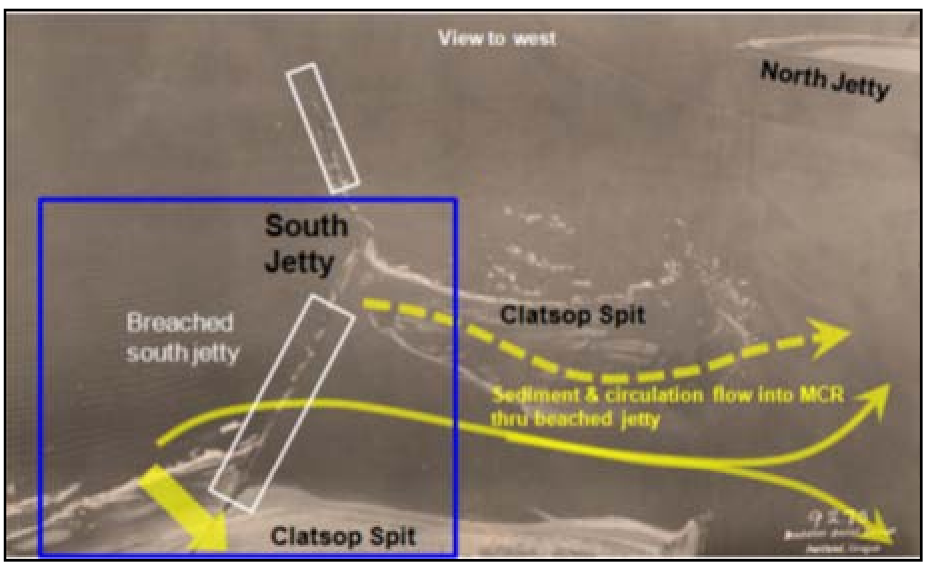
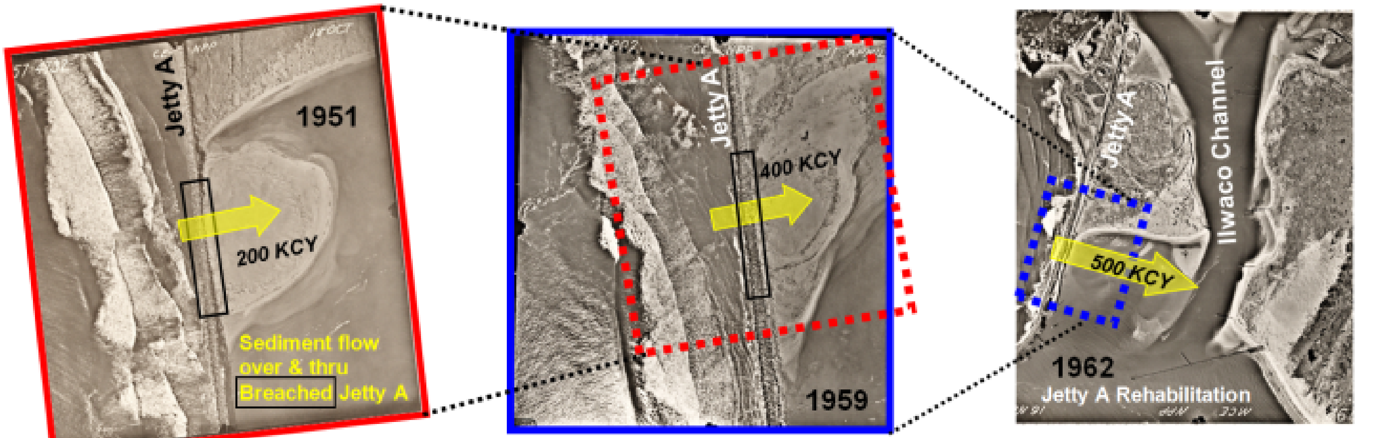
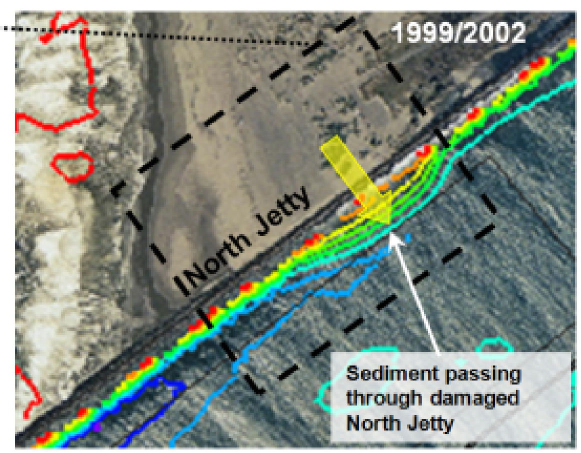


Figure 1-18. Historical Breaching of the North Jetty and Jetty A



Historical breaching of Jetty A. Jetty A was constructed in 1939 to halt northward migration of the inlet and re-direct currents away from the north jetty, In 1950, a 300-ft long breach developed at the mid-span of Jetty A allowing ~200 KCY to be transported (eastward) over the jetty and toward Ilwaco channel. Jetty A was rehabilitated in 1961-62 to restore function and prevent further sediment encroachment (closure) of the Ilwaco navigation channel. During 1951-61, approximately 500 KCY passed thru the Jetty A breach.

Had the NJ not been repaired "just-in –time" in 2005, it would have breached soon after allowing a very large volume of sediment to pass into the MCR inlet and the navigation channel.



Recent breaching of North Jetty. The North Jetty (NJ) was constructed in 1914-17 to stabilize the north side of the MCR inlet, and was repaired in 1939 & 1964. By 2002, several areas of the NJ were on the verge of breaching. The jetty cross-section between Sta 57-70 was degraded such that sediment was being transported through the jetty during high-tide storm wave conditions.

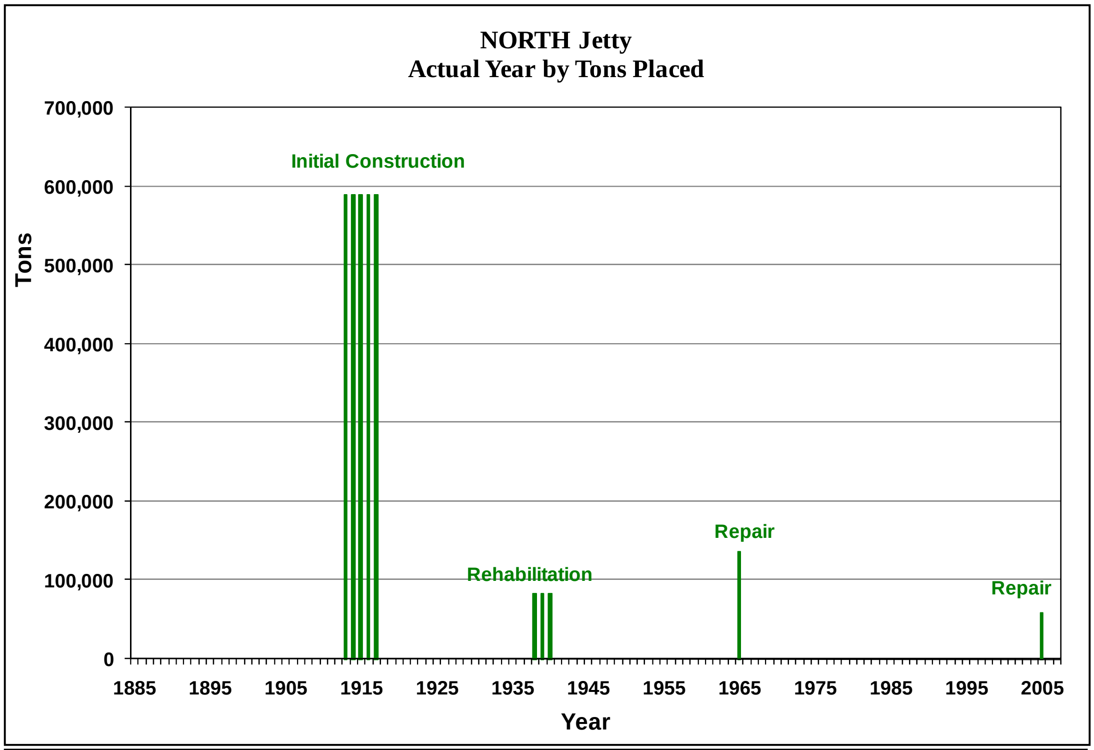
Figure 1-19. South Jetty Deterioration in 1930s

Mouth of Columbia River, Oregon; south jetty; old enrockment 2½ miles west of Clatsop Spit; rock in place at least 21 years; July, 1934. 200′ wide on top.

Figure 1-20. Concrete Monolith Construction at Seaward End of the South Jetty

Figure 1-21 through Figure 1-23 illustrate the actual year-by-year investment in stone tonnage for construction rehabilitation and repairs for the North Jetty, South Jetty, and Jetty A, respectively.

Figure 1-21. North Jetty Actual Year-by-Year Tonnage



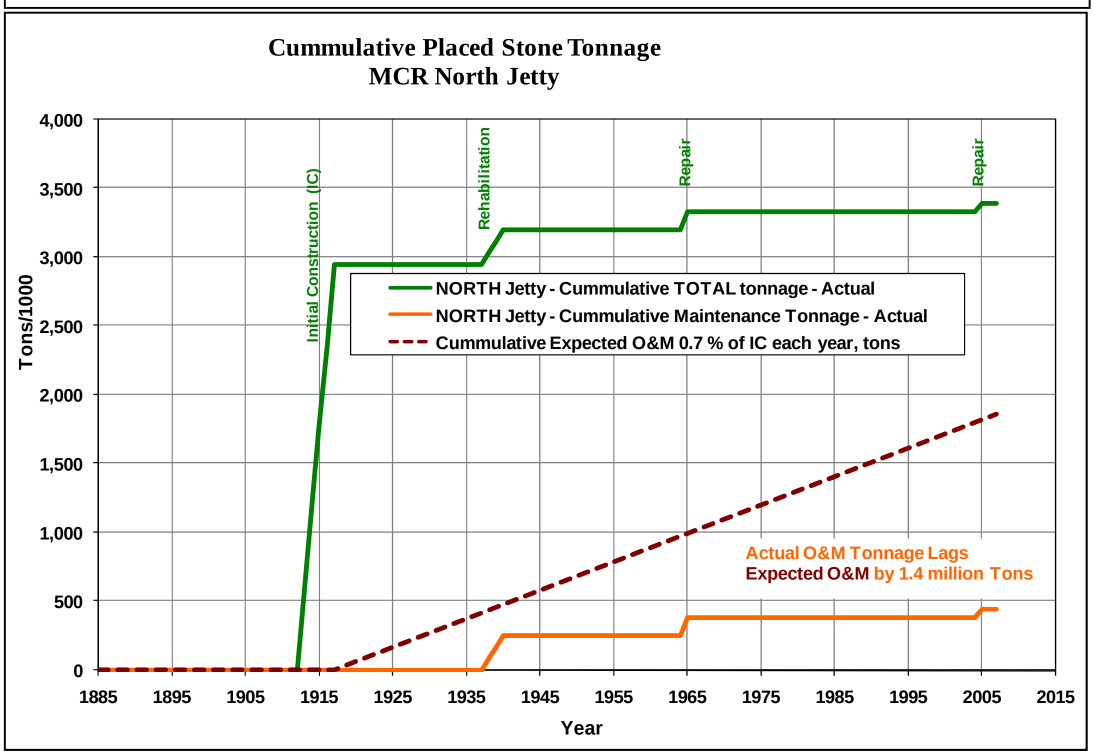
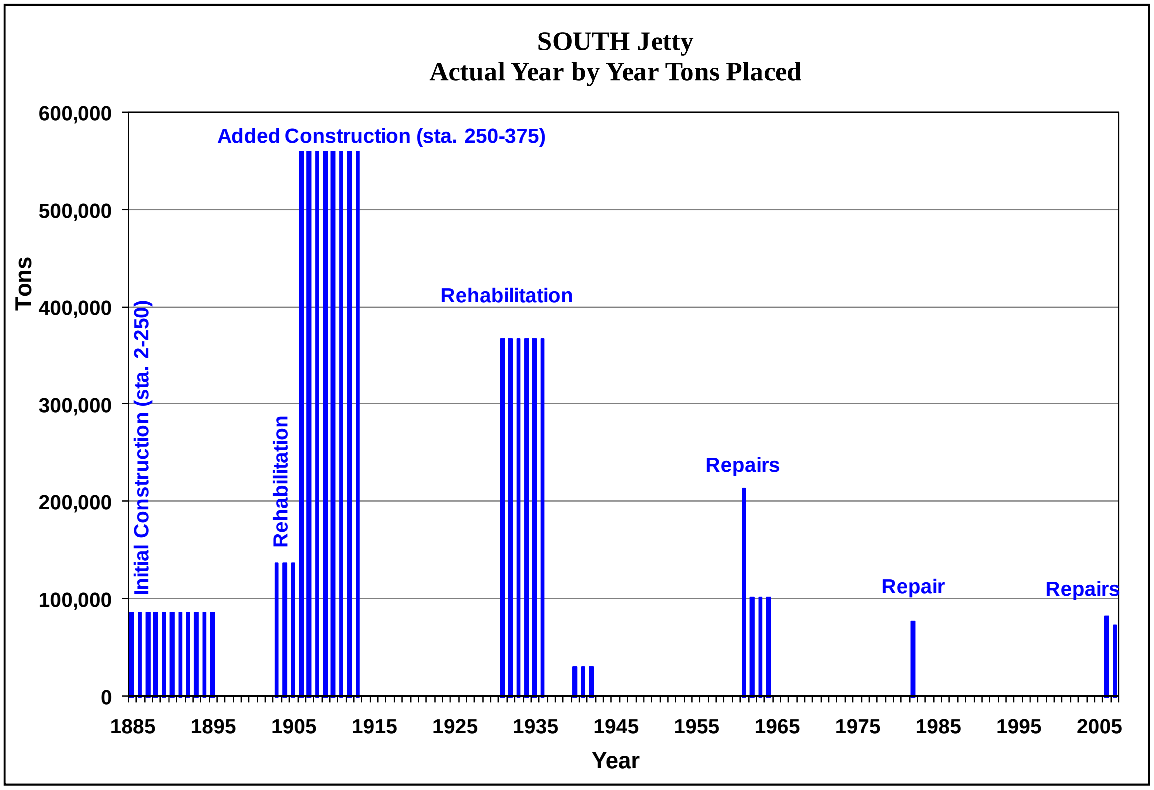


Figure 1-22. South Jetty Actual Year-by-Year Tonnage



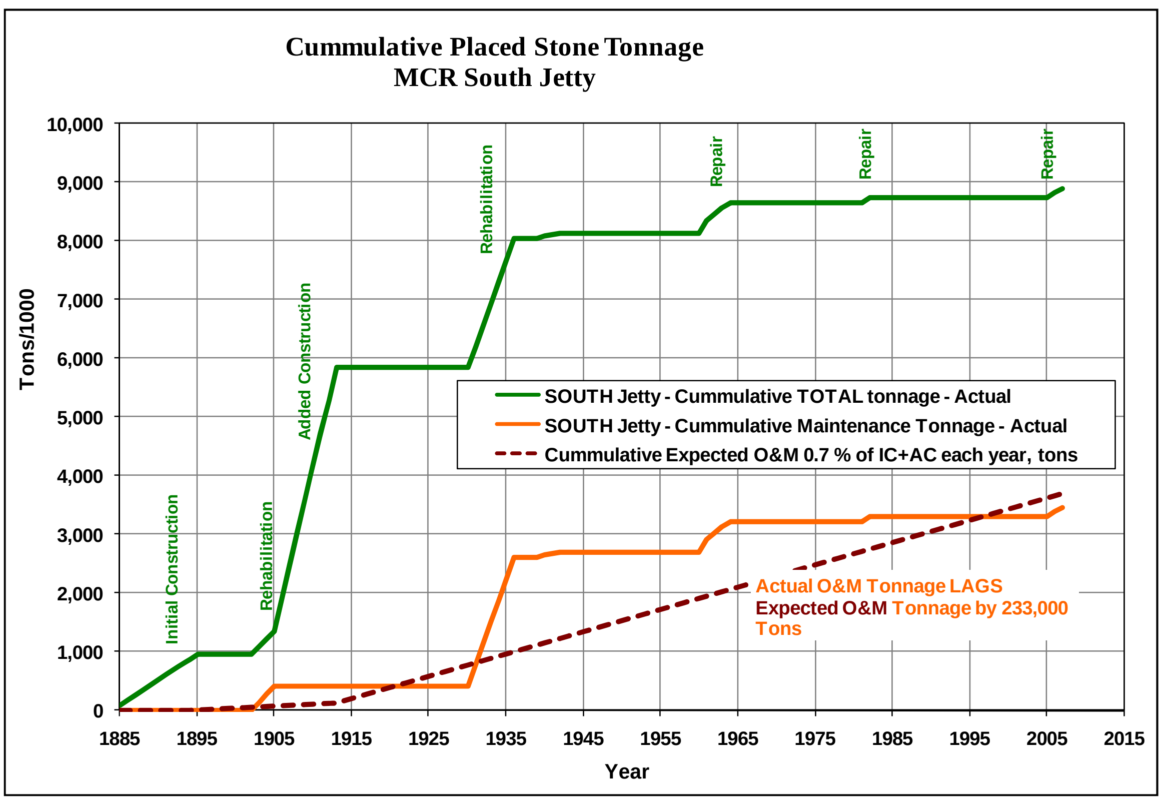
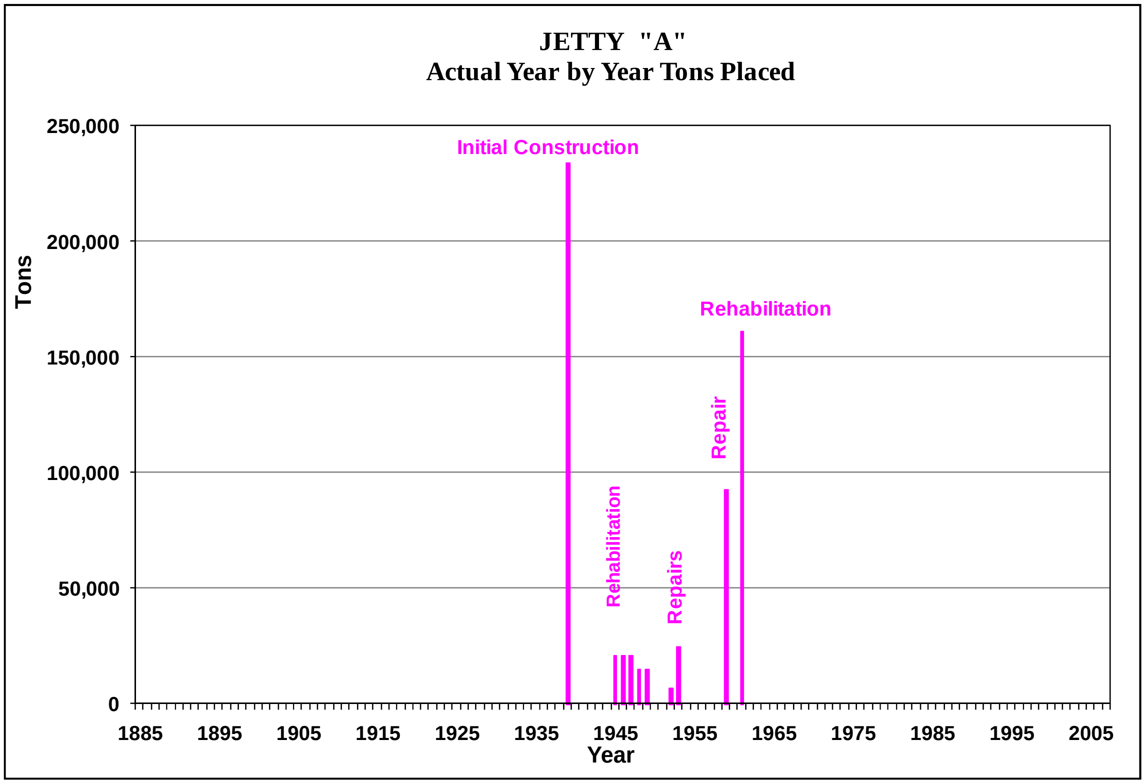
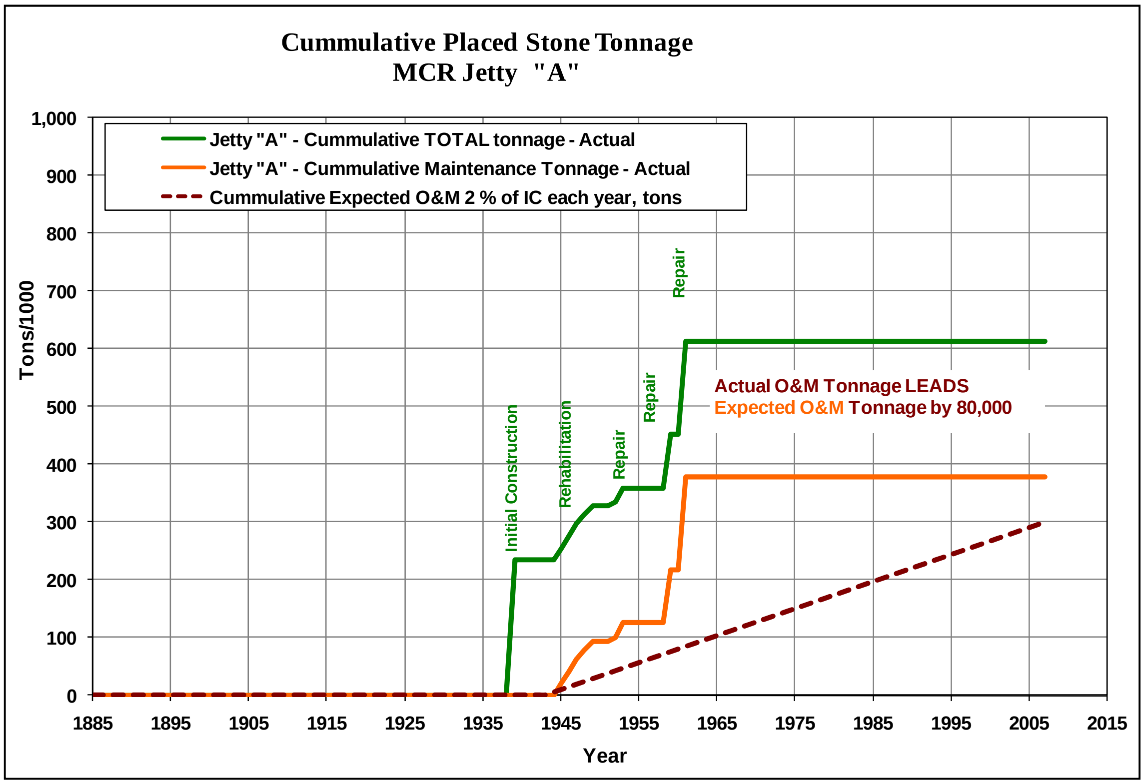


Figure 1-23. Jetty A Actual Year-by-Year Tonnage





1.5.4. **Expected Future Changes in Jetty Structures over time**

1.5.4.1. North Jetty

The North Jetty has receded about 2,100 feet in length since original construction (Figure 1-24 and Figure 1-25). The location of the jetty head is typically referred to as the last full jetty cross section at the design crest elevation. Based on historical recession rates, the jetty head will continue to deteriorate at a rate of about 20 to 50 feet per year. At this rate at the end of a 50-year period, it is expected to reach stations 76 to 90 (or about 1,800 feet of additional loss from its current position) in very close proximity to where the existing shoreline is today. Peacock Spit and Benson Beach are expected to continue to erode shoreward at a similar rate to the jetty length deterioration. Much of the sediment loss associated with shoreline retreat would migrate into the federal navigation channel and routine maintenance dredging of the MCR entrance would increase over time.

The North Jetty trunk will degrade by three distinct processes: direct wave impact, wave overtopping (affecting above-water portion of jetty), and scour at the jetty base (affecting below-water portion until it fails and destabilizes the above-water portion). The present channel side toe of the jetty is severely compromised due to foundation scour, while the landward half of the ocean side of the jetty is protected by high elevation bathymetry. Both sides of the seaward half of the jetty are exposed to large waves. The North Jetty acts as a wing dam to prevent Peacock Spit and Benson Beach from entering the inlet.

Figure 1-24. North Jetty Head Recession

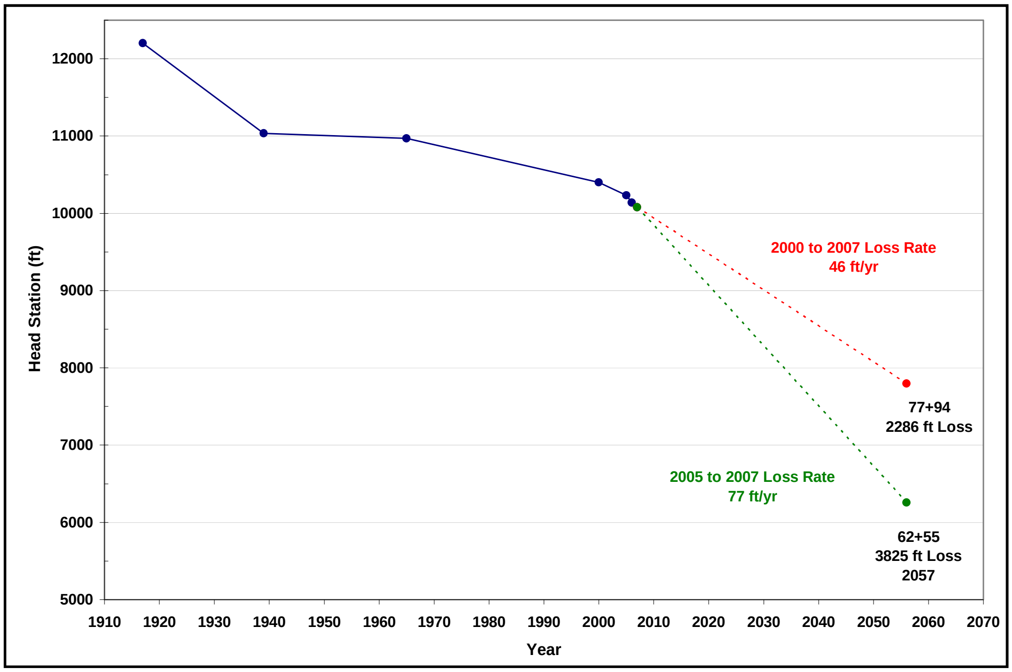
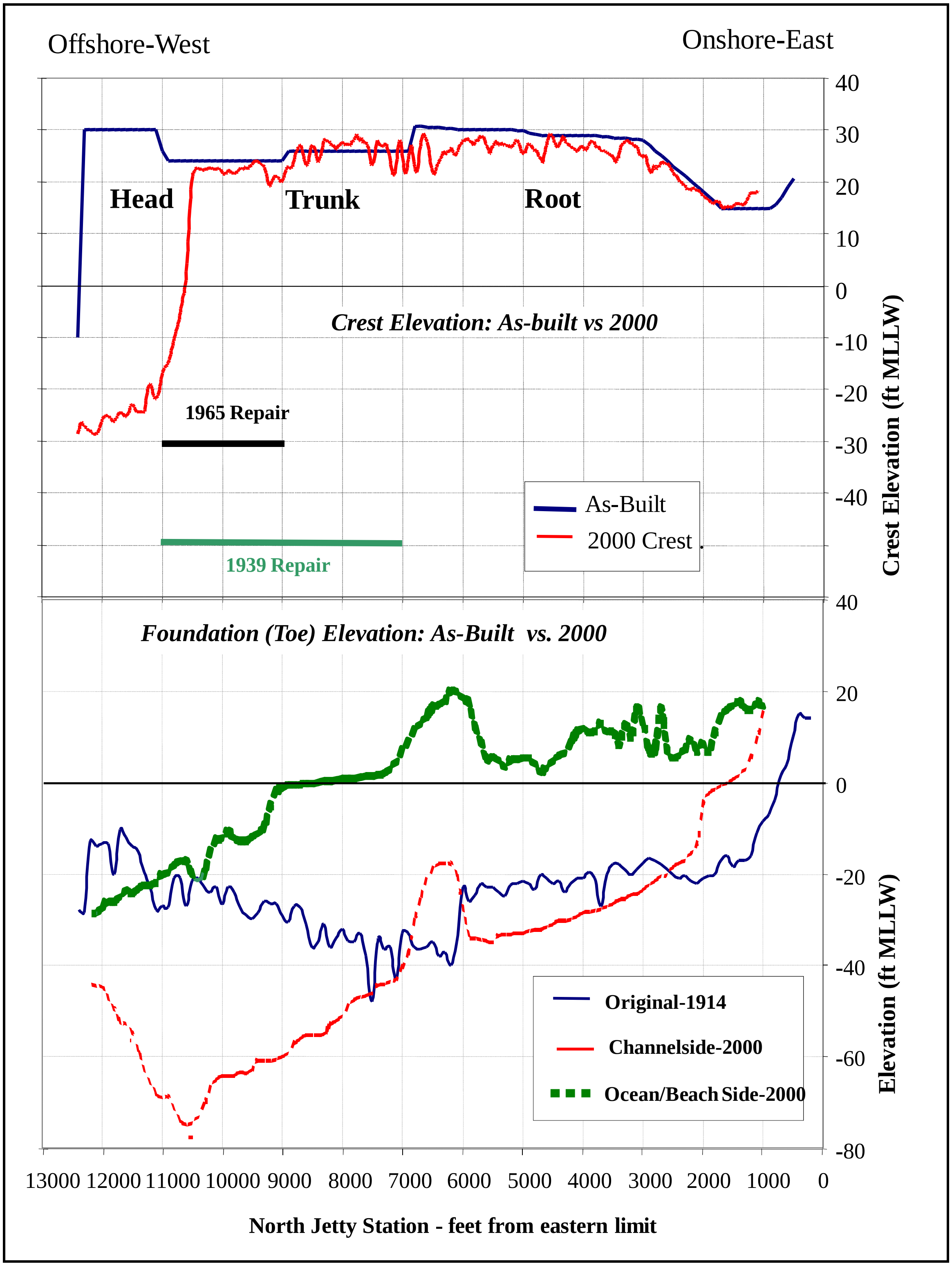


Figure 1-25. North Jetty Crest and Foundation Changes Over Time



1.5.4.2. South Jetty

The South Jetty has receded about 6,200 feet in length since original construction (Figure 1-26 and Figure 1-27). The part of Figure 1-26 between 1913 and 1964 illustrates the changing morphology and continued loss of the South Jetty length due to extreme wave exposure and ebb tidal shoal changes. Although the concrete monolith was constructed in 1941, the jetty continued to recede landward of the concrete monolith. Continued steepening and scouring of the foundation contributed to loss of structure length. The existence of the spur groins at stations 309 and 333 helped to slow the morphology change at those locations and in addition helped to maintain concrete terminal longevity. These spur groins are shown in Figure 1-28.

The projected jetty length recession in the future as shown in Figure 1-26 is based on extrapolating the existing rate of recession until the concrete monolith is expected to deteriorate to extent it no longer provides some protection to the seaward end of the Jetty. This is expected to occur in approximately 12 to 15 years based on recent observations and engineering judgment. Once the concrete monolith no longer provides protection of the seaward end of the jetty, recession of the jetty length will accelerate in the future.

Repeated repairs to the seaward half of the South Jetty (four repairs) have bolstered that reach of jetty's resilience over time. Other MCR activities which have influenced the recession rate and stability of the South Jetty head and seaward half are the 1954 channel deepening and slight channel realignment and the creation of ODMDS A (see Figure 1-4). Figures pertaining to the 1954 channel deepening can be seen in Appendix A, Figures A1-25, A1-26, and A1-29. The channel realignment shifted the MCR channel slightly to the north allowing Clatsop Spit to achieve more stability on the channel side of the South Jetty, providing more protection there. Disposal efforts at ODMDS A started in the 1950s and it was the primary disposal site for the 1954 channel deepening. Disposal at this site continued until 1994, at which point its use was discontinued. As seen in Figure 1-4, ODMDS A plays a large role in shielding the head of the South Jetty from incoming waves.

Currently, the concrete monolith still exists as a remnant structure seaward of the actual jetty head. Continued wave exposure and foundation scour, however, are undermining its stability. Since it serves as a type of anchor point for the ebb tidal shoal and the south jetty seaward half, if this is de-stabilized, more rapid South Jetty deterioration would be expected.

Like the North Jetty, the South Jetty trunk will degrade by direct wave impact, wave overtopping, and scour at the base of the jetty. The channel side of the jetty is in the lee of waves approaching the jetty directly from the Pacific Ocean. The channel side of the jetty is also protected by the high elevation bathymetry of Clatsop Spit, while the ocean side of the jetty is exposed to larger water depths and the direct attack of the Pacific Ocean wave environment.

Figure 1-26. South Jetty Head Recession

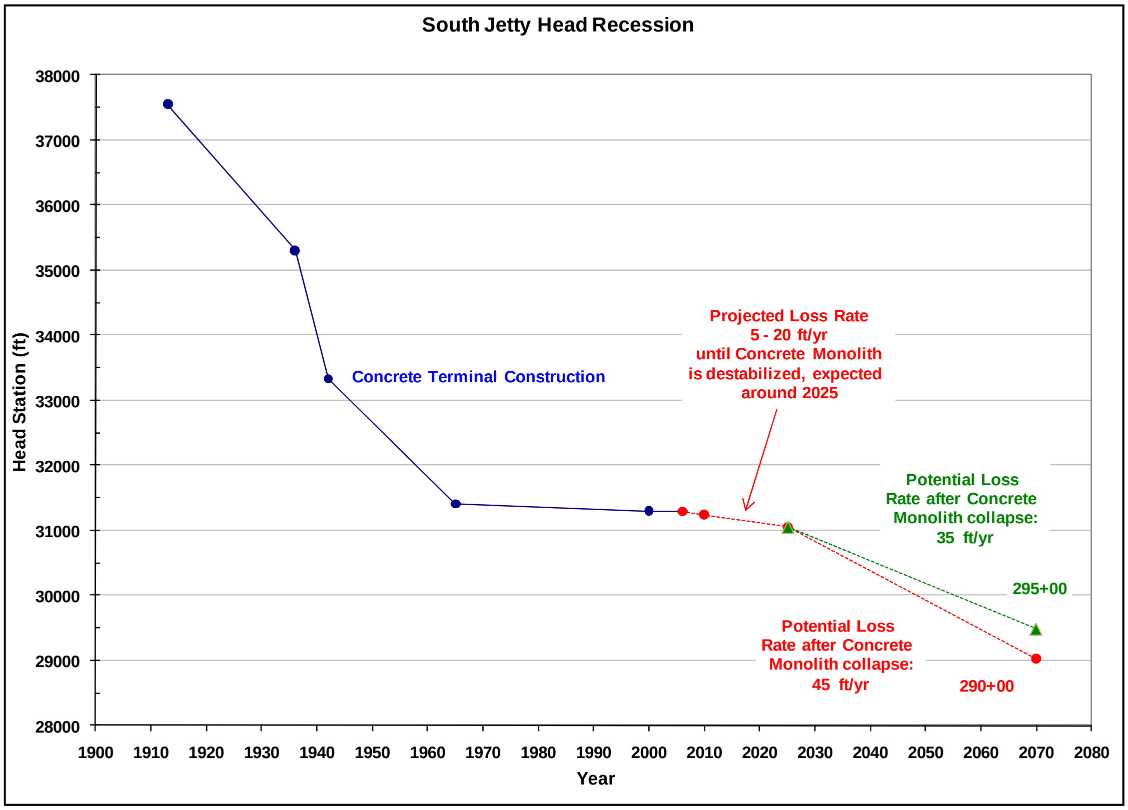


Figure 1-27. South Jetty Crest and Foundation Changes over Time

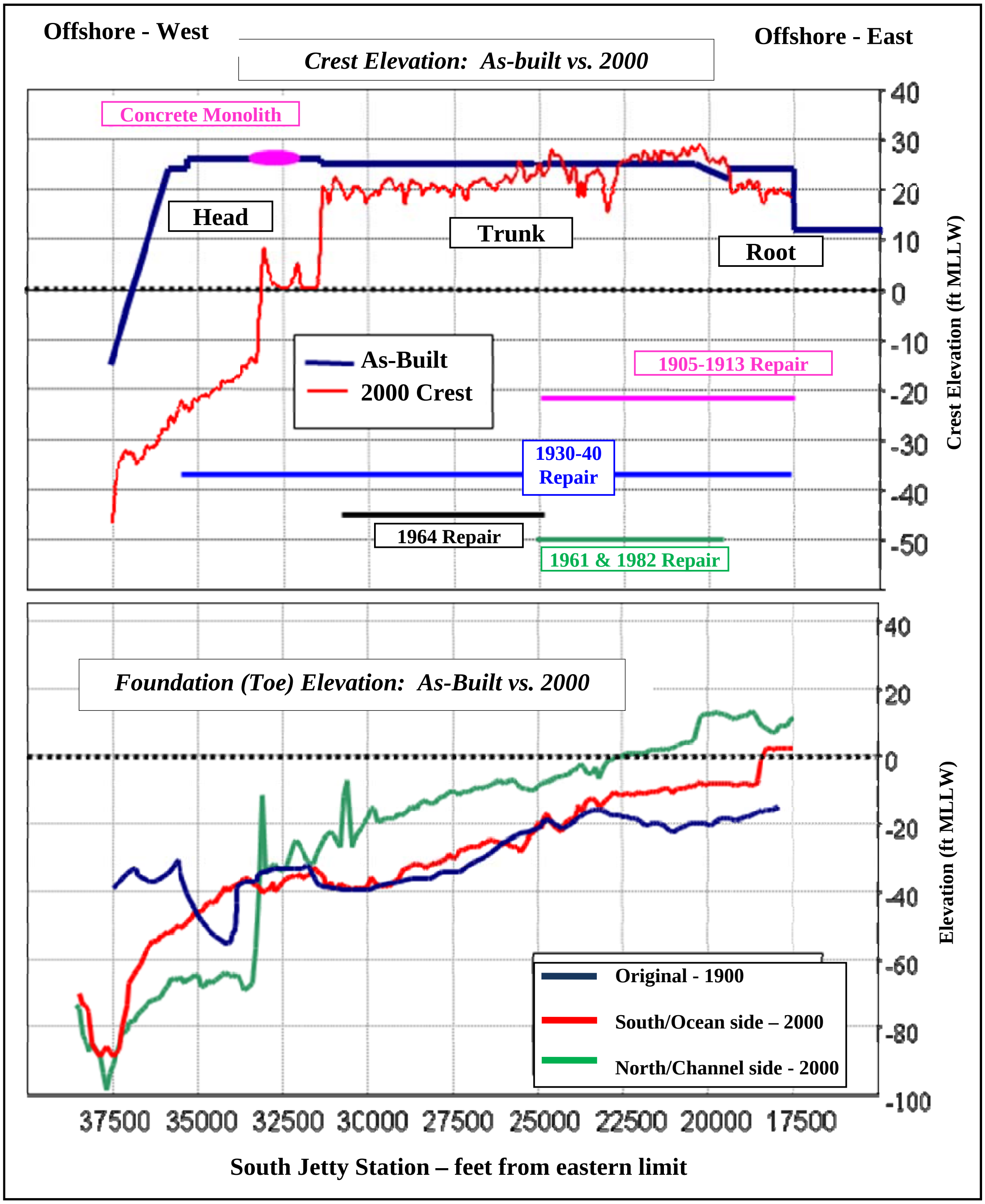
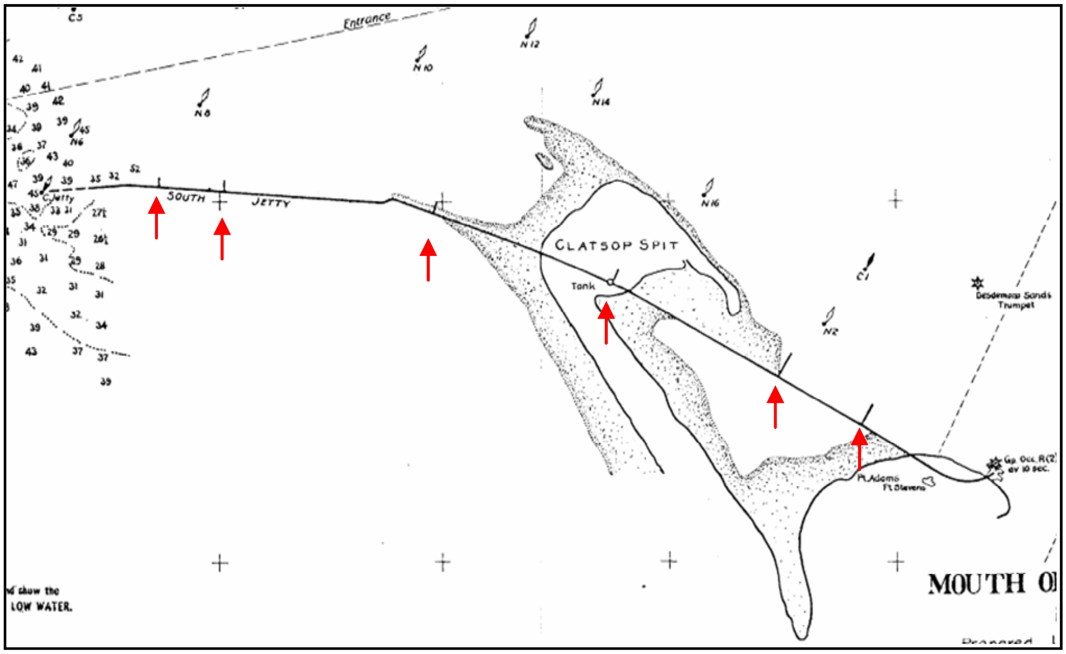
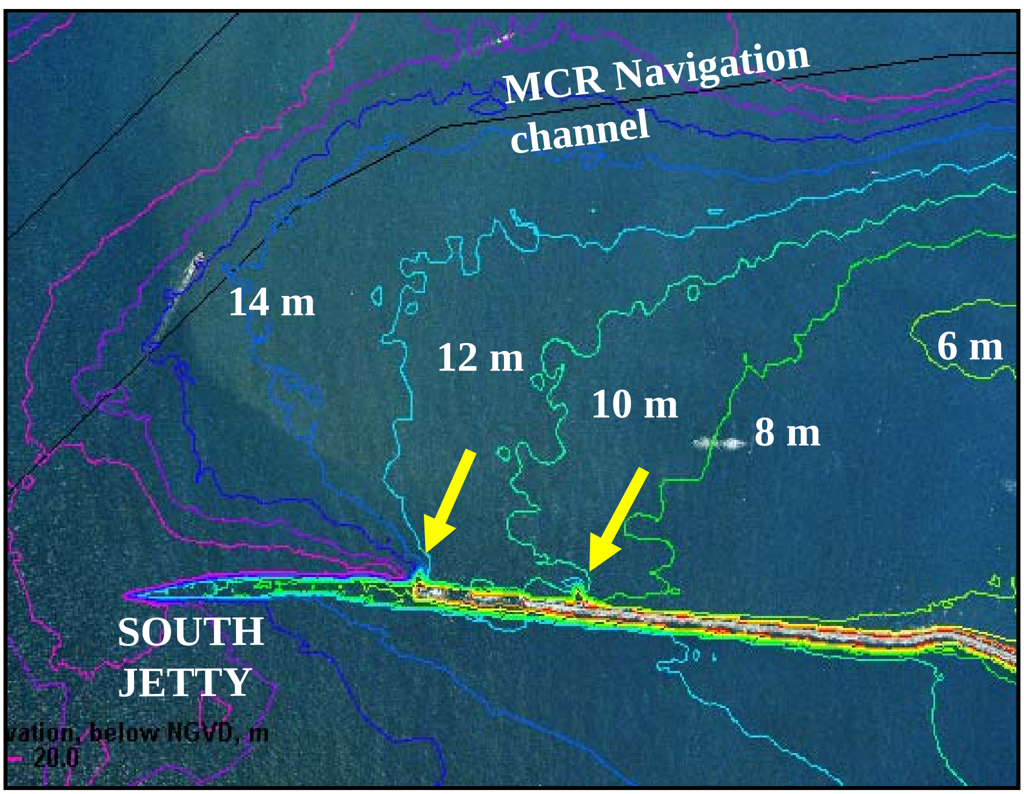


Figure 1-28. Spur Groin Construction and Influence on Stabilizing Underwater Contours along Channel Side of South Jetty





Concrete Monolith

During rehabilitation of the South Jetty in the 1930s, a 500-feet-long concrete cap was constructed to secure the jetty head at station 330. The seaward most 200 feet of the concrete cap was composed of a solid core monolith. (Figure 1-20) This cap has served well since 1940; however, the entire cap has been severely damaged due to the harsh wave climate that exists 3 miles offshore and is progressively failing. This cap serves as an anchor to secure and protect the un-reinforced area of the South Jetty immediately inshore of the cap. When the cap fails completely (i.e., falls off the jetty crest), the jetty trunk adjacent to the cap will rapidly deteriorate due to relentless wave action.

South Jetty Base Erosion

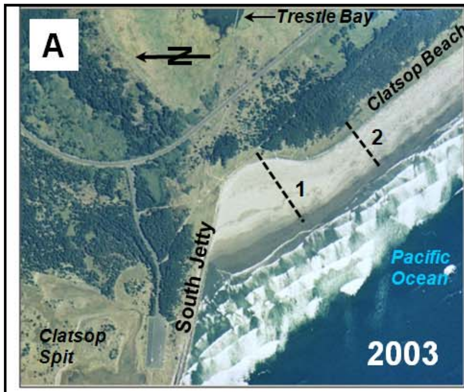
The shore area along the South Jetty root has experienced profound changes since the time of jetty construction. Before construction, the nearshore area immediately south of the jetty was dominated by a broad shallow ebb tidal shoal, exhibiting relatively shallow water depth. Construction of the South Jetty dissipated this shoal, resulting in a rapid trend of increasing water depth through time (see Figure 1-3). As the water depth along the south side of the jetty increased, wave action along the jetty root and adjacent shore area increased. The increased wave environment motivated rapid deterioration of the entire South Jetty and culminated with the significant breaching event along the South Jetty root in the late 1920s. During the 1930s, extensive efforts were undertaken to rebuild the South Jetty and re-establish the shore-land interface along the jetty's south-side root. Although the effort was successful, the result has been subjected to an increasingly harsh environment of wave action and related circulation since the 1930s.

Currently, the coastal shore interface along the South Jetty is in a condition of advanced deterioration (Figure 1-30 and Figure 1-31). The foredune separating the ocean from the backshore is almost breached. The backshore is a narrow strip of a low-elevation, accretion area that separates Trestle Bay from the ocean by hundreds of yards. The offshore area along the South Jetty (and to the south) continues to erode, promoting larger wave action to affect the shoreline along the South Jetty root. The back-dune of Trestle Bay has continued to advance westward due to increased circulation in the bay, seasonal wave chop, and hydraulic surcharging.

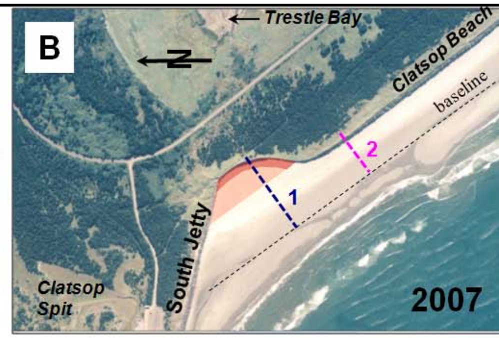
South Jetty Existing Spur Groins

Historical records show that six spur groins (#1-4, #6-7) were constructed along the channel side of the South Jetty (Table 1-6). Four groins were buried by accreted shoreline or sand shoal. The two visible, most seaward spur groins (at ~stations 309 and 333) clearly show an influence on the surrounding underwater contours. The 100-foot spur groins push the more extreme tidal velocities channel-ward, so that the shoal material at the base of the jetty is stabilized.

Figure 1-29   Historical Beach Erosion at South Jetty Root



MCR South Jetty root, south side where Clatsop Spit joins with Clatsop Plains/Beach. Panels A and B show the erosion embayment along the south jetty root for 2003 (high tide) and 2007 (low tide). The embayment & adjacent shore have receded 40 ft landward during 2003-2007, reducing the protective foredune along the embayment



Panel C shows cross-sections 1 and 2 for 2007(shown in panels A & B). Severe erosion in this area had threatened the inlet stability during early 1930s, when jetty rehabilitation and sand augmentation measures were implemented. Erosion has again become chronic since the late 1970s. The foredune protects the backshore (elevation 15-18 ft NAVD) from wave surge action during storms. If the foredune is breached, the backshore will be rapidly eroded. Without erosion abatement, it is estimated that that the Pacific Ocean will establish hydraulic connectivity with Trestle Bay in 10-15 years from 2009, and again threaten inlet stability. Panel C shows two options for protecting the foredune within the erosion embayment: A SAND berm template requires ~225,000 cy of sand placement, and a COBBLE berm template requires ~60,000 cy of cobble placement.

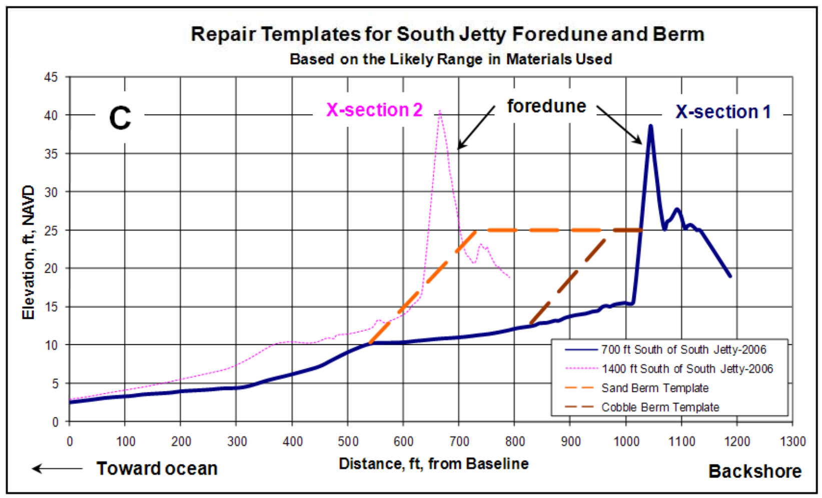


Figure 1-30. Clatsop Spit and South Jetty Root Erosion

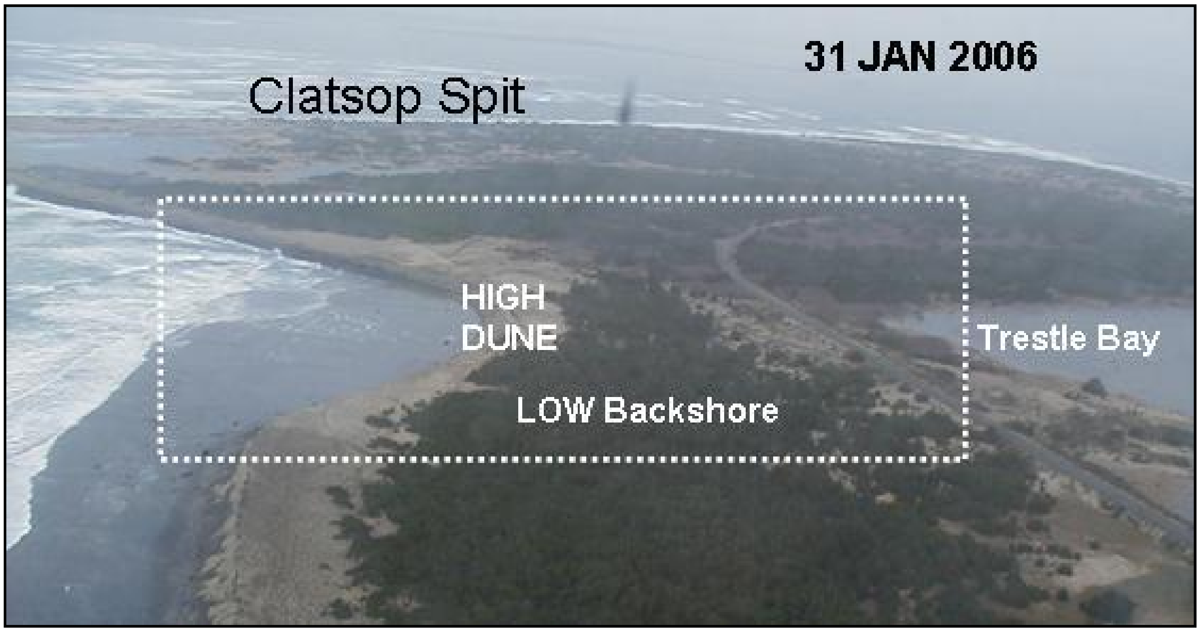


Figure 1-31. Active Shoreline Erosion at the Root of the South Jetty (oceanside)

Figure 1-28 illustrates the important effect of the groins on stabilizing the underwater shoal and protecting the South Jetty. These small structural features help with long-term structural stability by promoting sediment deposition along the jetty foundation and inhibiting the shoreline erosion occurring at the jetty root.

Table 1-6. Additional Structures at the South Jetty

Additional Structures	Year Completed	Station Location	Length (feet)	Current Condition
Spur Groin #1	1893	228+00	500	buried
Spur Groin #2	1893	156+00	600	buried
Spur Groin #3	1895	88+00	1,000	buried
Spur Groin #4	1895	52+00	1,000	buried
Shore Revetment	1896	25+80	3,955	buried
Spur Groin #6	1913	309+33	~110	existing
Spur Groin #7	1913	333+46	~90	existing

1.5.4.3. Jetty A

The purpose of Jetty A is to direct river currents away from the North Jetty. Jetty A has receded approximately 900 feet in length since original construction in 1939 (Figure 1-32 and Figure 1-33). The future recession rate for Jetty A is based on extrapolating the current rate of recession into the future. Two possible future recession rates are shown in Figure 1-32.

The vulnerability of Jetty A is influenced by its exposure to severe foundation scour along its outer end. The ocean side of Jetty A is impacted by ocean waves entering the MCR inlet, whereas the lee side sees practically no wave action. Due to the low elevation of the cross-section cross-section used at Jetty A, the lee side can be destabilized by waves overtopping the jetty from the ocean side. Note the proximity of the navigation channel to the end of Jetty A and how it anchors the entire north side morphology of the MCR inlet (from eastern end of Sand Island to North Jetty; see Figure 1-4). There are existing vulnerable reaches along Jetty A including reaches never repaired since 1917 construction, reaches of significant foundation change and high wave height exposure, and reaches that pose a concern with respect to the potential consequence of breaching.

Figure 1-32. Jetty A Head Recession

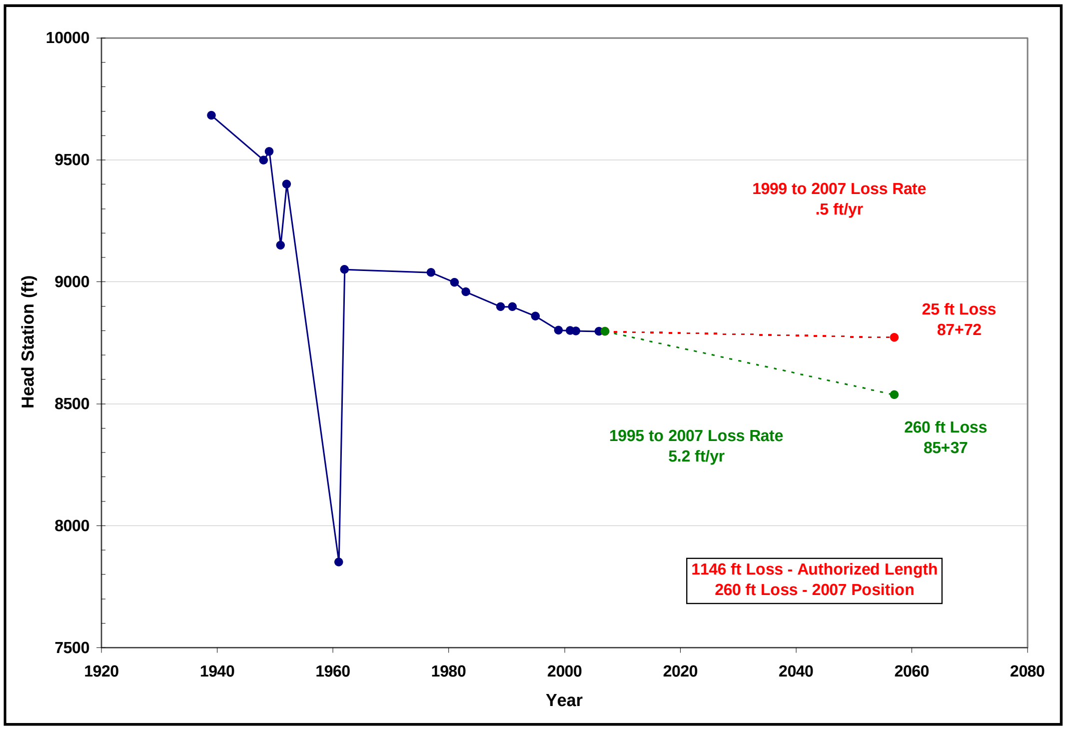
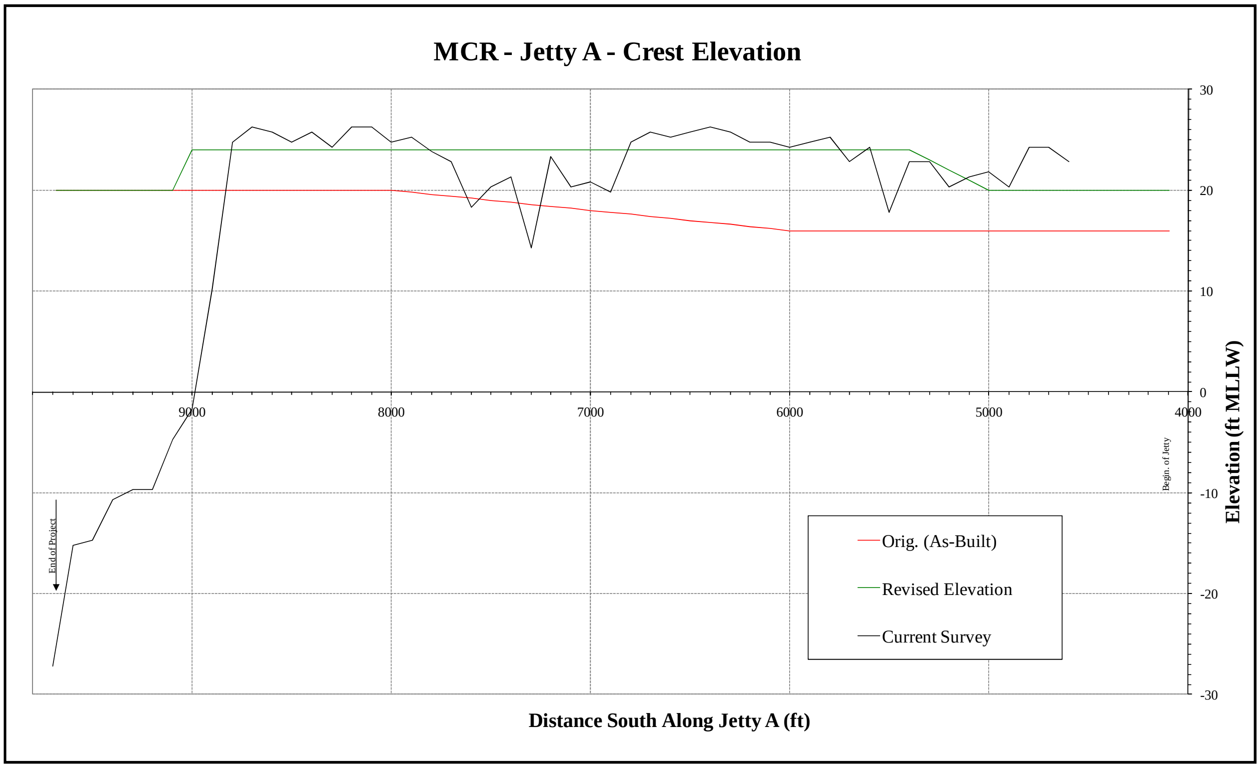
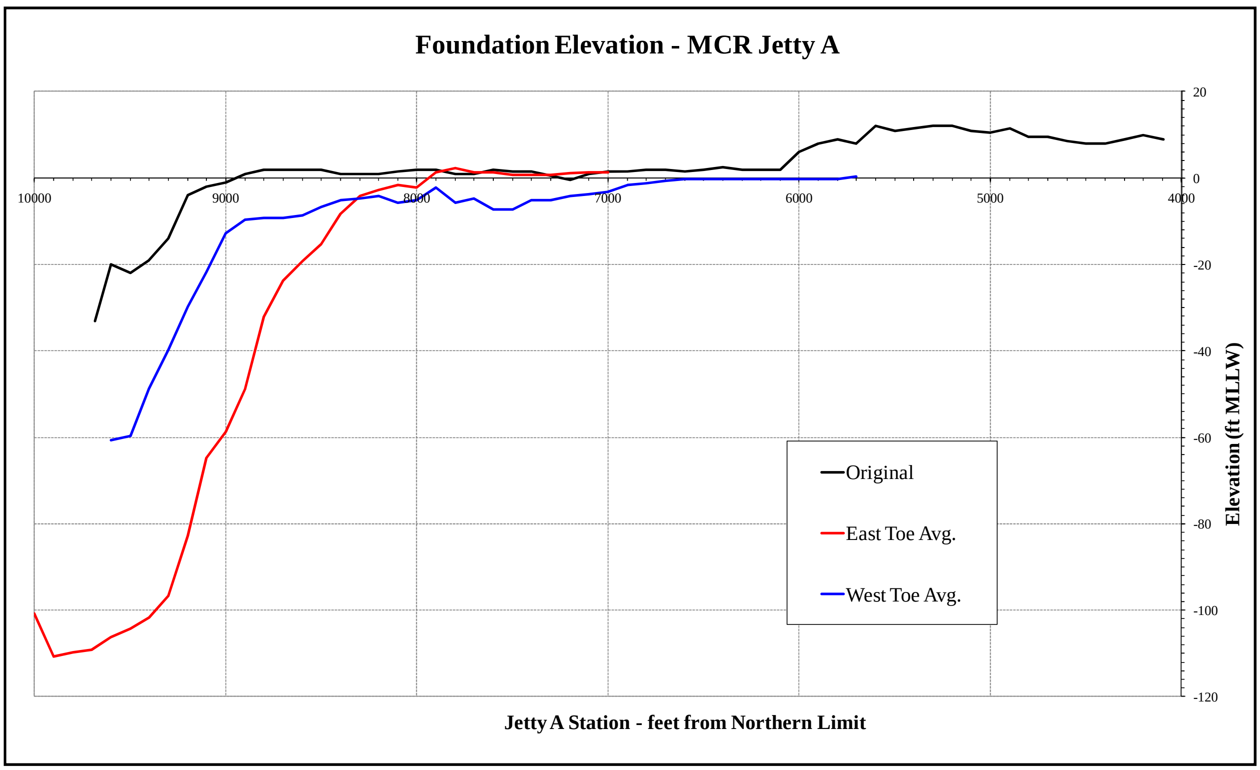


Figure 1-33. Jetty A Crest and Foundation Changes Over Time





1.5.4.4. Damage and Repair trends for MCR Jetties

The MCR jetties have required periodic and extensive repairs approximately every 20 years. Since initial construction, the North and South jetties have required the placement of 3.9 million tons of stone to maintain the functional integrity of each jetty. Collectively, this represents 47% of the stone used to construct both jetties.

Although considerable resources and effort have been invested to maintain the North and South jetties, the jetties have performed satisfactorily given the environmental setting. Damage sustained by the jetties is a process of both continual and episodic events, much like a linear trend with small steps. Jetty repair actions are not a continual process. They arise infrequently, when the cumulative damages are severe enough as to render the jetty susceptible to complete loss of function. A repair function would resemble an abrupt step-wise trend. Portions of all three jetties are currently in a significantly deteriorated condition, in part due to little or no maintenance of those areas over the structure life. Other reaches of the jetties are exposed to an increasing loading environment generated by ebb tidal shoal changes, increased water depths, and larger wave heights. Future and continued jetty performance will depend upon the level of rehabilitation that will be proposed to re-establish functional integrity.

1.6. DEEP-DRAFT NAVIGATION AT THE MCR – RELEVANCE OF JETTIES

During 1885-1939, phased construction of the three MCR jetties reformed a broad and treacherously variable 5-mile-wide inlet into a stable 2-mile-wide inlet having a consistent channel suitable for year-round navigation. The central project feature at the MCR inlet is the deep draft navigation channel (-48 to -55 feet) which is 2,640-feet wide and 6-miles long and extends through the inlet, connecting the lower Columbia River deep-draft navigation channel with the Pacific Ocean. Continued function of the MCR jetties is essential for maintaining the inlet's present configuration and securing the deep-draft navigation channel, which facilitates $20 billion in annual commerce. These structures have been in service for multiple decades and have, for the most part, functioned well. However, the practice of deferred maintenance, accelerating damage, and evolving site conditions has significantly degraded future functional performance of the MCR jetties. Loss of jetty function would compromise deep-draft navigation at the MCR.

While there's no existing methodology (technology/capability) to quantify impacts of continuing deterioration to deep-draft navigation, we can be sure that continued deterioration will result in a reduced ability to maintain channel depths required for current traffic. If the channel becomes unstable or reverts back to a reduced depth, the significant benefits of the Columbia/Snake River system will be at risk.

Navigation structures that have provided reliable function are now in a condition of high vulnerability. A condition of high vulnerability leads to an uncertain future, which could result in abrupt loss of structure function and various degrees of navigation impact. Active monitoring of vulnerable navigation structures at the MCR has facilitated real-time risk assessment and immediate contingency planning. It has become necessary to assess future life-cycle conditions to enable optimal formulation of long term investment strategies; including the option of jetty rehabilitation. A firm understanding of a structure's present condition and loading and response characteristics is required before one can successfully optimize life-cycle management strategies.

2. ECONOMIC CONSIDERATIONS

2.1. INTRODUCTION

This chapter provides the economic rationale for the federal interest, a summary of how costs are calculated, and the benefit-to-cost ratios of the various repair/rehabilitation alternatives.

The procedures adopted for use in economic[1] cost analysis stem from national policy and the National Economic Development (NED) efficiency objective. Life-cycle cost analysis presents a method by which economic benefits can be compared against economic costs to derive a cost-benefit ratio and to compute net economic benefits. Benefits and costs are converted to average annual equivalent values that represent the stream of investments and benefits accrued from those investments over the period of analysis.

2.2. FEDERAL INTEREST

The guidance for major rehabilitation projects is provided in Engineer Regulation (ER) 1105-2-100, ER 1130-2-500, and in Engineer Pamphlet (EP) 1130-2-500. ER 1105-2-100 states that for the majority of cases, the Federal interest in an existing project will be obvious, and that a reasonable argument showing that Federal interest should be provided in the report.

The Columbia/Snake Rivers are a significant waterway of the U.S. The Columbia/Snake River navigation system from the Pacific Ocean to Lewiston, Idaho is a vital transportation link for the states of Oregon, Washington, Idaho, and Montana, as well as for the Nation as a whole. According to the Center for Economic Development and Research, the Columbia/Snake River navigation system is the leading gateway for the Nation's wheat and barley exports. It is also the leading gateway for west coast wood and mineral bulk exports and the second ranked lead for automobile imports. Marine traffic passing the entrance of the Columbia River has increased by 34% from 32 million tons in 2003 to 42 million tons in 2010.

Failure to maintain navigation through the MCR project could lead to inefficiencies on a main artery of commerce in the region and the nation. The Columbia River is the nation's number one wheat and number one barley export gateway (PNWA). The MCR jetties serve as a gateway to the larger Columbia/Snake River navigation system, carrying about 42 million tons of cargo on an annual basis, with an estimated value of $20 billion in 2010, with about 1400 vessels with drafts 30 feet or greater use the River entrance (See Figures 2-1 and 2-2).

[1] USACE planners use economic cost information to make the basic efficiency decisions about alternative plans. NED costs are used to make these decisions. Once the efficiency decision has been reached, the USACE uses financial costs for project implementation, also referenced as fully-funded costs. A fully-funded cost is a financial cost, not an economic cost.

Figure 2-1 Columbia River Entrance Traffic, tonnage

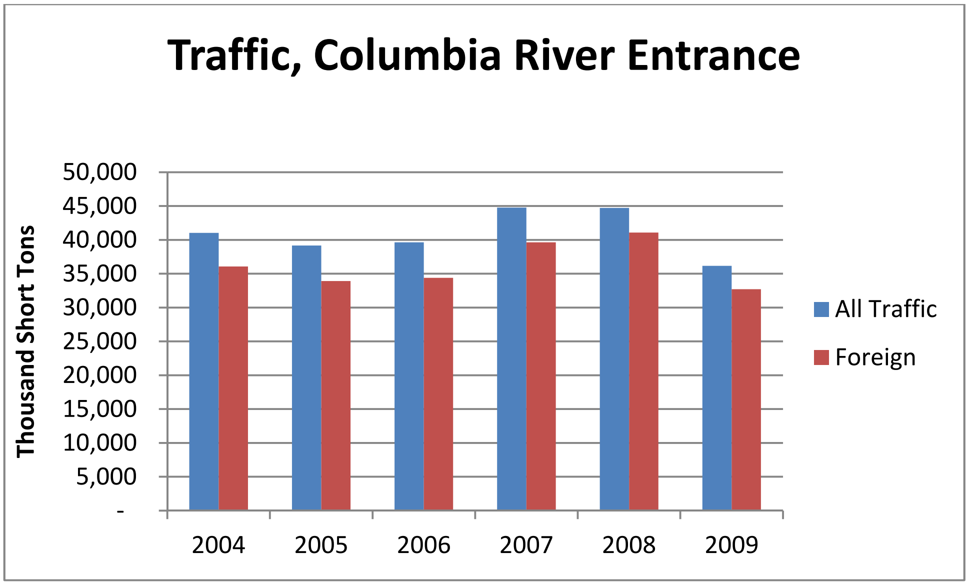
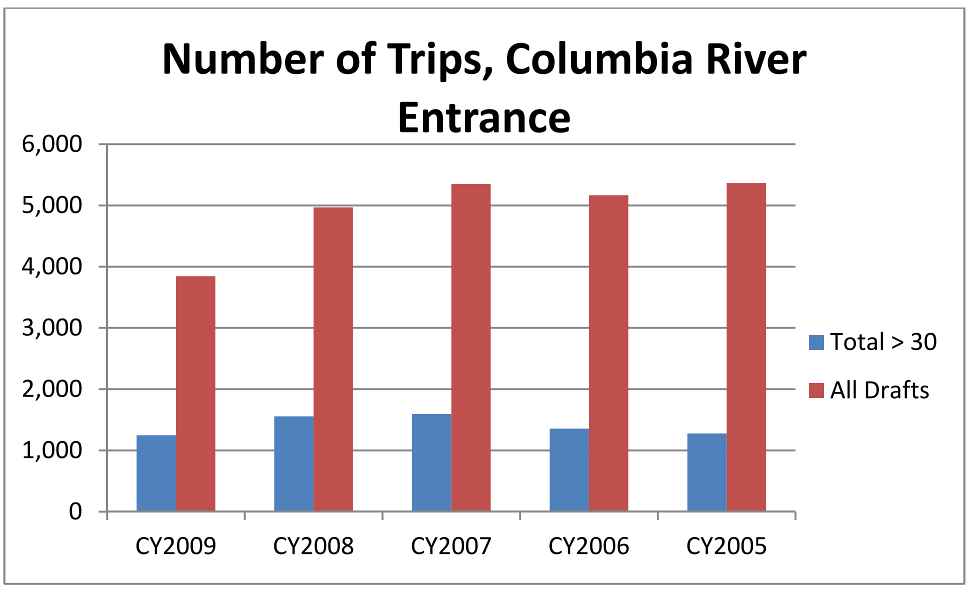


Figure 2-2 Columbia River Entrance Traffic, trips across the bar for all vessel drafts and a subset of those drafts deeper than 30 feet.



Appendix C, *Economic Analysis*, provides information and data on the importance of the Columbia/Snake River navigation system. The navigation output from the MCR project serves a priority purpose as defined in the Annual Program and Budget request for USACE Civil Works activities.

During 1885-1939, phased construction of the three MCR jetties reformed a broad and treacherously variable 5-mile-wide inlet into a stable 2-mile-wide inlet having a consistent channel suitable for year-round navigation. The central project feature at the MCR inlet is the deep draft navigation channel (-48 to -55 feet) which is 2,640-feet wide and 6-miles long and extends through the inlet, connecting the lower Columbia River deep-draft navigation channel with the Pacific Ocean.

Continued function of the MCR jetties is essential for maintaining the inlet's present configuration and securing the deep-draft navigation channel, which facilitates $20 billion in annual commerce. These structures have been in service for approximately one century and have, for the most part, functioned well. However, the practice of deferred maintenance, accelerating damage, and evolving site conditions has significantly degraded future functional performance of the MCR jetties.

Navigation structures that have provided reliable function are now in a condition of high vulnerability. A condition of high vulnerability leads to an uncertain future, which could result in abrupt loss of structure function and various degrees of navigation impact. Active monitoring of vulnerable navigation structures at the MCR has facilitated real-time risk assessment and immediate contingency planning. It has become necessary to assess future life-cycle conditions to enable optimal formulation of long term investment strategies; including the option of jetty rehabilitation.

Budget guidance in EC 11-2-199 (31 March 2010) defines major rehabilitation based on these thresholds: "The work will extend over at least two full construction seasons and will require at least $6.6 million in outlays. For inland waterways projects, the reliability threshold will be $14 million." The work on all three of the MCR jetties fits this definition for major rehabilitation.

2.3. BASE CONDITION

The base condition is the alternative against which all other alternatives are measured. Several considerations need to be determined when developing the base condition: determining operating trends of maintaining the jetties, current and projected reliability of all critical components, and planned maintenance on the project. These must all be provided throughout the entire study period. Section 3.8.3 describes the base condition in detail for each of the jetties.

The base condition for this study is identified as an interim repair approach where the upper portion of the cross-section is allowed to be damaged until approximately 35% is left remaining above -5 MLLW prior to repair actions being taken. (Since the model measures this damage with a probability density function, for purposes of discussion in this report, 30-40% is averaged to 35%—the fix-as-fails probability density function is averaged to 20%). In this way, maintenance is deferred such that the jetty can be maintained close to the margin of functional loss without breaching. The 35% threshold allows time to plan jetty maintenance before loss of function as efficiently as possible.

The benefit-cost ratio (BCR) evaluated within this report does not include traditional navigation benefit categories (transportation and delay benefits) and is strictly focused on optimizing the life-cycle maintenance costs for maintaining the MCR jetty system. The base condition for this analysis defines a level of maintenance for the jetties that prevents impacts to navigation function.

2.4. WITH-PROJECT CONDITION

The goal of implementing with-project alternatives is to maintain the Federal navigation channel and to avoid any negative impact to mission. All with-project alternatives include monitoring and scheduled repairs (i.e., repairs that are intended to occur before potential breaches impact navigation). Three basic with-project alternatives were developed and considered for the MCR jetties: scheduled repair, immediate rehabilitation, and scheduled rehabilitation. These basic alternatives were further expanded to include holding the head of each jetty. These alternatives are described in detail in Section 3.7 and 3.8 of this report.

2.5. BENEFITS ATTRIBUTABLE TO ALTERNATIVES

Transportation and delay benefits were not assessed because the assumption was the mouth of the Columbia River would remain open to navigation. To quantify transportation and delays is difficult in any entrance and specifically at the mouth of the Columbia River. There are infrequent closures at the MCR that are the decision of the U.S. Coast Guard due to storm and wave conditions at the entrance. The offshore wave climate, river and tidal currents, and shoaling all affect conditions at the bar. Consequently, separating those effects to be dependent upon the jetty would be difficult; therefore, the assumption was made that the Columbia River would remain open.

A fundamental economic assumption of the MCR jetties major rehabilitation study is that the navigation will be maintained throughout the period of analysis. In fact, in only one instance (1929) during the history of the jetty system has navigation been disrupted. This assumption can be made because of the monitoring and advance repair activities initiated by the Corps to maintain the functional integrity of the system.

This assumption implies that NED transportation benefits from the jetty system are constant across any alternative considered. The base condition maintains the functional integrity of the jetty system throughout the period of analysis.

The economic consideration is the cost effectiveness of the alternatives considered with costs avoided being the primary monetized benefit of the study. The alternatives identified as the most cost effective will minimize, to the greatest extent, future Federal investments required to maintain the functional integrity of the jetty system when compared against the base condition. The specific navigation costs considered in this report are the costs of maintenance activities for the three jetty system, these costs can be summarized as the cost of repairing or rehabilitating the structure and the increase in dredging costs relative to the alternative being considered. The direct costs for maintaining the jetties are summarized in table 2.6 by alternative. The costs are differentiated by type of repair; a planned rehabilitation cost, a scheduled O&M cost and an expedited repair cost. Because the alternatives vary in the timing and scope of repair activity, the total costs for an alternative can be compared against the base condition to identify the most cost efficient maintenance strategy. If no efficiency in repair timing and scope can be found that is superior to the base condition, the base condition is identified as the most efficient means of maintaining the jetties, and therefore the most efficient means of maintaining navigation at the MCR. A more efficient means of maintaining the MCR jetties lowers the costs of maintaining navigation at MCR, therefore increasing the BCR even if the navigation benefits themselves do not increase.

2.6. LIFE CYCLE COST ANALYSIS METHOD

The analytical method applied follows standard life-cycle cost accounting principles in that investments occurring intermittently over a fixed period of analysis are adjusted to account for the time value of money to create equivalent values at a common point in time. The common point in time for USACE planning purposes is designated as the base year, which is defined as the first year during which benefits of the project accrue. Investments and benefits that occur prior to the base year are escalated to the base and investments and benefits that occur after the base year are discounted to the base. The present worth equivalent values are then summed and amortized over the period of analysis to derive an average annual equivalent value. The rate that is used for discounting and amortizing is published annually by the U.S. Department of the Treasury for USACE investment and benefit calculations (see Table 2-1).

In order for various alternatives with differing investment strategies to be equitably compared, guidance requires that the same period of analysis be used for all alternative plans. The period of analysis is defined as the time horizon for project benefits, deferred installation costs, and operation, maintenance, repair, rehabilitation, and replacement (OMRR&R) costs. OMRR&R costs are the expected costs over the period of analysis for operation, maintenance, repair, rehabilitation, and replacement necessary to maintain the benefit stream and agreed-upon levels of mitigation of losses to fish and wildlife habitats. For USACE navigation projects, the period of analysis is typically 50 years.

Also an equitable comparison of alternatives requires that a common price level for costs be applied. Usually, comparative economic cost values are developed for planning level estimates of alternatives. Historical bid cost data, experience, and/or unit prices adjusted to expected project conditions are acceptable methods of developing project costs for these alternatives. The selected plan is then refined to create a Total Project Cost using the USACE-certified MCACES (MII) cost model in accordance with guidance.[2]

The costs applied in the life-cycle cost analysis are USACE-provided 2012 values. The period of analysis is 50 years, from beginning of fiscal year 2015 to end of fiscal year 2064. The project economic evaluation rate applied is the FY12 Federal interest rate of 4.0 percent. Prices used do not include inflation. End of year values were calculated for the life cycle cost analysis.

Table 2-1 Parameters specific to the MCR jetties life-cycle cost analysis

Price Level	CENWP-produced 2012 values
Period of Analysis	50 years, BOY 2015-EOY 2064
Federal interest rate	FY12 rate of 4.0 percent
Base Year	2015 No escalation of costs was necessary; only discounting over the period applies over the period. See discussion in Appendix C
Interest during Construction	Not applicable, see discussion in Appendix C
Implementation Schedule	Table 1, Appendix C
Unit Cost Components of Alternatives	Tables 2-5, Appendix C
Results of Cost Effectiveness Analysis	Table 6, Appendix C

2.7. BASE YEAR AND INTEREST DURING CONSTRUCTION

Alternative plans can differ in their implementation timing, that is, not all alternatives or features have to be in place at the beginning of the period of analysis. As project on-line dates are varied, annual benefits and costs will often vary. In general, the more the benefits vary through time and the longer the time to implementation from the base year (first year of period of analysis), the stronger this effect will be. The best schedule for implementing project features shall be considered as an element in the formulation and evaluation of alternative plans.[3]

[2] U.S. Army Corps of Engineers, ER 1110-2-1302, Engineering and Design, Civil Works Cost Engineering, 15 September 2008.
[3] U.S. Army Corps of Engineers, ER 1105-2-100, Planning Guidance Notebook, paragraph 2-4 (o), 22April 2000.

In Appendix C, Table C-4 lists the alternatives evaluated and the construction schedules of the alternatives that have rehab components for the three jetties in the Mouth of the Columbia River Jetty system: North Jetty, South Jetty, and Jetty A. All alternatives have an annual dredging component cost estimated which is not reflected in Appendix C, Table C-4, but is incorporated into the life cycle cost analysis. Other repair costs occur intermittently over the period of analysis and are incorporated into the life cycle cost analysis also.

The base year was set at the beginning of implementation period in the year 2015 based on two factors:

1) The implementation periods are lengthy due to the large quantity of rock required to complete the work, seasonality of construction, the rock supply and storage activities; and,
2) Benefits will begin accruing with each implementation stage.

This method is intended to produce a straight-forward and consistent comparison of alternatives. All alternative costs are discounted at the end of the year to the beginning of the base year 2015 using the stated Federal interest rate and amortized over the period of analysis to produce average annual equivalent values. This method will allow for the simple combination of alternatives among the three jetties to identify a combination least cost plan because all economic costs for all three jetties will be represented as equivalent costs.

Also due to the expectation of an immediate accrual of benefits, interest during construction (IDC) was not calculated. IDC is calculated typically when completion of construction is required before benefits are realized. For the MCR jetties rehabilitation alternatives, benefits are assumed to be realized immediately beginning with each activity for which costs are generated.

Also because the first year of construction is also the designated base year due to the expectation of an immediate accrual of benefits, no escalation of costs prior to the base year was necessary. Costs incurred over the period of analysis were discounted to the base year.

2.8. LIFE-CYCLE COSTING OF MCR JETTIES ALTERNATIVES

This life cycle cost analysis should not be confused with the derivation of total project costs which are financial and take into consideration factors of implementation. The life cycle cost analysis presented represents a method by which alternatives can be compared equitably and decisions regarding economic efficiency can be made.

A life cycle cost analysis was performed over the 50-year project life for the alternatives listed in Appendix C, Table C-17 with consideration, as appropriate, of project construction costs and associated operations and maintenance (O&M) and other costs over the period. Each alternative, with the exception of the “fix-as-fails” alternatives, was modeled allowing the jetty trunks to recede over the period of analysis and then again with holding the current jetty length constant.

2.8.1. Unit Cost Components of Alternatives

Repairs, rehabilitation, and dredging are projected throughout the period of analysis in response to scenarios developed with the SRB Model. USACE-provided 2012 cost variables contribute to the jetty alternatives cost estimates over the period of analysis and are assembled to reflect the activities that define each alternative’s repair strategy:

1. Repair activities: unit costs/ton of rock for expedited, base, and scheduled repairs, specific to jetty structure;
2. Rehabilitation activities: unit costs/ton of rock for a variety of scaled activities ranging from minimal to large;
3. Additional fixed costs of activities associated with rehabilitation for every year that rehabilitation occurs: mob/demob; jetty crest haul road construction; barge off-loading facility; mitigation costs; dredging costs; and offloading costs;
4. Jetty head capping: unit cost/ton of rock specific to each jetty;
5. Spur construction: fixed cost specific to each jetty; and
6. Normal dredging: unit cost/cy of sediment dredged specific for North Jetty, same unit cost for South Jetty and Jetty A.

All alternatives contain expedited repair activities and normal dredging activities. All alternatives contain O&M activities that are base repair, interim repair, or scheduled repair.

Appendix C, Table C-4 presents the array of unit and fixed costs applied in the life cycle cost analysis. The derivation of these costs and their application is discussed in detail in Appendix E, MCACES Cost Estimates. Appendix C, Table C-6 through Table C-16 display the cost components specific to each of the alternatives considered for the three jetties in the Mouth of the Columbia River system. Alternatives that share the same unit and fixed costs are listed together in the displays.

2.9. CE/ICA FOR MITIGATION

Wetland mitigation options for Jetty A and the South Jetty are very limited. No land is available near Jetty A; therefore, it's most cost effective to use lands near the North Jetty because construction mobilization costs are much lower there. Also, it is environmentally preferable to use lands near the North Jetty.

The basic assumption behind the Cost Effectiveness/Incremental Cost Analysis (CE/ICA) for wetland mitigation is that each alternative analyzed has the same specific mitigation requirement because each has the same construction impacts independent of construction methods. Consequently, a CE/ICA was conducted for three options for wetland mitigation on the South Jetty and Jetty A.

Using a 2:1 mitigation ratio, the acreages are 5.30 acres for the South Jetty and 1.82 acres for Jetty A. The options were replacement within the project area, acquiring private property offsite, and mitigation banking:

- Option A: onsite mitigation
- Option B: private property at $6,000 per acre (base cost for Option A plus $6k per acre)
- Option C: mitigation banking at $75,000 per acre (flat rate)

Table 2-2 shows all combinations of the described three options. Since the output is the same for all alternatives, incremental cost analysis is not possible beyond the first calculation (further calculations would be dividing costs by zero). Also due to the output being the same for all alternatives, by default the best value option is the one with the lowest cost. Consequently, the least cost plan was selected—Option AA—for 7.12 acres at $92,560.

Table 2-2 Wetland Mitigation – Cost Effectiveness

	Jetty A Options		South Jetty Options
A	$23,660 for 1.82 Acres	A	$68,900 for 5.3 Acres
B	$34,580 for 1.82 Acres	B	$100,700 for 5.3 Acres
C	$136,500 for 1.82 Acres	C	$397,500 for 5.3 Acres

Alt	Total Output (Acres)	Total Cost ($)
AA	7.12	92,560.00
AB	7.12	124,360.00
AC	7.12	421,160.00
BA	7.12	103,480.00
BB	7.12	135,280.00
BC	7.12	432,080.00
CA	7.12	205,400.00
CB	7.12	237,200.00
CC	7.12	534,000.00

It is an important to note that the EA for the MRR covers mitigation for the base condition, which includes dune augmentation/stabilization on the South Jetty; and lagoon fill and critical repairs (STA 86-99) on the North Jetty. Table 2-3 outlines all mitigation requirements per the EA.

Table 2-3 Mitigation Identified per the EA

Area Affected	Impacted Acreage	Mitigation Acreage	Comment
North Jetty			
Wetland	1.14	2.28	Base Condition: MMR
404 Waters Lagoon	8.02	12.03	Base Condition: MMR
Other 404 Waters	4.36	6.54	CE/ICA during DDR phase
South Jetty			
Wetlands	2.65	5.30	CE conducted
404 Waters	13.84	20.76	CE/ICA during DDR phase
Jetty A			
Wetlands	0.91	1.82	CE conducted
404 Waters	6.60	9.90	CE/ICA during DDR phase

Mitigation for the 404 sites will be assessed and a CE/ICA conducted during the detailed design report (DDR) phase of the MRR project. Since the exact environmental impacts are unknown, the worst-case impacts, from a cost standpoint, were developed—maximizing avoidance of impacts. For instance, impacts associated with delivery of jetty stone are currently unknown; hence, during the DDR phase, when there's more certainty on modes of delivery, these impacts will be reassessed. For the time being we are assuming the worst-case impacts associated with the project footprint, and that they are all the same for each alternative evaluated. For purposes of the cost estimate, barge delivery was assumed and costs associated with mitigation for 404 impacts based on a similar project. The total estimate for 404 waters mitigation is $3.6M.

It is recognized that impacts need mitigation based on the extent and quality. Consequently, the Corps will define the mitigation required in coordination with an Adaptive Management Team (AMT) of state and Federal resource agencies. Then a CE/ICA will be conducted during the DDR phase on the newly defined mitigation requirement.

2.10. INTERFACE BETWEEN THE SRB MODEL AND THE LIFE CYCLE COST ANALYSIS

The life cycle cost analysis is performed separately and subsequently to the SRB Model calculations. The execution of the SRB model results in calculations of jetty degradation and required repair (e.g. material quantities required to create a defined condition based on the alternative considered, described in Appendix A1). The output files containing quantities from this model analysis are then used as inputs to the cost analysis to estimate life-cycle costs and other parameters for each alternative. The cost analysis is performed via a set of Microsoft Excel spreadsheets. This section discusses the life cycle cost component of the analysis and the outputs of the SRB model which feed the life cycle cost analysis.

The SRB model creates outputs that contain a set of mean values for seven types of activities—rehabilitation; expedited repair, emergency repair; interim repair, base repair, scheduled repair, and normal dredging. These output parameters are listed in the life cycle cost spreadsheets which have a consistent nomenclature, generally titled "MCR_LifeCycleCosts_{name of jetty}_{name of alternative}". These files are built automatically from a single template file “cost_template.xlsx” by calling MCR_COST script in Matlab. The script takes SRB Model CSV files from “output” folder for each alternative and converts them into Microsoft Excel files. The main CSV files are listed in Table 2-4.

Table 2-4 Output CSV Files Used to Populate Life Cycle Cost Analysis Spreadsheets

Output File	Description
OUTPUT_Repair_for_COST_MEAN_INNER.csv	Stone volumes for inner range of the jetty for emergency, expedited, fix-as-fail, interim and scheduled repairs.
OUTPUT_Repair_for_COST_MEAN_MIDDLE.csv	Stone volumes for middle range of the jetty for emergency, expedited, fix-as-fail, interim and scheduled repairs.
OUTPUT_Repair_for_COST_MEAN_OUTER.csv	Stone volumes for outer range of the jetty for emergency, expedited, fix-as-fail, interim and scheduled repairs.
OUTPUT_Rehab_for_COST_MEAN.csv	Stone volumes for minimum, small, moderate and large rehab templates and head capping.
OUTPUT_Dredging_for_COST_MEAN.csv	Maintenance dredging volumes.
OUTPUT_Head_Recession_Repair_COST_MEAN.csv	Repairs on North Jetty due to scour associated with Jetty “A” head recession.

Note: Emergency repairs were not used in the SRB Model for the MCR Jetties.

The cost for each activity is calculated in the MCR_LifeCycleCosts spreadsheets, based on actions and volumes projected by the SRB Model to which unit and fixed prices are applied. The unit prices are initially specified in “cost template” spreadsheet on the “Setup” sheet for all jetties and activities. The referencing of the unit costs within the spreadsheets allows for updating, modification, and adjustment, if necessary.

Only the values that occur during the period of analysis, 2015-2064, are considered in the life cycle cost analysis even though the SRB Model outputs a stream of volumes.

In the above example, the cost for repair options is calculated in each “Repair” worksheet (Expedited Repair is shown), and unit costs are linked to the “Setup” sheet for named jetty. The present worth equivalent values for all activities associated with each alternative response scenario are totaled and accumulated into a summary spreadsheet, “Cost_Summary.xlsx,” and then the present worth equivalent values are amortized over the period of analysis to create average annual equivalent values.

Example of Life Cycle Cost Spreadsheet for North Jetty Scheduled Repair Hold Head with Reference Unit Costs and Input Volumes from the SRB Model can be found at the end of this chapter in Table 2-6.

2.11. SUMMARY OF COSTS AND BENEFITS

Table 2-5 displays the most effective alternatives among the 71 alternatives evaluated for the three jetties in the MCR jetty system. The most cost effective alternatives are those that produce the greatest net excess benefits over costs. The full array of alternatives is displayed in Table 6 of Appendix C.

Table 2-5 Costs and Benefits of the Most Cost Effective Alternatives

Jetty	Most Cost Effective Alternative	Net Excess Average Annual Benefits	Average Annual Costs	Benefit to Cost Ratio
North Jetty	Scheduled Repair Holding Head at Current Location	$251,729	$2,984,682	1.09
South Jetty	Base Case without Project	$0	$9,566,691	1.0
Jetty A	Scheduled Repair Holding Head at Current Location	$383,847	$913,260	1.42

The project has a combined BCR of 1.1 for the system (all three jetties).

Table 2-6 Average Annual Costs, Benefit-Cost Ratio (BCR), and Net Excess Benefits for the Alternatives for the MCR Jetties

Alternatives	Location	Present Worth Equivalent (PWE) Rehab cost	OM Repair Cost, PWE	Expedited Repair Cost, PWE	PWE Dredge Cost	Present Worth Equivalent Total Costs	Average Annual Costs, 50 yrs, Discount Rate of 4%	Rank	BCR	Net Excess Benefits
NJ_fut1_base	North Jetty	$ -	$ 43,483,297	$ 18,294,141	$ 5,745,391	$ 67,522,829	$ 3,143,201	7	1.00	$ -
NJ_fut1_fixasfail_repair	North Jetty	$ -	$ 47,127,448	$ 31,051,319	$ 9,070,316	$ 87,249,083	$ 4,061,462	9	0.77	$ (918,261)
NJ_fut1_sched_repair	North Jetty	$ -	$ 52,578,389	$ 5,686,726	$ 5,058,668	$ 63,323,783	$ 2,947,735	2	1.07	$ 195,466
NJ_fut10_sched_repair	North Jetty	$ 18,175,847	$ 47,573,752	$ 2,299,182	$ 686,001	$ 68,734,782	$ 3,199,618	8	0.98	$ (56,417)
NJ_fut10_sched_repair_no_headcap	North Jetty	$ 6,528,978	$ 50,833,281	$ 4,564,115	$ 1,755,867	$ 63,682,241	$ 2,964,421	3	1.06	$ 178,780
NJ_fut21_immed_rehab_minimum	North Jetty	$ 52,472,326	$ 35,908,260	$ 24,324,006	$ 1,089,727	$ 113,794,320	$ 5,297,148	21	0.59	$ (2,153,947)
NJ_fut21_sched_rehab_minimum	North Jetty	$ 39,704,409	$ 44,608,202	$ 28,006,290	$ 1,095,975	$ 113,414,876	$ 5,279,485	20	0.60	$ (2,136,284)
NJ_fut23_immed_rehab_moderate	North Jetty	$ 89,293,775	$ 12,936,100	$ 4,244,548	$ 1,097,156	$ 107,571,579	$ 5,007,479	14	0.63	$ (1,864,277)
NJ_fut23_sched_rehab_moderate	North Jetty	$ 69,715,513	$ 24,011,772	$ 7,473,647	$ 1,097,031	$ 102,297,963	$ 4,761,991	10	0.66	$ (1,618,789)
NJ_fut24_immed_rehab_large	North Jetty	$ 143,825,997	$ 11,222,355	$ 2,712,764	$ 1,105,272	$ 158,866,389	$ 7,395,262	31	0.43	$ (4,252,061)
NJ_fut24_sched_rehab_large	North Jetty	$ 118,616,188	$ 22,485,339	$ 5,798,197	$ 1,098,505	$ 147,998,229	$ 6,889,347	28	0.46	$ (3,746,146)
NJ_fut30_immed_rehab_comp4_small	North Jetty	$ 83,424,547	$ 19,395,026	$ 5,429,701	$ 1,104,763	$ 109,354,038	$ 5,090,452	18	0.62	$ (1,947,251)
NJ_fut30_sched_rehab_comp1_large	North Jetty	$ 81,574,446	$ 27,297,796	$ 6,918,151	$ 1,102,078	$ 116,892,471	$ 5,441,368	23	0.58	$ (2,298,167)
NJ_fut30_sched_rehab_comp2_medium	North Jetty	$ 70,164,796	$ 33,909,672	$ 10,515,999	$ 1,097,015	$ 115,687,482	$ 5,385,275	22	0.58	$ (2,242,074)
NJ_fut30_sched_rehab_comp3_small	North Jetty	$ 57,532,418	$ 34,551,913	$ 11,475,056	$ 1,099,171	$ 104,658,558	$ 4,871,877	12	0.65	$ (1,728,676)
NJ_fut30_sched_rehab_comp4_small_modi	North Jetty	$ 67,691,228	$ 29,582,945	$ 8,548,724	$ 1,098,724	$ 106,921,621	$ 4,977,223	13	0.63	$ (1,834,022)
NJ_fut1_base_hold	North Jetty	$ -	$ 45,581,279	$ 17,239,113	$ 1,297,094	$ 64,117,485	$ 2,984,682	4	1.05	$ 158,519
NJ_fut1_sched_repair_hold	North Jetty	$ -	$ 52,624,881	$ 8,227,048	$ 1,263,206	$ 62,115,135	$ 2,891,472	1	1.09	$ 251,729
NJ_fut10_sched_repair_hold	North Jetty	$ 6,528,978	$ 52,657,418	$ 5,917,201	$ 107,887	$ 65,211,483	$ 3,035,608	5	1.04	$ 107,594
NJ_fut10_sched_repair_no_headcap_hold	North Jetty	$ 6,528,978	$ 52,657,418	$ 5,917,201	$ 107,887	$ 65,211,483	$ 3,035,608	5	1.04	$ 107,594
NJ_fut21_immed_rehab_minimum_hold	North Jetty	$ 46,592,043	$ 41,227,611	$ 33,312,072	$ 212,286	$ 121,344,013	$ 5,648,588	26	0.56	$ (2,505,387)
NJ_fut21_sched_rehab_minimum_hold	North Jetty	$ 35,931,411	$ 48,241,987	$ 36,021,769	$ 213,118	$ 120,408,285	$ 5,605,030	25	0.56	$ (2,461,829)
NJ_fut23_immed_rehab_moderate_hold	North Jetty	$ 86,371,801	$ 15,610,263	$ 6,007,196	$ 204,447	$ 108,193,707	$ 5,036,439	16	0.62	$ (1,893,238)
NJ_fut23_sched_rehab_moderate_hold	North Jetty	$ 69,679,740	$ 24,916,564	$ 9,847,343	$ 210,703	$ 104,654,350	$ 4,871,681	11	0.65	$ (1,728,480)
NJ_fut24_immed_rehab_large_hold	North Jetty	$ 140,112,840	$ 13,117,471	$ 4,196,469	$ 211,699	$ 157,638,479	$ 7,338,103	30	0.43	$ (4,194,902)
NJ_fut24_sched_rehab_large_hold	North Jetty	$ 118,027,857	$ 22,754,889	$ 8,002,403	$ 206,565	$ 148,991,715	$ 6,935,594	29	0.45	$ (3,792,393)
NJ_fut30_immed_rehab_comp4_small_hold	North Jetty	$ 79,831,559	$ 21,586,609	$ 6,878,059	$ 211,117	$ 108,507,343	$ 5,051,039	17	0.62	$ (1,907,837)
NJ_fut30_sched_rehab_comp1_large_hold	North Jetty	$ 80,721,731	$ 27,921,580	$ 9,105,782	$ 207,261	$ 117,956,354	$ 5,490,892	24	0.57	$ (2,347,691)
NJ_fut30_sched_rehab_comp2_medium_hold	North Jetty	$ 69,009,106	$ 35,529,792	$ 16,604,130	$ 209,844	$ 121,352,873	$ 5,649,001	27	0.56	$ (2,505,799)
NJ_fut30_sched_rehab_comp3_small_hold	North Jetty	$ 56,340,116	$ 36,133,099	$ 17,748,473	$ 209,304	$ 110,430,992	$ 5,140,585	19	0.61	$ (1,997,384)
NJ_fut30_sched_rehab_comp4_small_modi_hold	North Jetty	$ 66,862,172	$ 30,193,525	$ 10,511,543	$ 211,826	$ 107,779,067	$ 5,017,137	15	0.63	$ (1,873,936)
SJ_fut1_base	South Jetty	$ -	$ 124,368,852	$ 65,319,484	$ 15,825,079	$ 205,513,416	$ 9,566,691	1	1.00	$ -
SJ_fut1_fixasfail_repair	South Jetty	$ -	$ 154,015,463	$ 106,571,926	$ 18,167,108	$ 278,754,497	$ 12,976,078	27	0.74	$ (3,409,387)
SJ_fut1_sched_repair	South Jetty	$ -	$ 155,248,600	$ 38,803,225	$ 13,262,722	$ 207,314,546	$ 9,650,534	2	0.99	$ (83,843)
SJ_fut10_sched_repair_head	South Jetty	$ 16,437,078	$ 158,723,371	$ 39,813,235	$ 2,350,720	$ 217,324,404	$ 10,116,495	8	0.95	$ (549,804)
SJ_fut10_sched_repair_head_spur	South Jetty	$ 19,998,057	$ 156,915,984	$ 39,782,613	$ (104,239)	$ 216,592,415	$ 10,082,420	7	0.95	$ (515,730)
SJ_fut21_immed_rehab_minimum	South Jetty	$ 94,706,725	$ 122,305,794	$ 71,910,838	$ 656,423	$ 289,579,780	$ 13,479,997	28	0.71	$ (3,913,306)
SJ_fut21_sched_rehab_minimum	South Jetty	$ 92,348,060	$ 123,178,076	$ 72,250,306	$ 2,271,724	$ 290,048,166	$ 13,501,800	29	0.71	$ (3,935,110)
SJ_fut22_immed_rehab_small	South Jetty	$ 131,704,995	$ 81,632,245	$ 37,423,698	$ 642,669	$ 251,403,607	$ 11,702,888	20	0.82	$ (2,136,198)
SJ_fut23_immed_rehab_moderate	South Jetty	$ 166,886,298	$ 55,193,738	$ 26,907,678	$ 651,704	$ 249,639,418	$ 11,620,765	19	0.82	$ (2,054,074)
SJ_fut24_immed_rehab_large	South Jetty	$ 197,642,022	$ 48,054,714	$ 24,417,989	$ 666,262	$ 270,780,987	$ 12,604,909	23	0.76	$ (3,038,219)
SJ_fut30_immed_rehab_comp1_large	South Jetty	$ 165,540,641	$ 50,121,201	$ 24,463,129	$ 654,928	$ 240,779,900	$ 11,208,353	12	0.85	$ (1,641,662)
SJ_fut30_immed_rehab_comp2_modi1	South Jetty	$ 140,252,551	$ 69,906,088	$ 29,183,544	$ 645,537	$ 239,987,719	$ 11,171,476	11	0.86	$ (1,604,786)
SJ_fut30_immed_rehab_comp3_small	South Jetty	$ 126,237,680	$ 98,427,080	$ 47,509,245	$ 638,659	$ 272,812,665	$ 12,699,484	25	0.75	$ (3,132,794)
SJ_fut30_immed_rehab_comp4_medium	South Jetty	$ 149,429,699	$ 56,559,458	$ 25,752,445	$ 636,443	$ 232,378,045	$ 10,817,245	9	0.88	$ (1,250,554)
SJ_fut30_immed_rehab_comp5_modi2	South Jetty	$ 138,337,388	$ 74,483,592	$ 32,141,931	$ 643,312	$ 245,606,223	$ 11,433,019	15	0.84	$ (1,866,328)
SJ_fut30_sched_rehab_comp5_modi2	South Jetty	$ 133,674,486	$ 78,005,678	$ 33,594,509	$ 2,267,908	$ 247,542,581	$ 11,523,157	17	0.83	$ (1,956,466)
SJ_fut1_base_hold	South Jetty	$ -	$ 133,035,346	$ 70,855,824	$ 3,448,363	$ 207,339,534	$ 9,651,697	3	0.99	$ (85,006)
SJ_fut1_sched_repair_hold	South Jetty	$ -	$ 162,122,740	$ 44,637,874	$ 3,464,621	$ 210,225,234	$ 9,786,027	6	0.98	$ (219,336)
SJ_fut10_sched_repair_head_hold	South Jetty	$ -	$ 161,343,418	$ 44,511,357	$ 3,472,142	$ 209,326,917	$ 9,744,210	5	0.98	$ (177,519)
SJ_fut10_sched_repair_head_spur_hold	South Jetty	$ 3,560,979	$ 159,570,547	$ 44,263,508	$ 1,005,076	$ 208,400,110	$ 9,701,067	4	0.99	$ (134,376)
SJ_fut21_immed_rehab_minimum_hold	South Jetty	$ 91,398,236	$ 125,812,946	$ 75,949,998	$ 982,492	$ 294,143,672	$ 13,692,447	31	0.70	$ (4,125,756)
SJ_fut21_sched_rehab_minimum_hold	South Jetty	$ 89,417,259	$ 127,069,463	$ 76,050,994	$ 1,182,063	$ 293,719,779	$ 13,672,715	30	0.70	$ (4,106,024)
SJ_fut22_immed_rehab_small_hold	South Jetty	$ 128,416,185	$ 84,760,274	$ 40,598,117	$ 959,498	$ 254,734,074	$ 11,857,922	22	0.81	$ (2,291,231)
SJ_fut23_immed_rehab_moderate_hold	South Jetty	$ 163,256,392	$ 57,735,451	$ 29,489,975	$ 958,877	$ 251,440,695	$ 11,704,615	21	0.82	$ (2,137,924)
SJ_fut24_immed_rehab_large_hold	South Jetty	$ 193,616,692	$ 50,339,018	$ 26,637,632	$ 977,710	$ 271,571,052	$ 12,641,687	24	0.76	$ (3,074,996)
SJ_fut30_immed_rehab_comp1_large_hold	South Jetty	$ 161,557,709	$ 52,350,112	$ 26,740,892	$ 987,110	$ 241,635,824	$ 11,248,196	14	0.85	$ (1,681,505)
SJ_fut30_immed_rehab_comp2_modi1_hold	South Jetty	$ 136,193,839	$ 72,353,794	$ 31,297,987	$ 991,260	$ 240,836,879	$ 11,211,005	13	0.85	$ (1,644,314)
SJ_fut30_immed_rehab_comp3_small_hold	South Jetty	$ 122,136,857	$ 100,952,754	$ 49,560,868	$ 963,439	$ 273,613,918	$ 12,736,783	26	0.75	$ (3,170,092)
SJ_fut30_immed_rehab_comp4_medium_hold	South Jetty	$ 145,361,941	$ 58,992,129	$ 28,035,398	$ 956,164	$ 233,345,633	$ 10,862,286	10	0.88	$ (1,295,595)
SJ_fut30_immed_rehab_comp5_modi2_hold	South Jetty	$ 134,303,982	$ 76,761,873	$ 34,418,559	$ 981,236	$ 246,465,650	$ 11,473,025	16	0.83	$ (1,906,335)
SJ_fut30_sched_rehab_comp5_modi2_hold	South Jetty	$ 130,152,680	$ 80,747,881	$ 35,877,959	$ 1,209,929	$ 247,988,449	$ 11,543,912	18	0.83	$ (1,977,221)
JA_fut1_base	Jetty A	$ -	$ 10,980,535	$ 9,947,673	$ 5,883,989	$ 27,864,698	$ 1,297,107	7	1.00	$ -
JA_fut1_fixasfail_repair	Jetty A	$ -	$ 15,335,784	$ 13,348,321	$ 9,989,360	$ 40,492,645	$ 1,884,941	9	0.69	$ (587,833)
JA_fut1_sched_repair	Jetty A	$ -	$ 14,805,882	$ 4,058,395	$ 5,717,313	$ 25,603,094	$ 1,191,829	4	1.09	$ 105,278
JA_fut22_immed_rehab_small	Jetty A	$ 27,618,540	$ 92,962	$ 109,165	$ 159,258	$ 27,999,156	$ 1,303,366	8	1.00	$ (6,259)
JA_fut23_immed_rehab_small	Jetty A	$ 26,027,435	$ 112,896	$ 111,624	$ 158,641	$ 26,429,828	$ 1,230,314	5	1.05	$ 66,794
JA_fut1_base_hold	Jetty A	$ -	$ 11,673,628	$ 9,550,914	$ 249,130	$ 21,473,672	$ 999,604	2	1.30	$ 297,504
JA_fut1_sched_repair_hold	Jetty A	$ -	$ 15,289,267	$ 4,078,021	$ 251,543	$ 19,618,831	$ 913,260	1	1.42	$ 383,847
JA_fut22_immed_rehab_small_hold	Jetty A	$ 26,930,688	$ 164,806	$ 123,260	$ (6,207)	$ 27,202,767	$ 1,266,294	6	1.02	$ 30,813
JA_fut23_immed_rehab_small_hold	Jetty A	$ 25,242,976	$ 187,586	$ 127,435	$ (6,478)	$ 25,541,739	$ 1,188,973	3	1.09	$ 108,134

2.12 MRR Benefits Discussion

As with all coastal major rehab projects, the MCR MRR alternatives considered—including the base condition—maintain the navigation benefits of the project. While it would have been possible to formulate a base condition that included substantial interruptions in service, that scenario was deemed untenable as it would have required the Corps to ignore observed jetty degradation and the obvious impending and certain failure of the MCR system.

The MRR base condition (discussed in Sections 2.3 and 3.84) consists of a reasonably efficient plan in which thorough annual jetty inspections are used to initiate repairs when significant degradation is observed. Given the efficacy of the base condition, it is difficult for any alternative that includes large initial expenditures to reduce total present value costs. If none of the alternatives evaluated provide cost savings over the base condition, then the base conditions for all three jetties would become the least cost plan, this would result in an overall BCR of 1:1, indicating that the base condition was the most efficient plan for each jetty.

Essentially, the MCR Jetties System is faced with a binary decision: a maintenance strategy that allows for the possibility of a breach and sediment closing the navigation channel or one that doesn't. The Corps chose the latter.

For the South Jetty, no alternative was identified that could significantly reduce costs relative to the base condition that met the requirement of maintaining reliable navigation. The North Jetty is subject to higher wave energy and has a higher associated risk to navigation. The North Jetty recommended plan recognizes that risk and implements a more aggressive repair strategy which reduces unplanned (expedited) repairs. However, this recommended plan is similar to the base condition and therefore provides real but not dramatic incremental benefits A high functioning Jetty A not only reduces expedited repair on Jetty A but also reduces repair costs to the North Jetty so again, a pro-active repair schedule yielded cost savings over the lifetime of analysis.

For the North Jetty the incremental benefits are achieved by lowering overall repair costs through enacting a more pro-active maintenance plan which reduces expedited repairs by increasing scheduled repairs (see table 2.6 highlighted plan for North Jetty). A similar efficiency was found for Jetty A, and therefore both the North Jetty and Jetty A have positive BCRs reflecting the lower costs of the recommended plans when compared to the base condition. The South Jetty recommended plan is the base condition, therefore the individual BCR for the South Jetty is 1:1, (recommended plan divided by base plan). The South Jetty is also the most expensive of the three jetties to maintain, followed by the North Jetty (BCR (1.09). In order to calculate a combined BCR, the BCRs for each jetty are weighted by the cost of the recommended plan for that jetty. When the weighted average is calculated the least expensive Jetty, Jetty A (BCR 1.42) has less influence on the overall combined BCR than the North and South Jetties and a combined BCR of 1.1 results.

Given that the project's base condition theoretically prevents a breach in the jetties, project navigation benefits are not at risk. Consequently, the major rehab effort described in this report does not produce a high benefit-to-cost ratio because the project prevents a jetty breach and sediment from blocking the navigation channel. Also, with the inclusion of the base condition as the recommended plan for the South Jetty, benefits for that project feature are essentially treated as equaling costs, despite the actual substantial benefits associated with maintaining navigation at the project. The benefits for the major rehabilitation project are incremental relative to the base condition strategy, rather than accounting for the actual overall navigation project purpose benefits.

Lastly, and perhaps most significantly, the project's combined BCR of 1.1 for the system (all three jetties) doesn't capture all the benefits related to protecting the entrance the Columbia River navigation channel (105 miles, 43 feet deep; $182M channel deepening project completed in 2010) and the Columbia/Snake River system. For example, $20B of cargo annually travels through the entrance protected by MCR Jetties. Furthermore, over $900M in new infrastructure investment has been made to date in the Pacific Northwest since 2010.

In brief, the district maintains that the MCR jetty system is the most significant coastal navigation structure in the Pacific Northwest; one that provides economic benefits far beyond a BCR of 1.1 indicates.

3. ENGINEERING CONSIDERATIONS

3.1. GENERAL

This chapter provides the engineering basis for the development and analysis of the alternatives. This chapter includes:

- A characterization of the wave climate and morphologic processes at the MCR;
- The current issues/risks of deterioration or failure for each of the jetties and associated consequences;
- A characterization of the design of each jetty and the relevant performance modes;
- The description of the methodology and model used for assessing the reliability and life-cycle performance of the jetties, including alternatives;
- A summary of how the model was calibrated using historical and hindcast data; and
- A description of each of the repair/rehabilitation alternatives, including the model analysis results related to projected future long-term maintenance actions and reliability.

3.2. PROJECT LOADING BY FORCING ENVIRONMENT

3.2.1. Waves at the MCR Inlet

The ocean entrance at the MCR is characterized by large waves and strong currents and has been considered one of the world's most dangerous coastal inlets (Gonzalez 1984, Ozkan-Haller 2008). The sea state at the MCR during storm conditions is characterized by high swell approaching from the northwest to southwest combined with locally generated wind waves from the south to southwest. During October-April, the seasonal average wave height is 9 feet and period is 12 seconds. During intense winter storms, waves can exceed 30 feet; individual waves with a height of 45-55 feet were recorded 5 miles south of the MCR in water depth of 135 feet (Moritz 2001). During May-September, average wave height and period is 5 feet and 9 seconds, respectively.

As waves propagate shoreward toward the MCR, the waves are modified (waves begin to shoal and refract) by the asymmetry of the underwater morphology of the MCR. Nearshore and tidal currents are also modified by the jetties and morphology. These modified currents interact with shoaling waves to produce a complex and agitated wave environment. The asymmetric configuration of the MCR and its morphology is characterized by the significant offshore extent of Peacock Spit on the North Jetty's north side, southwesterly alignment of the North and South jetties and channel, and the absence of a large shoal on the south side of the MCR. The asymmetry of the MCR causes incoming waves to be focused onto areas that would not otherwise be exposed to direct wave action.

3.2.2. Time-varying Changes in MCR Nearshore Wave Climate

The changes in regional and localized waves at the project site since original construction can be described from two separate perspectives. The first approach is to look at any trends of the regional wave environment associated with variable climate effects. The second approach is to look at the impacts of morphology evolution on the depth-limited characteristics of the waves at the project.

Measurements of the deep water waves offshore of the MCR project area are available from 1984 to present (National Data Buoy Center). Analysis of this deep-water wave data set suggests that the storm-related wave heights and frequency of storms may be increasing over the period or record. Due to the relatively short data record, it is not known whether this trend is persistent or just a subset of a larger data set that experiences a wide range of wave heights. The data record describes deep water wave conditions. However, the wave heights actually impacting the MCR jetties are shallow water waves, being transformed to shoreward over the nearshore bathymetry. The actual impact (associated with climate variation) on shallow wave heights at the structure will be dampened by the depth-limited characteristics of the project site; namely, wave height is physically reduced as the water gets shallower, oftentimes eliminating any increased increment of wave height by the time it reaches the project. This fact introduces the second element of wave height change over the project life: morphology change at the inlet. If the nearshore bathymetry (submerged shoals) at the project area becomes deeper over time, waves (height) affecting the structure can increase. The opposite is true for morphology accretion; increased waves will likely erode the shoals.

The morphology created by and surrounding the jetty construction protects the jetties from large damaging waves. If the morphology along the jetties recedes excessively, large damaging waves can attack and destabilize the jetties. A combined wave- and water-level modeling approach was applied to account for the evolving nature of the morphology at the MCR. The modeling effort used a numerical model called STWAVE (Steady-State spectral WAVE; Smith et al., 2001) to transform offshore waves to the project site. This model is used to simulate the two-dimensional propagation of a wave field as it travels through winds and current and encounters variable bathymetry. Jetty life-cycle analysis and design utilized this wave model to estimate waves in the past, present, and future.

3.2.3. **Water Levels at the MCR Coastal Margin**

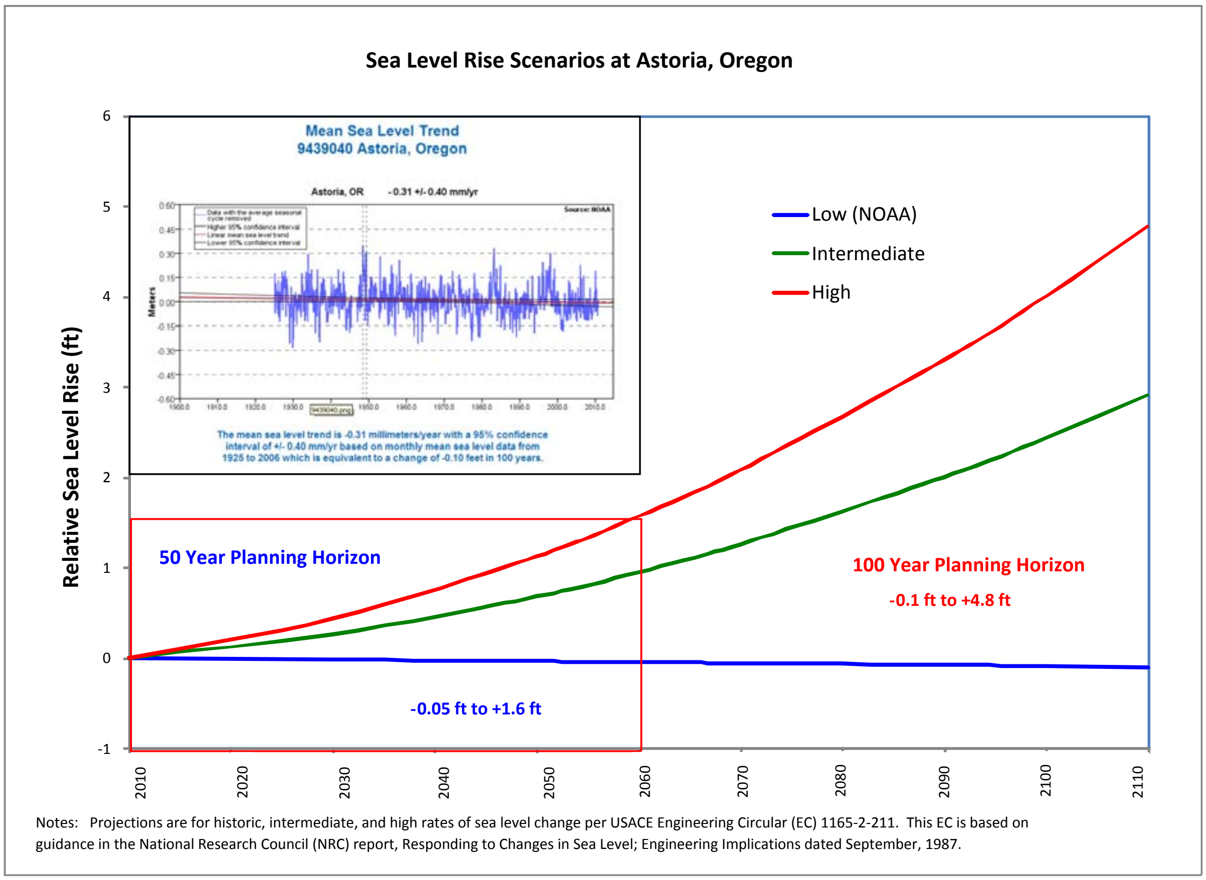
Astronomical tides at the MCR are mixed semi-diurnal with a diurnal range of 8.5 feet. Twice each day, the MCR is the hydraulic battlefield between two distinct water masses, the freshwater outflow of the Columbia River and the marine inflow from ocean tides. The instantaneous flow rate of estuarine water leaving the MCR during ebb tide can exceed 2 million cfs and the flow rate of marine water entering the MCR during flood tide can exceed 1 million cfs. Currents in the navigation channel can attain 5 knots (8 feet/second) and are highly variable in time and space. The nearshore wave and tidal environment is greatly affected by Peacock and Clatsop spits, due to the spits' significant offshore extent. The orientation of the shoals/spits has arisen due to the interaction of jetties, waves, currents and sand; thus, the morphology and coastal processes at the MCR are linked.

A high water level along the coastal margin allows larger waves to attack the jetties and displace armor stones, if the armor layer is not adequately designed and constructed. Water levels along the Oregon Coast are primarily a function of astronomical tide influences. Other factors that can influence water levels are atmospheric pressure, wind set-up, and wave set-up. Wave set-up can be modulated by infragravity transients, which are low frequency variations of the water surface (1-4 minute period) induced by groups of storm waves. Collectively, these "other factors" are called storm surge; when the observed water level exceeds the predicted tidal water level during storms. The total storm-induced water level (SWL, used for calculation of nearshore wave height) was estimated by adding "storm surge" to predicted tidal water level. Each component for water level was defined in terms of a probability density function used for generating a randomized total water level when simulating the life-cycle of the MCR jetties within the life-cycle analysis model (see Appendix A2, *Reliability Analysis, Event Tree Formulation and Life-cycle Simulation*).

3.2.4. **Potential for Sea Level Change**

The potential effect of sea level rise was included for assessments of future jetty performance at MCR. Future sea level rise was estimated within the Stochastic Risk-Based (SRB) model as outlined in EC-165-2-211 [USACE 1 October 2011]. The EC prescribes a method for defining three future projection curves which are used to bound the estimate for sea level rise over time. The sea level projections (curves) are site specific and are derived based on the historical sea level trend blended with the eustatic effect (see Fig. 3-1). EC curve #1 defines the lowest expected bound for sea level rise and basically provides an extrapolation of the historical observed rate. EC curve #2 defines a “prudent” intermediate trend and EC curve #3 defines the highest expected bound incorporating potential acceleration. A MCR (SRB) model, discussed in detail later in this report and appendix A2, was developed to evaluate jetty response to wave forcing at the MCR. The sea level projections that were used within the SRB model were based on the National Ocean Survey (NOS) station at Astoria, Oregon. The potential sea level change at the project site over the 50 year planning horizon ranged somewhere between -0.05 ft to +1.6 ft. See Figure 3-1 for the projected sea level change curves used.

Figure 3-1. Sea Level Rise Scenarios



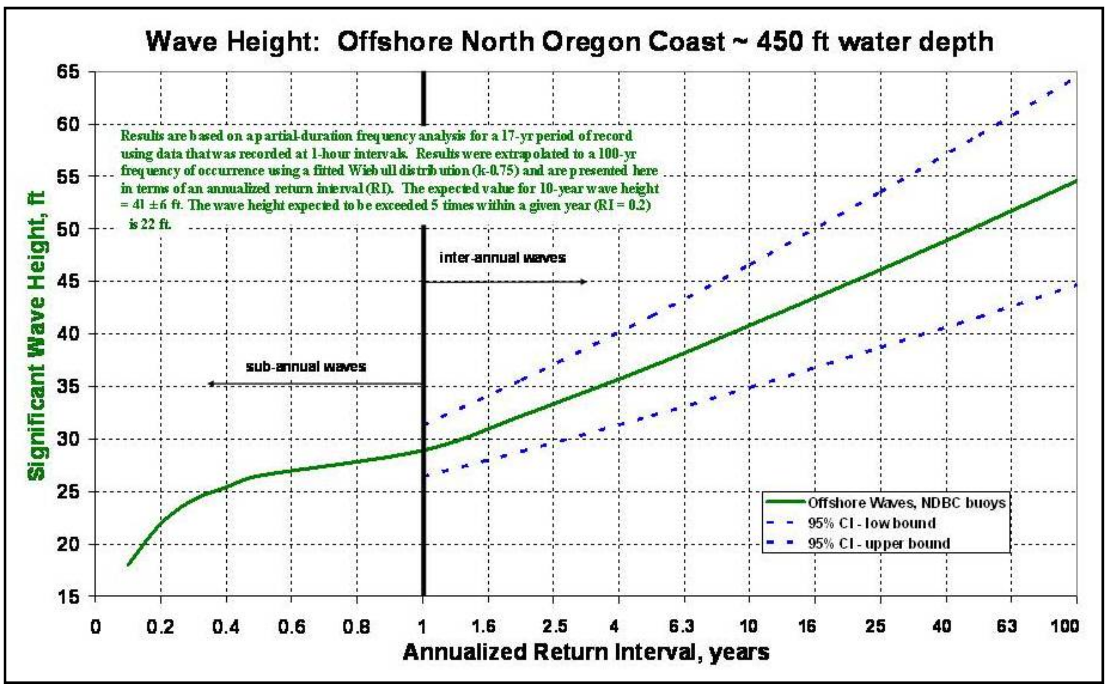
Within the SRB model, each jetty life-cycle realization was assigned a randomly generated sea level rise trend, which is bounded by EC curve #1 and EC curve #3. A total nearshore water level is estimated for each storm by adding the estimated sea level rise (for a given year) to the nearshore storm-induced water level. With the slightly greater water level at the project site during these realizations, the incident wave height was also adjusted accordingly. So the future case scenarios incorporate both a higher water level as well as the impact on wave height. Sea level rise effects were not included within the historical assessment of jetty performance (hindcast).

The relatively minor sea level change at the project site makes the inclusion of sea level change in the total loading environment less of a driving factor for a long-term maintenance strategy. In addition, due to the uncertainty of future sea level rise scenarios, the most likely approach for very large rubblemound structures for future maintenance would be to develop an adaptable maintenance strategy that could be modified as the gradual change is observed.

3.2.5. **Definition of Wave Climate at the MCR Jetties**

An analysis of the wave record from buoys at the National Data Buoy Center (1984-2008) is the basis for defining the offshore wave environment at the MCR (Moritz 2006, 2007). Results from this analysis are shown in Figure 3-2. The storm wave "climate" affecting each MCR jetty was estimated by synthesizing the offshore storm wave environment in terms of a series of observed wave events. Each offshore wave event was described in terms of a directional wave spectrum. A phased-average spectral wave model was used to transform the candidate offshore wave events to various locations along each jetty, for a range of water levels. The wave environment at the jetties was estimated using STWAVE (Smith et al., 2001).

Figure 3-2. Offshore Wave Height Expressed in Terms of Annualized Return Interval



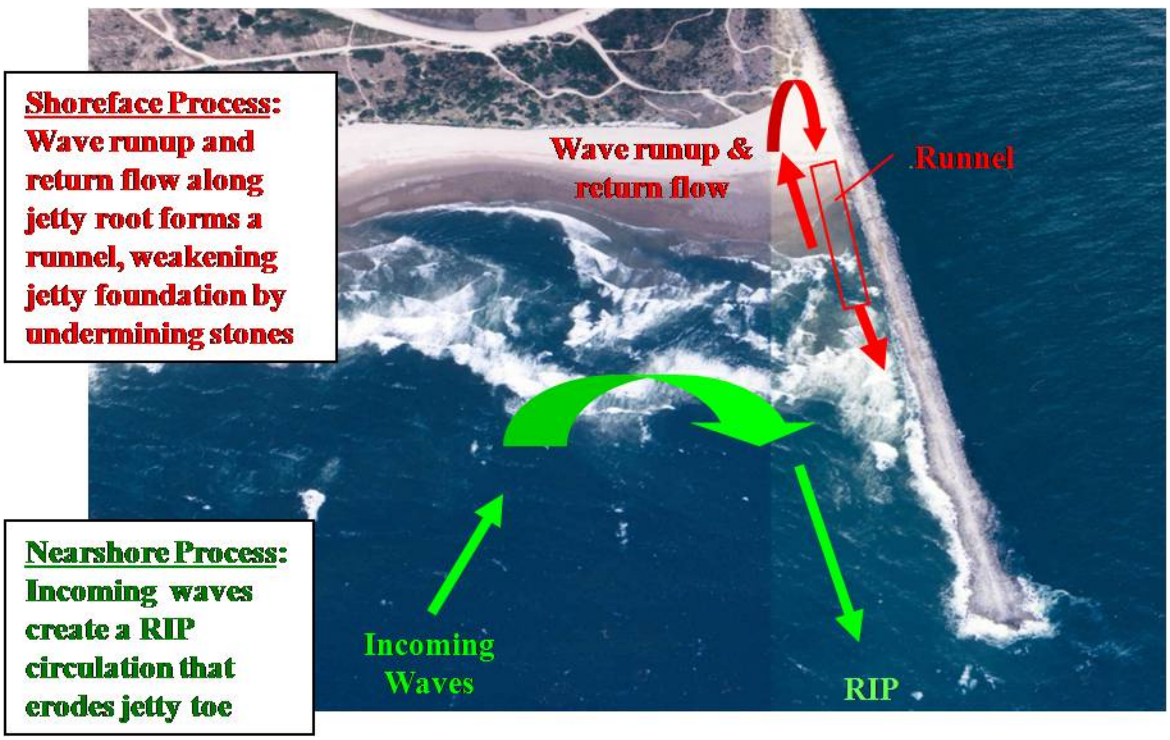
3.3. STRUCTURES AND MORPHOLOGY

3.3.1. **Interaction of Structures and Morphology**

Since original jetty construction, several large physical process changes have altered the current and projected future reliability of the MCR jetty system. These large process changes gradually impact the stability of the structures and the reliability of the system and are primarily driven by changes in inlet morphology and observed changes in wave climate. Increased channel depths and ebb tidal shoal erosion has led to increased depths along both sides of the seaward portions of the jetties. As increased depths are secured in the improved navigation channel, larger waves are able to enter the channel and attack the jetties, in addition to undermining the sandy foundation upon which they rest. These increased channel depths primarily affect the channel-side of the jetties and particularly the North Jetty, which is closer to the navigation channel.

During 1993 to 2000, the 40-foot contour on the ebb tidal shoal receded landward at a rate seven times faster than during 1930 to 1993, as shown in Figure 1-10 (Chapter 1). As the ebb tidal shoal recedes, the wave and current regime at the entrance and jetties changes. The jetty length and the ebb tidal shoal configuration are somewhat inter-connected. As one changes, the other is altered as well. Shoreline position and stability on the outsides of the jetty system is also connected to the jetty head position and jetty length. As the jetty length recedes, the shoreline is exposed to greater wave and storm impacts, eventually having a negative effect on the stability of the jetty roots. Figure 3-3 illustrates shoreface and nearshore processes adjacent to a jetty.

Figure 3-3. Shoreface and Nearshore Processes at a Jetty



3.3.2. **Existing Condition of MCR Jetties and Shoals**

The existing condition and robustness of the MCR jetties can be characterized by looking at the maintenance history, as well as the current cross section deficit of each jetty compared to a standard or typical design cross-section. The maintenance history of each jetty was discussed in Chapter 1. Figure 3-4 through Figure 3-6 summarize that information in approximately 50-year increments, a typical design life for a coastal structure. Also plotted on these figures is the estimated expected maintenance for the jetties over that same time period using 0.7% multiplied by the construction volume per year of structure life. In extreme exposure of the structure, the expected maintenance requirements described above would predict more stone would be required to maintain the cross-section integrity.

In particular, the last 50 years has seen a reduction in maintenance activity at the jetties. Some of the repair activities for Jetty A utilized readily available but under-sized stone for maintenance activities, which is reflected in the fairly large stone volume placed on the structure over its lifetime.

Another measure of the existing rubble-mound structure condition would be to simply calculate the deficit of stone volume between the existing structure surface and a standard or typical design cross-section. Figure 3-4 through Figure 3-6 illustrate that comparison for the three jetties. Existing South Jetty deficits range from approximately 410,000 to 700,000 tons of stone to bring the existing structure up to a minimum or small cross-section. For the North Jetty, approximately 240,000 to 570,000 tons of stone would be needed to bring the existing structure up to a standard minimum or moderate cross-section. Jetty A would need approximately 87,000 tons to bring the existing structure up to a smaller cross-section. A range of stone volumes is reported here to provide a framework for considering design or structure modifications necessary to respond to increased loading of the structure at some locations. The design cross-sections will be discussed in more detail later in this section of the report.

Figure 3-4. North Jetty Maintenance Record Summary

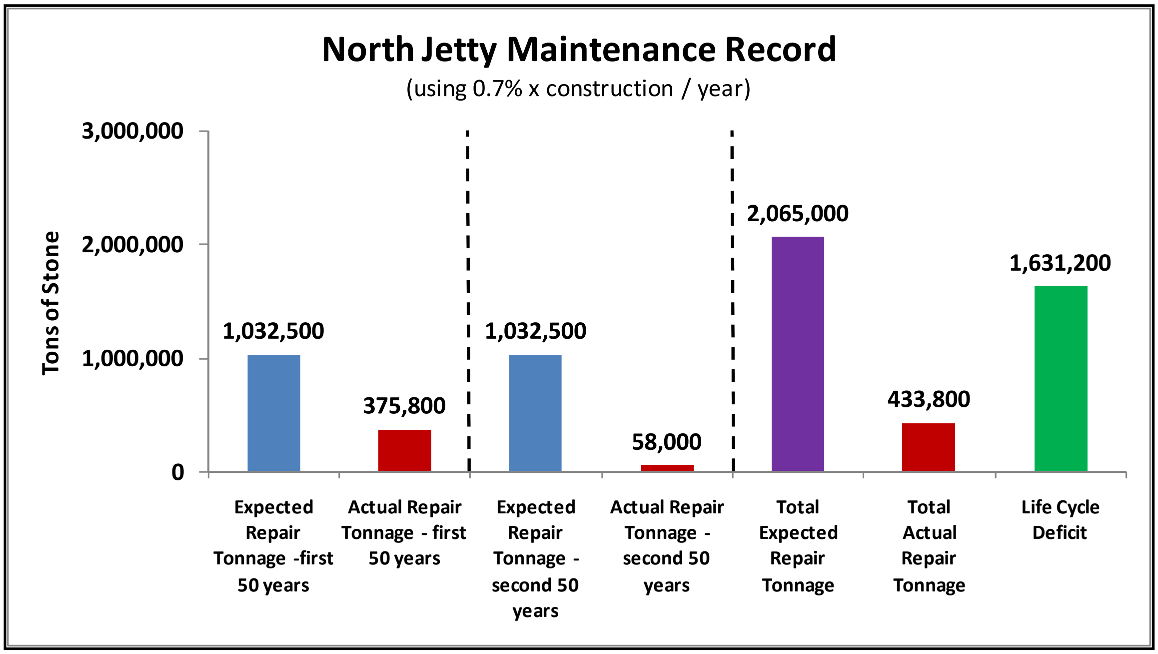


Figure 3-5. South Jetty Maintenance Record Summary

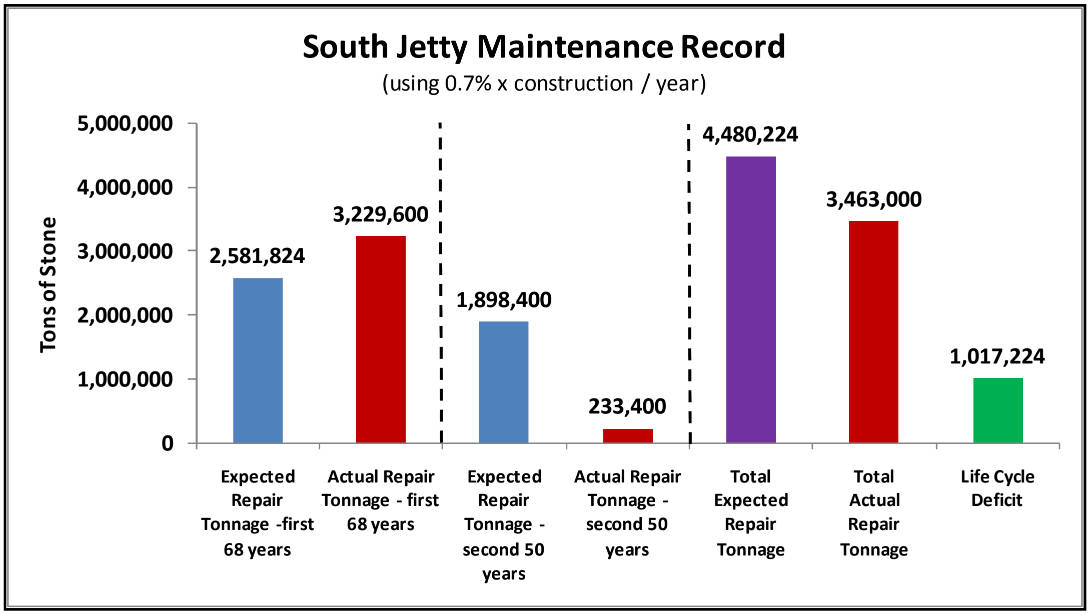
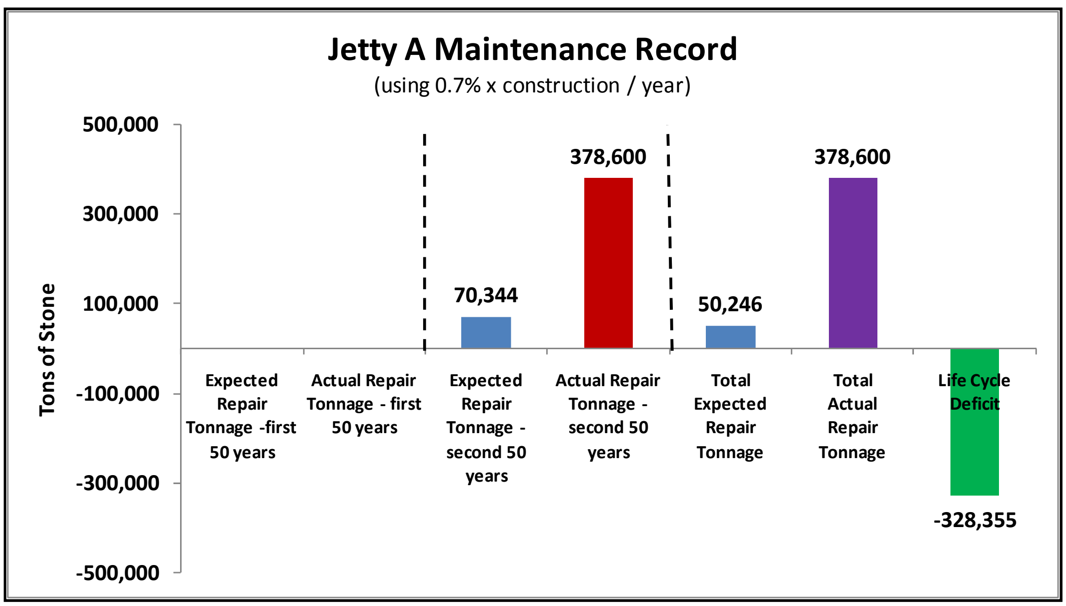


Figure 3-6. Jetty A Maintenance Record Summary



The existing condition of the three jetties provides information that is utilized in numerous ways throughout this analysis and study. First and foremost it serves as an ending point for the hindcast analysis of the jetties. Secondly, it provides information on the level of deterioration of the structures and the existing reliability. Survey methods range from aerial light detection and ranging (LIDAR) combined with bathymetric surveys to annual, on-the-ground surveys using GPS and hip-chain to locate station. The 2010 on-the-ground survey is included as Appendix A-4 in the report. Future surveys will use LIDAR/bathymetric methods and be compared biannually to track damage and jetty stone loss. Existing condition information for this analysis was obtained through a comprehensive multi-beam and above water survey of the structures which was combined into a digital terrain model of each structure.

The results from that survey for the North Jetty are illustrated in Figure 3-7 through Figure 3-8. The results from that survey for the South Jetty are illustrated in Figure 3-9 through Figure 3-10. These figures contain key condition characteristics relevant to reliability and design: crest elevation and crest width. A standard minimum design crest width is included in these figures for comparison purposes. This minimum design cross-section will be discussed in more detail later in this section of the report. The crest widths illustrated in these figures show a wide variation with widths within a segment varying from zero to greater than a typical minimum design crest width. Additional information about the existing condition of the MCR jetties and shoals, and historic maintenance records can be found in Appendix A1, Section 6.

Crest elevation and jetty length changes are documented in Figure 1-25, Figure 1-27, and Figure 1-33 with respect to a complete project survey conducted in 2000. For the North Jetty, jetty length loss of approximately 2,100 feet and significant channel-side foundation erosion (up to 60 feet change in depth) impacting approximately the seaward half of the jetty are the most significant. In addition, as shown in Figure 1-6, the north side of the North Jetty is being increasingly exposed to higher wave and water level conditions due to the erosion of Benson Beach. For the South Jetty, jetty length loss of approximately 6,200 feet has worked interactively with ebb tidal shoal changes to increase loading particularly for the seaward half of the structure. The concrete monolith at approximately station 330 and the channel-side spur groins have slowed down the physical morphological changes at that location. Jetty A has lost approximately 900 feet and in addition, a large scour hole at the southern end of the Jetty A head, up to 120 feet in depth, has impacted its stability.

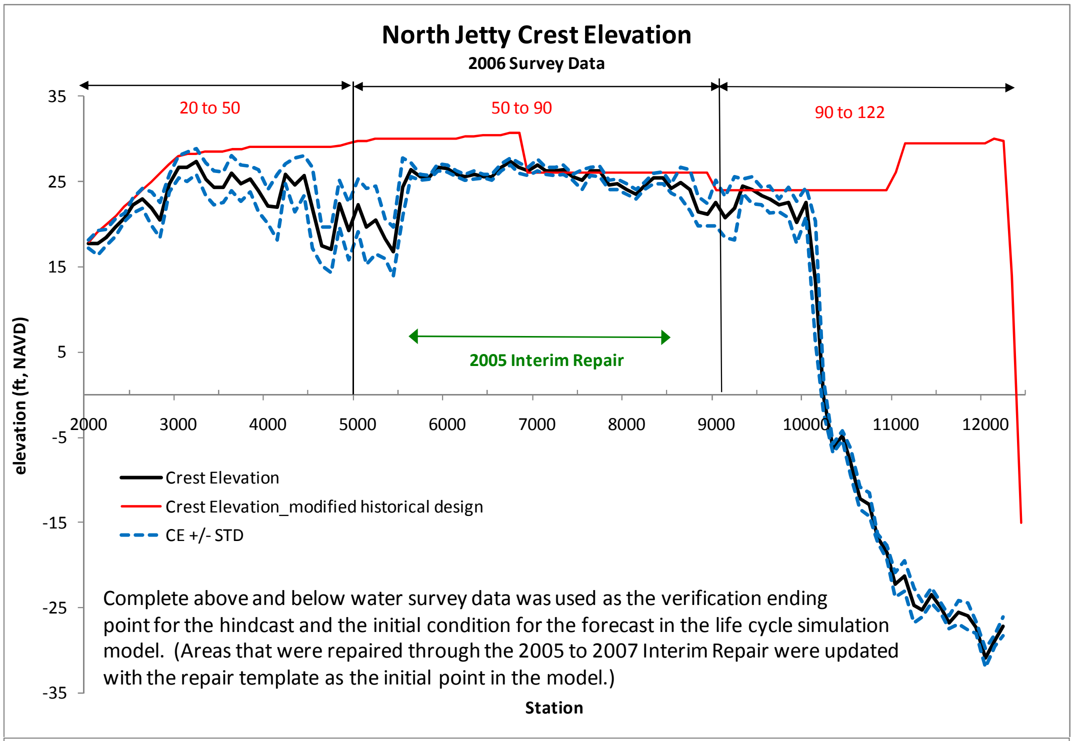
The service life of stones on the jetties is one of the important factors in determining how well the jetty will hold up through time. Significant amounts of stone broken or worn away by wave action through time could lead to jetty structure instability. Stone composition and durability varies from quarry to quarry, so it’s important for stones to meet a minimum criterion to ensure their longevity, such as the current Portland District Jetty Stone Standards discussed in paragraph 4 in Appendix B. The high standards in place by the District for over the past 50 years aids in the overall performance of the jetties. Unfortunately for many jetties along the Oregon coast, original construction took place without any measureable stone quality requirements. As a result, inferior stone, often sandstone, was utilized extensively, which had the potential to shorten the life expectancy of the jetty. All stone utilized for original construction of the MCR jetties, as well as for subsequent repairs, came from volcanic sources, which perform much better than those from sedimentary sources.

Stones utilized for the North Jetty came from a variety of sources, as identified in Table 1-3. All sources of stone, including those for original construction, came from quarries in volcanic rock that have met current District quality standards. Both Fisher and Skookumchuck quarries are in existence today, and even though lab tests weren’t conducted at the time of their first use, stone quality, by visual observation has not changed through time and would still meet current stone requirements. Stones have good survivability with very little breakage occurring after initial placement and while some wear is present to edges of the stones, it is not enough to significantly compromise the interlocking properties.

Stones for the South Jetty original construction, as shown in Table 1-2, came from quarries along the lower Columbia and Willamette Rivers. Although actual quarry locations are unknown, design requirements stipulated use of basalt, which is a hard, durable volcanic rock that holds up well in a marine environment. Subsequent repairs and extensions through 1982 utilized stone from the well known Fisher Quarry, over 7.5 million tons or 83% of all stone used on the jetty during original construction and maintenance to present day. This consists of all stone currently exposed on the outer surface of the jetty and meets the current stone requirements and continues to perform well in the jetty structure.

Stone for Jetty A original construction and early repairs, as identified in Table 1-4, came from the Skookumchuck Quarry as well as the Naselle Quarry, both of which are volcanic rock and have been tested recently and meet the current quality standards. Stones from both of these quarries, which provided the full base material for the jetty and 53% of the total volume of material placed, have undergone very little additional breakage and wear and continue to perform well. The latest repairs to Jetty A, from 1951 to 1962, utilized local volcanic basalt breccia from Cape Disappointment. This material is considered inferior and was considered to be marginal quality at the time. Service records in 1958 (USACE), however, based on visual performance through time, showed the material to be wearing well and was allowed for use in subsequent repairs. This material continues to perform adequately to this day and annual inspections of the jetty show very few additional instances of breakage or wear.

Figure 3-7. North Jetty 2006 Survey Data – (a) crest elevation and (b) crest width. Utilized as the verification endpoint for the hindcast simulation and the beginning point for the life cycle forecast



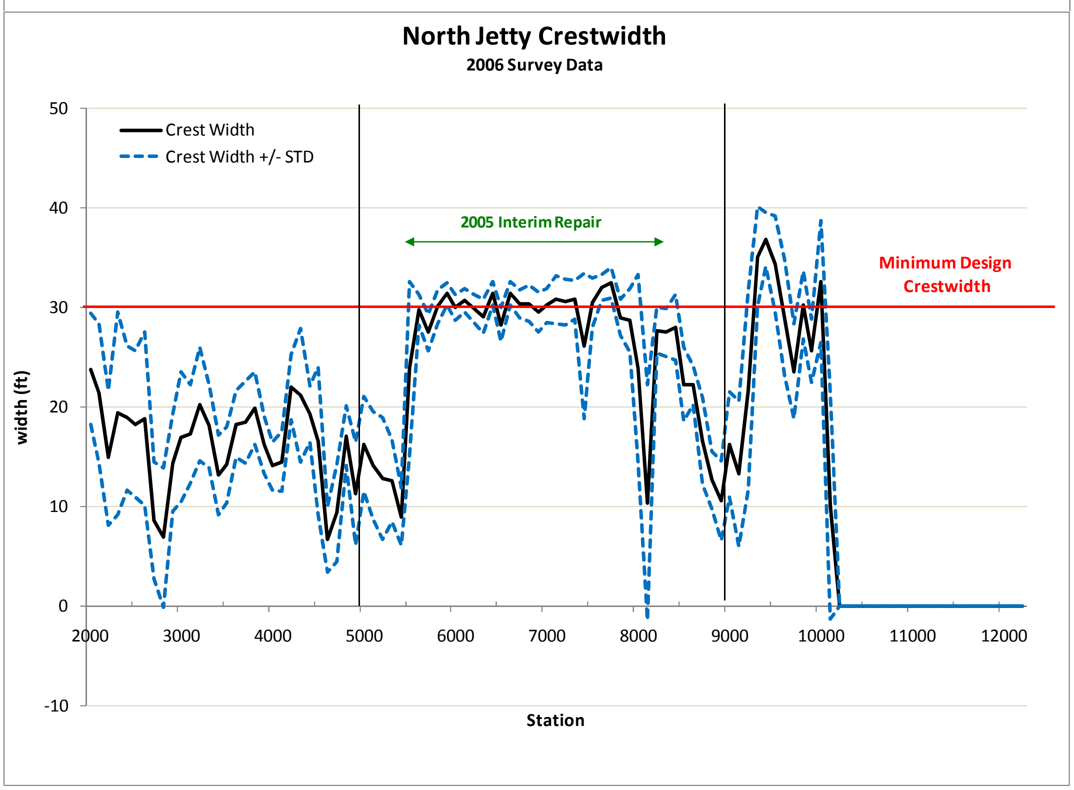


Figure 3-8. North Jetty 2006 Cross-section deficit.

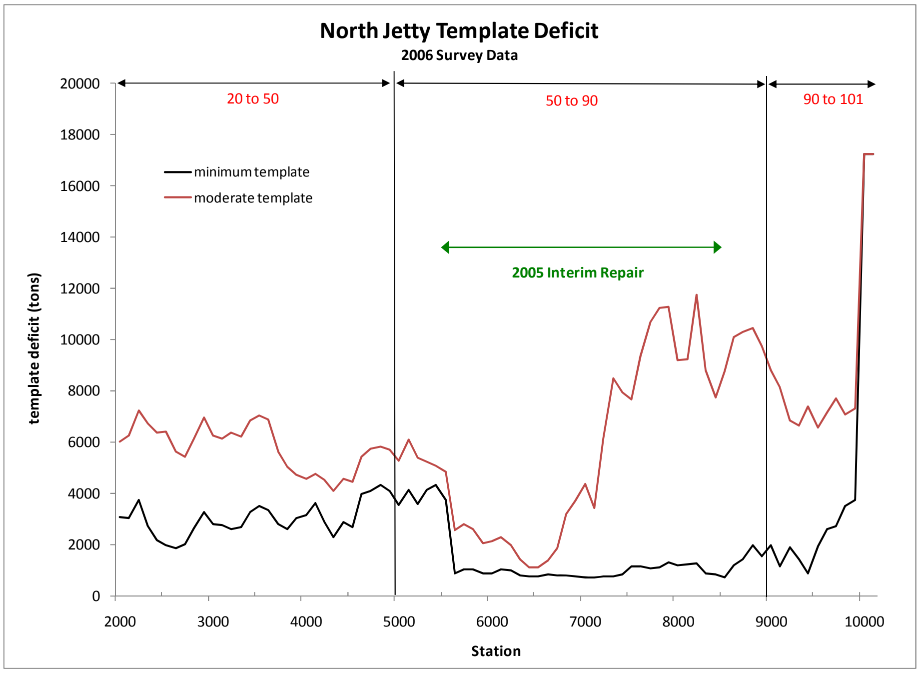
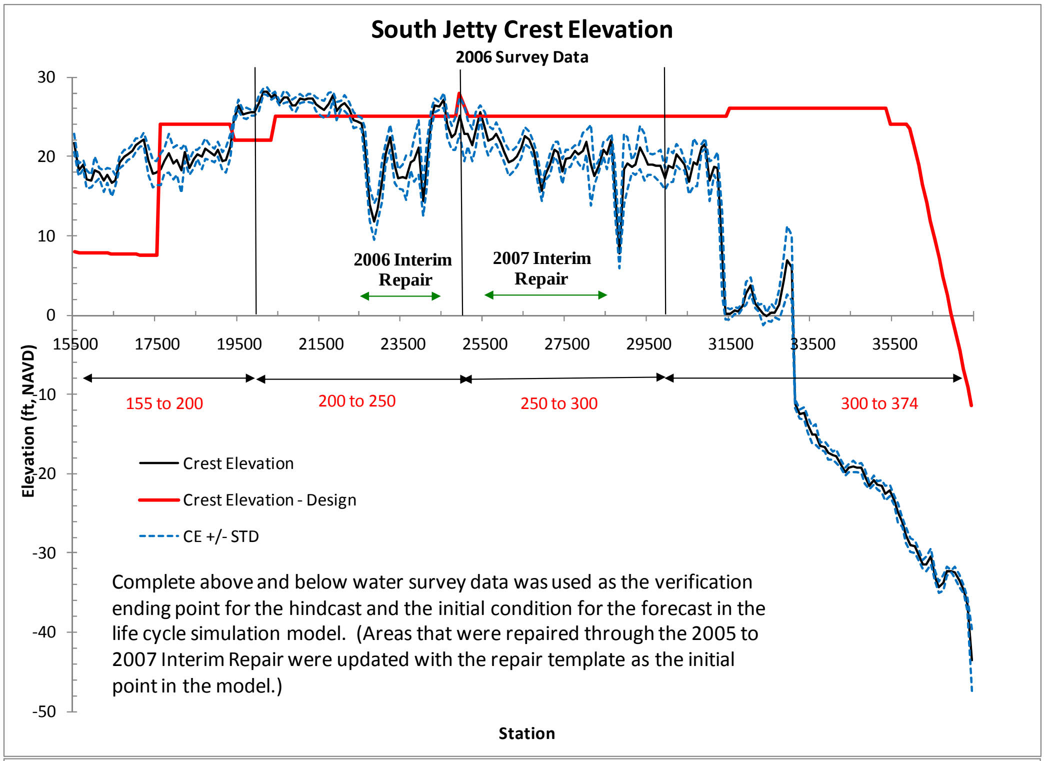


Figure 3-9. South Jetty 2006 Survey Data – (a) crest elevation and (b) crest width. Utilized as the verification endpoint for the hindcast simulation and the beginning point for the life cycle forecast



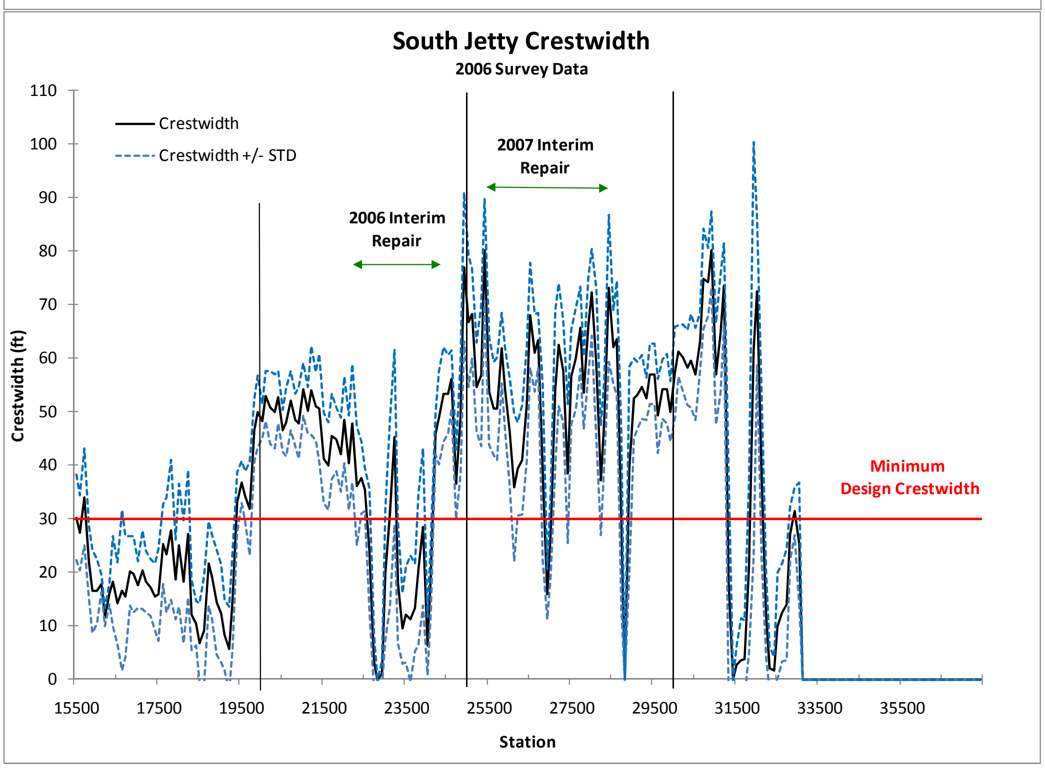


Figure 3-10. South Jetty Cross-section Deficit.

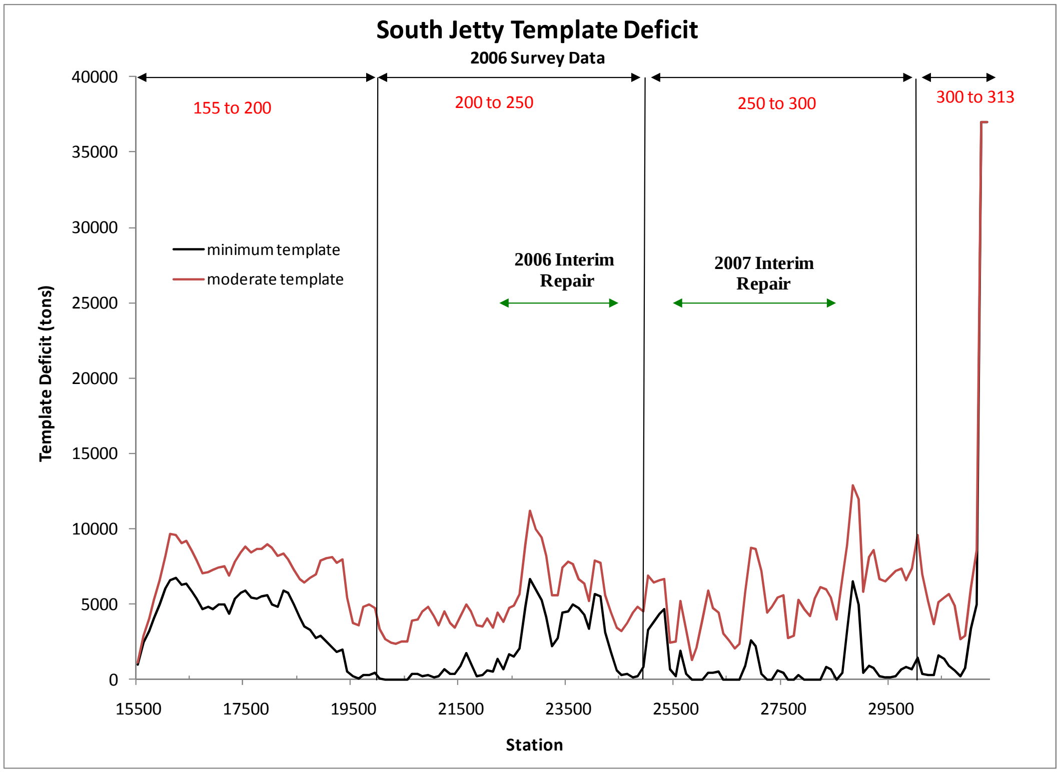
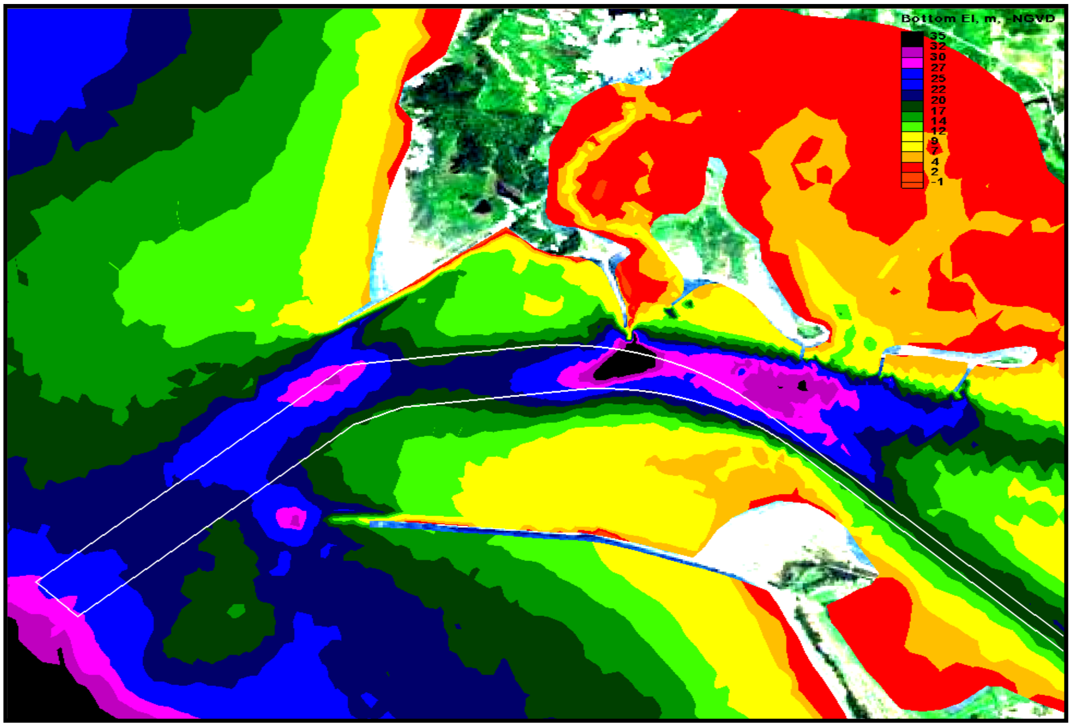


Figure 3-11 illustrates the critical shoals surrounding and supporting the MCR jetties. Ebb tidal shoal changes and jetty length recession impacts all areas identified in Figure 3-11. Ebb tidal shoal recession and reorientation is shown in Figure 1-10. The jetties continue to recede from their original length. The head positions of the South and North jetties and Jetty A are currently shorter than authorized lengths by 6,200 feet, 2,200 feet, and 900 feet, respectively. Due to the interaction of wave patterns and currents with the jetty configuration, the shorter jetty lengths can increase underwater shoal erosion and motivate increased recession of shoreline position adjacent to the jetties. Loss of jetty length also exposes the remaining structure to increased forces.

Figure 3-11. Areas of MCR Morphology (#1-#8) Affected by Jetty Deterioration



The South Jetty was constructed in 1885-1895 to stabilize the highly transient tidal shoals (bar) and establish a deep draft navigation channel through the MCR inlet. During 1903-1913, the jetty was rehabilitated and extended offshore to increase jetty function for stabilizing the inlet.

Jetty A length recession has additional impacts on areas #2 to #7 in Figure 3-11. In particular, Jetty A was constructed in order to help stabilize the location of the navigation channel and to reduce shifting of Clatsop Spit (#5 to #7) northward. This added control helps stabilize the channel-side foundation shoal for the North Jetty (#2). Morphology areas #1 and #8 are directly related to jetty length, as well as ocean processes that develop rip currents along the jetty length.

Figure 1-25, Figure 1-27, and Figure 1-33 illustrate foundation changes along each side of each jetty with respect to the 2000 survey. In addition to the foundation changes along the exposed areas of the jetties, along the landward half of the North Jetty another de-stabilizing flow path has developed through the structure as tidal flow moves through the structure to the accreted part of Peacock Spit, along the north side of the structure. Increased storm activity and intensity over recent decades has accelerated adjacent shoreline erosion threatening to expose the deteriorated jetty root structure on both the North and South jetties.

3.3.3. **Projected Relevant Future Geomorphologic Change**

There are many processes that drive scour effects along the toe of coastal structures. In the past, the mechanism for jetty scour at MCR has been due to many interacting processes. Initially, tidal channel re-alignment due to jetty construction was the dominate mechanism for morphology change and scour. As the inlet responded to incremental jetty construction during 1885 to 1939, channel re-alignment stabilized as the inlet equilibrated to its present configuration. Rip currents, tidal currents, vortex shedding and other secondary flow effects, and wave action are now the processes that are believed to affect scour along the jetties. Even if the hydrodynamic aspects of scour are fully understood, there remains the difficulty of coupling the hydrodynamics with sediment transport. Consequently, most scour prediction techniques consist of rules of thumb and fairly simplistic empirical guidance developed from laboratory and field observations. If consistent hydrodynamic conditions persist over a sufficient time span, scour holes and trenches eventually reach a stable configuration. Appendix A5 summarizes historical morphological changes at the MCR project.

What is known about jetty scour at MCR is based primarily on observation of bathymetric change over time and space, with insight being supplemented by hydrodynamic modeling. The scour depth realized at the terminus of the originally constructed jetties has stabilized to a point of equilibrium; scour depth is no longer increasing along the jetty tips. The scour at areas inshore of the jetty tips continue to evolve along each jetty, but at a rate reduced from the initial stages of inlet response to jetty construction. Table A2-6 to Table A2-8 (Appendix A2) summarize scour depths that have been observed to date along each jetty. The maximum vertical extent of scour is believed to have equilibrated, but the scour zone is believed to migrate along each jetty based on jetty head recession and landward recession of the shore-jetty root interface. Future projection of scour depth is presented in these tables, based on past scour trends. It is likely that the spur groins evaluated will be subjected to some scour as the seabed locally adjusts to the presence of these elements. A given percentage of overbuild (10-20%) has been included within the MCACES cost estimate to account for natural reshaping of the groins as they are placed.

For this study, the jetty head features evaluated, would occur on existing relic stone which is the remnant from previous jetty construction and repair sequences. Relic stone has been in its present configuration for more than 10 years at the areas where jetty head features were evaluated. Construction of jetty head features on relic stone serves two purposes, (a) keeping the jetty head feature on the stable relic stone base and avoiding construction of the jetty features on scour-susceptible sand, and (b) minimizing material cost and construction complexity by maximizing the use of relic stone. If the jetty head cross-section extends beyond the relic stone, the quantity of material needed to complete the cross-section rapidly increases and the operating radius requirement (reach) for material placement rapidly increases.

For all three jetties, the jetty head features evaluated would terminate significantly shoreward from the originally constructed jetty head. The North, South, and Jetty A head locations were evaluated at approximately 2000 ft, 6000 ft, and 400 ft landward of the original jetty head position. The significant underwater relic stone base remains in place. For the North and South jetties, the jetty head feature evaluated would be placed at a location approximately 100 ft offshore from the present above water jetty terminus, within the extent of significant relic stone which makes construction of the head structure more practical. For Jetty A, the jetty head feature evaluated would be placed at a maximum distance of approximately 400 ft from the present jetty terminus, also within the extent of the significant relic stone. The rationale for the 100-ft extension for the North and South Jetties is that a complete standard jetty head structure requires at least 100 ft of new armor placement with an additional 100 ft of transition from the head structure within the existing jetty terminus. For Jetty A, the jetty is extended further to restore the required performance in stabilizing the navigation channel. In all cases, the catch point for the bottom slope of the jetty head feature is intended to be set back at least 10 ft from the fall line of the relic stone. The final location and configuration of the evaluated jetty head features will reassessed using detailed survey data and physical model studies and refined during the design documentation report phase prior to construction if part of the selected plan. Because the jetty head features will be constructed on a relic stone base, jetty head features are not expected to require scour blankets or launched toes.

The effect of toe scour on future life-cycle performance of jetty head features has been evaluated using future scour depths presented in table A2-6 to A2-8. Future scour depth along evaluated jetty head locations is estimated to extend below the present seabed elevation by 10-20 ft, depending on jetty location. The strategy for dealing with scour along the jetty head feature locations is to minimize the exposure of these features to scour by keeping the feature entirely on the relic stone and to account for toe continued scour of the relic stone base in assessment of the jetty head feature.

3.3.4. Present Risk and Reliability Issues for the MCR Jetties

Given the age of the infrastructure (+100 years for the primary structures), the existing condition of the jetties, and the modifications to morphology and possibly design wave climate over the project life, there are specific areas along each jetty that at a higher level of risk for accelerated deterioration or failure. Risk and reliability issues are also related to the potential consequence should a failure occur and are covered in more detail in the following sections. Table 3-1summarizes the relative risk and sensitivity of the primary reaches of each of the jetties.

Table 3-1. Relative Sensitivity and Importance of Jetty Reaches

(for all categories, "High" indicates sensitivity and higher risk and "Low" indicates non-sensitivity and lower risk)

	Construction Accessibility[1]	**Degree of Annual Loading[2]**	**Impacts of Failure[3]**
North Jetty			
20 to 50	Low	Low	Low
50 to 90	Medium	Medium	High
90 to 122	High	High	High
South Jetty			
150 to 200	Low	Low	Low
200 to 250	Medium	Medium	Medium
250 to 300	High	High	Medium
300 to 375	High	High	High
Jetty A			
40 to 60	Medium	Low	Low
60 to 80	Medium	Medium	Medium
80 to 97	High	Medium	High

[1]***Construction Accessibility*** *– The ability to mobilize quickly to the failure area and execute a repair action. Rated on sensitivity, i.e.* ***High*** *= not easily accessible,* ***Medium*** *= accessible under some conditions at reduced production rates,* ***Low*** *= easily accessible to achieve a repair.*
[2]***Degree of Annual Loading*** *– The degree of annual loading indicates the magnitude of loading and the potential for multiple loading directions. Rated on sensitivity, i.e.* ***High*** *= high magnitude and/or frequent and multiple loading directions,* ***Medium*** *= moderate magnitude of loading and some cases of multiple loading directions,* ***Low*** *= low magnitude and little potential for multiple loading directions.*
[3]***Impacts of Failure*** *– Potential for high impacts upon failure either structurally or regarding sediment movement. Rated on sensitivity, i.e.* ***High*** *= high impact on rest of structure or other structures, potential for significant increased dredging,* ***Medium*** *= moderate impact on rest of structure or other structures, potential for moderate increased dredging,* ***Low*** *= low impact on rest of structure and little impact on dredging.*

3.4. POTENTIAL CONSEQUENCES OF JETTY FAILURE

3.4.1. Systematic Jetty Performance and Impacts

In an aerial sense, a jetty consists of three parts (Figure 3-12). The head is the seaward terminus and is exposed to the most severe wave action. The trunk forms the connection from jetty head to subareal (subtidal) beach, retains subtidal shoals, and confines circulation within the inlet. The root forms the connection from the jetty trunk to shore and prevents accreted landforms from migrating into the inlet. Deterioration of a jetty's head, trunk, or root will have different impacts on the functionality of the structure and inlet. Stabilization of the jetty head is critical to long-term project function and maintenance. The most critical parts of a jetty in the short-term are the root and trunk. Appendix A1, Section 13 discusses each of these failure consequences further. The consequences of a breach at the North and South jetties and Jetty A were discussed in Section 1.6.

The head performs as a type of anchor for all of the components of the navigation entrance, serving to protect the landward portion of the jetty structure, the configuration of the underwater shoals and the adjacent shoreline position, the location and configuration of the seaward-most part of the navigation channel, and finally the overall ebb tidal shoal. Omission of stabilization of the jetty head in any long-term maintenance or rehabilitation plan would introduce a higher level of uncertainty regarding maintenance funding (jetty repair and dredging), as well as projected performance of the navigation entrance.

The jetty root (trunk) retains the subareal part of a shoal that would otherwise encroach upon the navigation channel. A breach at the root or trunk would release the tidal shoal and result in rapid in-filling of the navigation channel. Additional complications resulting from a breached jetty root (or trunk) include reduced hydraulic efficiency of the inlet, destabilization of the remaining jetty foundation, and severe shoreline erosion within or outside of the inlet.

Figure 3-12. North Jetty, View to the North

General components of a coastal jetty and damage consequences. Jetty head recession leads to progressive loss of jetty function which can impact inlet dredging requirements and stability of other jetty areas. Cumulative jetty trunk damage can result in a trunk breach which can have functional consequences on the inlet. Cumulative jetty root damage can result in a root breach which can have serious functional consequences on the inlet. Note plume of suspended sediment transported past the jetty head and into the MCR inlet.

In some instances, a jetty segment may be damaged at such a high rate as to fail before timely repair can be implemented. A given jetty segment is assumed to lose function when the upper cross-section area has been reduced to less than 15 ±5% of the original standard upper cross-section. If a jetty segment fails within the body of the jetty, the segment is considered breached. If the breached segment was acting to retain the inlet's morphology, the failed segment may release a large volume of sand into the inlet which has the potential to impact MCR navigation. Figure 3-13 and Figure 3-14 show an example of a breached jetty at a smaller navigation entrance and the resulting adjacent shoreline sediment loss. Figure 3-15 through Figure 3-16 illustrate various navigation entrance impacts subsequent to different areas of jetty failure.

Figure 3-13. Example of a Breached Jetty

Figure 3-14. Adjacent Shoreline Response to Jetty Breach

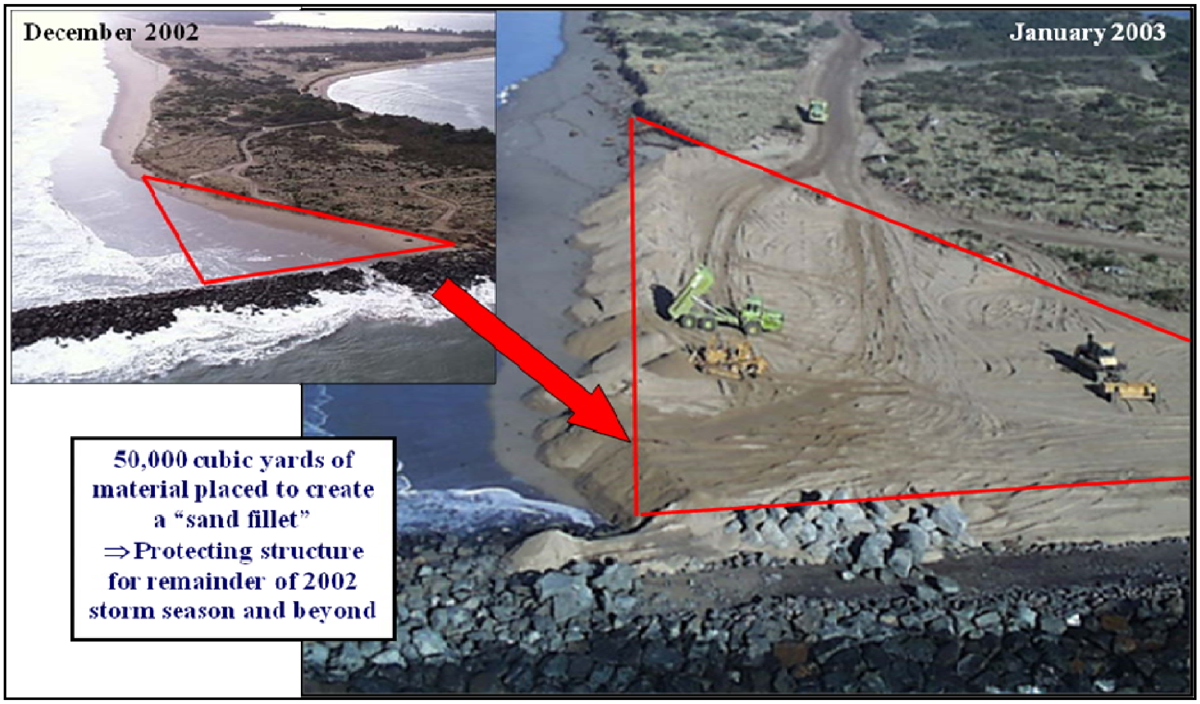
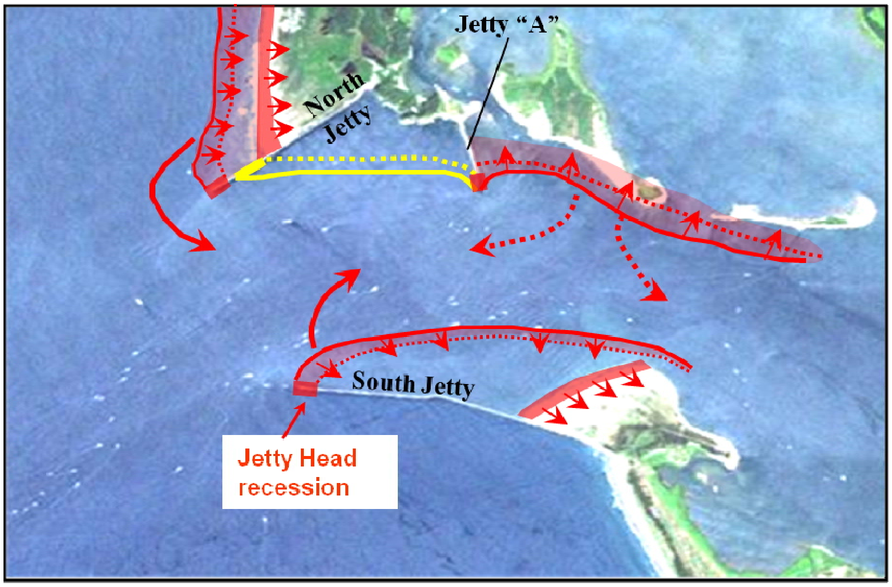


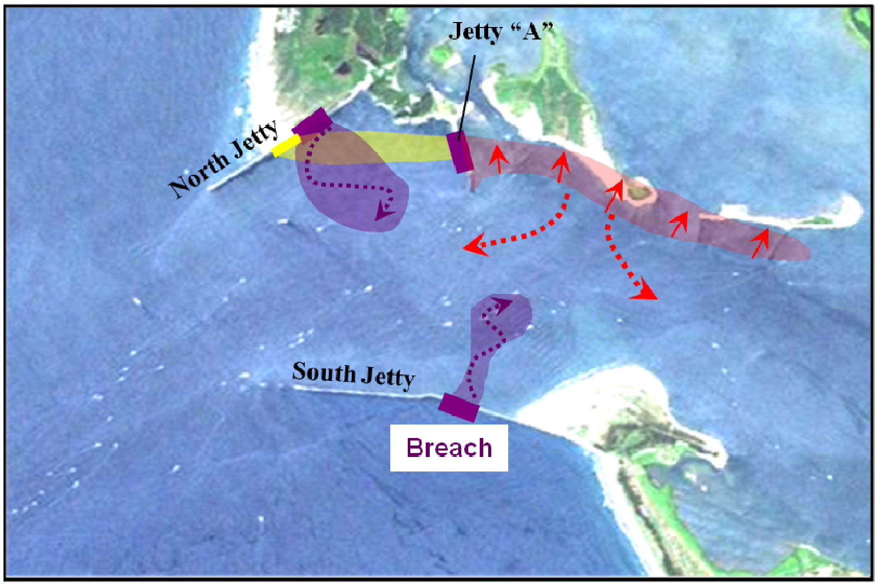
Figure 3-15. Response to Jetty Head Recession



As a jetty head recedes landward, sand from the retained morphology is released and transported past the receding jetty and deposits in the navigation channel. The bathymetry deepens adjacent to the jetty and the morphology recedes, exposing the jetty to increased wave action. Head recession at Jetty A exposes the North Jetty to increased scour.

Enhanced rip currents form along the jetties acting to erode the jetty foundation (dotted line) and motivate continual loss of morphology adjacent to roots of the jetties, exposing the jetty foundation of each jetty to increased wave action and scour. Much of the eroded sediment is tranported into the MCR inlet.

Figure 3-16. Response to Jetty Breach



A jetty breach, if allowed to occur at the MCR would allow flow through the jetty and destabilize adjacent morphology. Elevated shoaling at the MCR would occur. Aggressive dredging may be required to maintain the MCR navigation channel and the jetty may require emergency repair. The distinction should be made between jetty damage and jetty failure and MCR project function failure. The primary function of the MCR project is to maintain the navigation channel for deep draft shipping. The secondary function evaluated in the structure rehabilitation effort is to significantly extend the life and reliability of the jetties in order to reliably maintain the primary function. Sub-categories addressed in order to accomplish the primary purpose included prevention of a significant breach to the jetties, minimizing dredging of the channel, minimizing the frequency and magnitude of the required jetty repairs, and reducing the degradation rate of the jetties over time.

A jetty breach, if allowed to occur, would likely occur during winter (October through March) in response to storm waves. Due to the typically severe weather conditions at the MCR during winter months, emergency jetty repairs (to fill the breach) and/or emergency dredging activities (to maintain the navigation channel) may not be possible or may only be possible at a reduced rate, with the end result potentially being impacts to navigation until the actions can be completed. Jetty repairs are expensive and due to the sheer size of the structures usually include high costs of mobilization. Because these jetties are typically repaired from the top of the structure (especially during winter months), construction of a haul road is required for each jetty repair effort. In addition, there are some areas along the seaward half of the North and South jetties for which emergency jetty repairs during the winter months could not be conducted, due to the exposure of the construction site to overtopping wave conditions.

The degree of navigation impact motivated by a breached segment is dictated by how many neighboring segments breach, the volume of shoaling that could be mobilized into the inlet, and the proximity of the breached segment(s) to the navigation channel. In the analysis of the MCR project, a breach of the North Jetty is expected to be a more serious threat to the primary function of the project.

This is due to its proximity to the navigation channel, as well as its current function of holding back Peacock Spit from encroachment into the channel. If this scenario occurs, impacts to navigation are quite likely.

3.5. Engineering Approach

The engineering analysis of the potential rehabilitation plans covered two primary areas: (1) jetty cross-section repair, and (2) engineering features which address larger process deterioration of the jetty structures. Tools used for design analysis in this study included historical performance at the MCR, other case studies, two-dimensional physical modeling, hydrodynamic numerical modeling, and life-cycle performance analysis. The South Jetty and Jetty A were evaluated for cross section repair options, spur groins to reduce jetty scour, and jetty head reconstruction as shown in the figures. The North Jetty was evaluated for cross section repair options, spur groins to reduce jetty scour, stabilization of backfill area along the jetty root and jetty head reconstruction.

3.5.1. Delineation of Structure Design Reaches

Utilizing the design climate for each jetty structure, the existing condition of each structure, and the identified potential process impacts along each jetty length, the key design reaches for each jetty are shown in the figures and tables in the following subsections. The basic categories of design concern can be grouped into the following categories:

- Front-slope wave attack;
- Back-slope overtopping wave attack;
- Foundation loss;
- Adjacent shoreline recession; and
- Backside foundation loss.

3.5.1.1. North Jetty Design Reaches

The North Jetty is divided into five reaches (Figure 3-18 and Table 3-2). The different design reaches are used in the composite design cross-sections to engineer the size of the armor stone to the requirements of the reach. Half of the jetty is backed by accreted land on the north side. The seaward half of the jetty, while it does not have land behind it, is also backed by the substantial underwater shoal in the form of Peacock Spit. The North Jetty, as well as its significant submerged jetty head, functions to hold back this significant shoal from the navigation channel. These features can be clearly seen in Figure 3-18. Benson Beach is located on the north side of the jetty at the transition between above and below water features of the spit. Also visible in Figure 3-18 are the deepening contours on the channel-side of the jetty and the lagoon located on the North side of reach 1 and reach 2 that is considered for repair in the maintenance report; lagoon fill is part of the base condition for this rehabilitation study. Each of the North Jetty design reaches is further described in Appendix A1, Section 8.

Figure 3-17. North Jetty Design Reaches and Adjacent Bathymetry

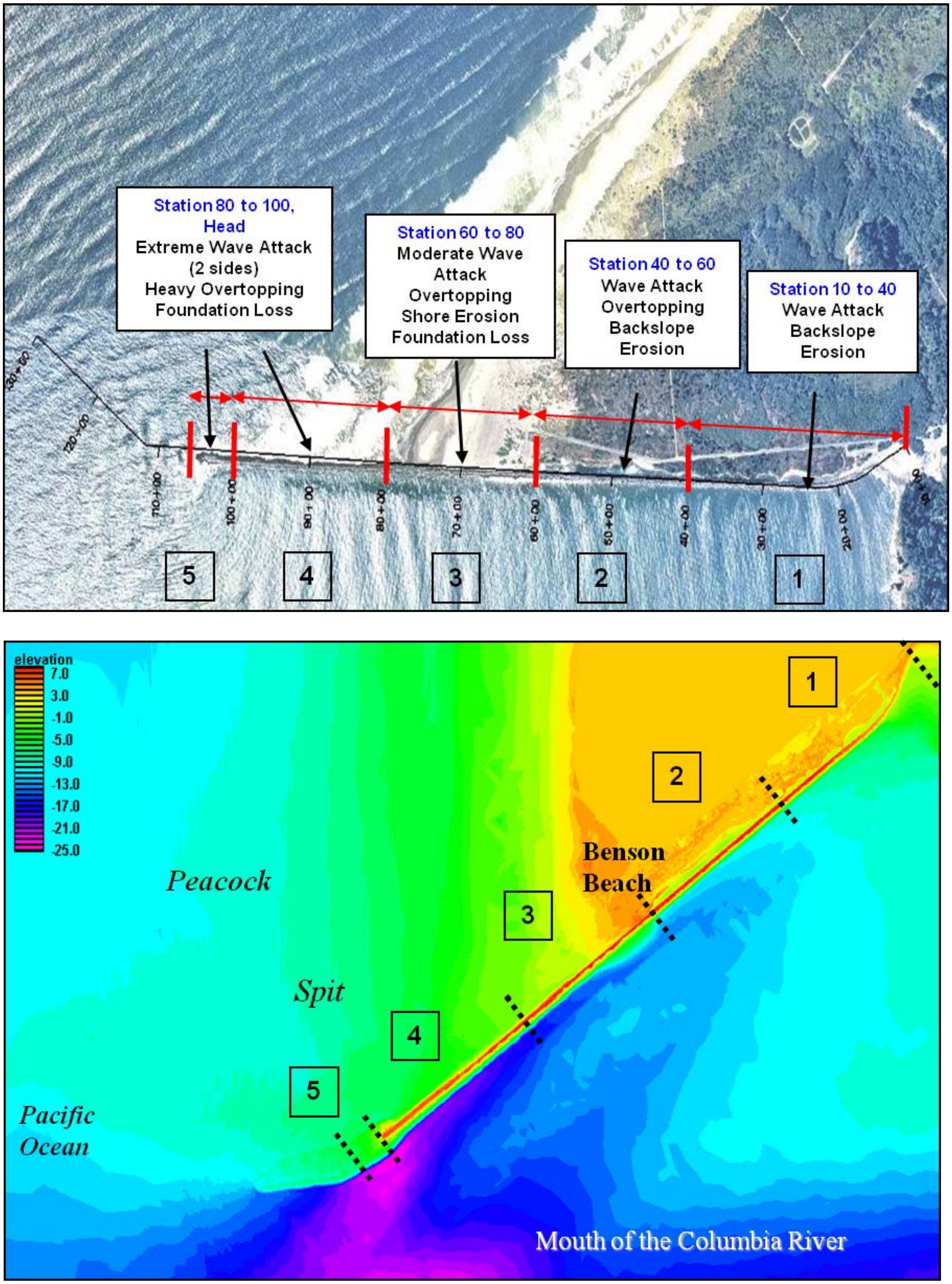


Table 3-2. North Jetty Design Input Parameters

Reach/ Stations	Crest Elevation (ft, MLLW)	Crest Width (ft)	Design Wave Height (ft)		Depth at Toe (ft, MLLW)		Design Issue
			Ocean	Channel	Ocean	Channel	
Reach 1 (Stations 10 to 40)	15 to 25	10 to 30	0	10 to 14	+4 to +15	-10 to -20	Minor frontslope wave attack (1), Backside foundation
Reach 2 (Stations 40 to 60)	20 to 27	10 to 30	0	14 to 17	+3 to +11	-9 to -13	Moderate frontslope wave attack (1), overtopping (1), Backside foundation
Reach 3 (Stations 60 to 80)	20 to 25	20 to 35	5 to 21	17 to 18	-1 to +15	-15 to -55	Moderate frontslope wave attack (2), overtopping (2), Foundation loss (1), Shore erosion
Reach 4 (Stations 80 to 100)	17 to 25	10 to 40	21 to 25	18 to 20	-2 to -15	-55 to -65	Extreme frontslope wave attack (2), Heavy overtopping (2), Foundation loss (1)
Reach 5 (Head)	19 to 20	15 to 40	26	20	-10 to -17	-65 to -75	Extreme frontslope wave attack (3), Heavy overtopping (3), Foundation Loss (3)

3.5.1.2. South Jetty Design Reaches

The South Jetty is divided into six reaches (Figure 3-19 and Table 3-3). Only the first reach of the South Jetty is backed by above-water accreted land. The remainder of the structure is exposed to environmental forces from both sides. The significant underwater shoal on the north side of the South Jetty provides protection both in terms of foundation stabilization and reduced wave height exposure. Although the South Jetty extends out into fairly deep water depths, the portion being evaluated for this rehabilitation effort is located shoreward of the greatest water depths. Each of the South Jetty design reaches is further described in Appendix A1, Section 8.

Figure 3-18. South Jetty Design Reaches and Adjacent Bathymetry

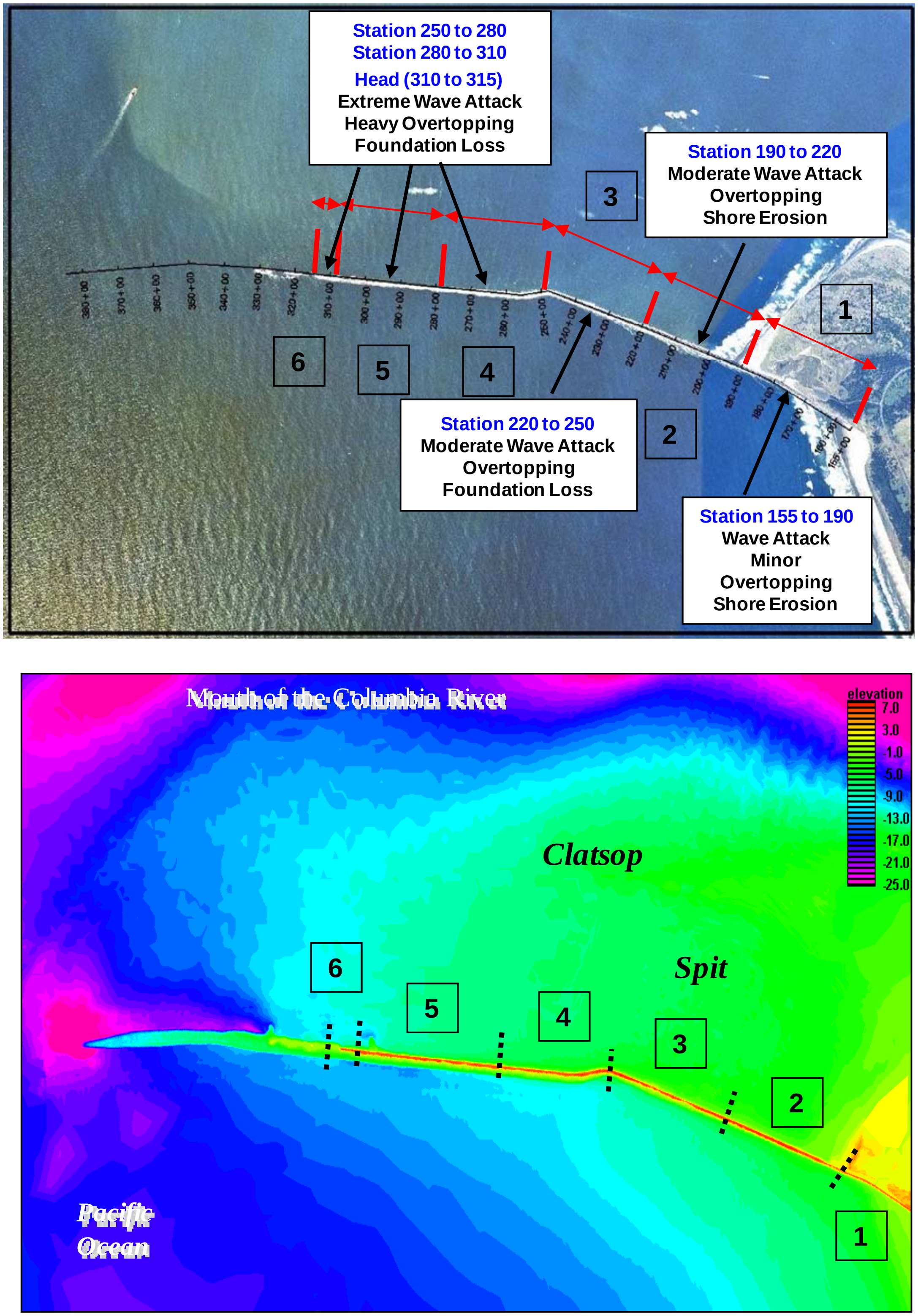


Table 3-3. South Jetty Design Input Parameters

Reach/ Stations	Crest Elevation (ft, MLLW)	Crest Width (ft)	Design Wave Height (ft)		Depth at Toe (ft, MLLW)		Design Issue
			Ocean	Channel	Ocean	Channel	
Reach 1 (Stations 155 to 190)	13 to 20	4 to 20	10 to 16	0	-2 to +15	+4 to +37	Minor frontslope wave attack (1), Minor overtopping (1), Shore erosion
Reach 2 (Stations 190 to 220)	14 to 25	4 to 37	16 to 25	16 to 18	-2 to -10	-4 to +4	Moderate frontslope wave attack (1), overtopping (1), Shore erosion
Reach 3 (Stations 220 to 250)	20 to 25	20 to 30	25 to 32	18 to 20	-10 to -22	-5 to -8	Moderate frontslope wave attack (1), overtopping (1), Foundation loss (1)
Reach 4 (Stations 250 to 280)	20 to 25	25 to 40	32 to 35	20 to 21	-23 to -32	-8 to -15	Extreme frontslope wave attack (2), Heavy overtopping (2), Foundation loss (2)
Reach 5 (Stations 280 to 310)	15 to 25	14 to 40	35 to 36	20 to 21	-32 to -39	-15 to -22	Extreme frontslope wave attack (2), Heavy overtopping (2), Foundation Loss (2)
Reach 6 (Head)	7 to 20	6 to 30	36	21	-33 to -39	-23 to -30	Extreme frontslope wave attack (3), Heavy overtopping (3), Foundation Loss (3)

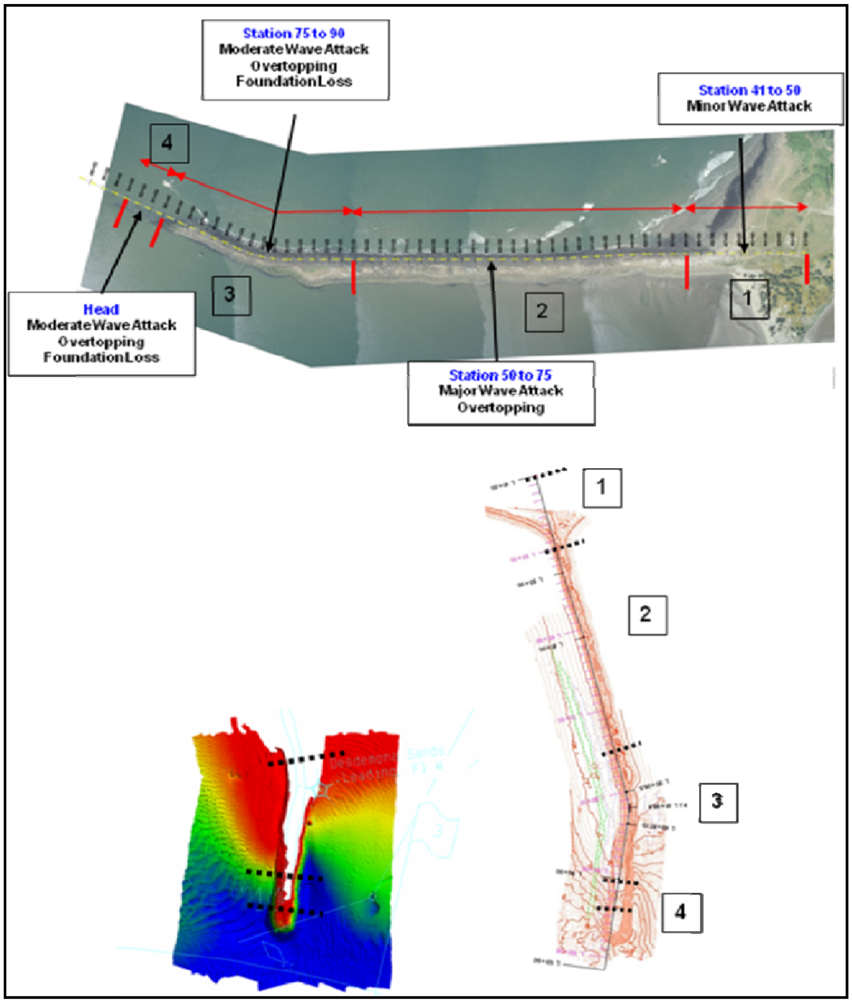
3.5.1.3. Jetty A Design Reaches

Jetty A is divided into four reaches (Figure 3-20 and Table 3-4). Jetty A was constructed as a very large spur groin directed perpendicularly into the Columbia River to help train the navigation channel away from the North Jetty foundation. While it is exposed to a lesser wave climate than the other two jetties, it has suffered severe scour at its southern tip that has contributed to its recession. In addition, wave modeling at the MCR entrance has identified an area of increased wave attack at the center part of the jetty length. Wave attack on Jetty A is limited to the ocean or western side of the structure. Similar to the other two jetties, Jetty A was constructed on top of a large underwater shoal, the continued erosion of which will undermine the structure, as is already evident on its southern end. Each of the Jetty A design reaches is further described in Appendix A1, Section 8.

Table 3-4. Jetty A Design Input Parameters

Reach/ Stations	Crest Elevation (ft, MLLW)	Crest Width (ft)	Design Wave Height (ft)		Depth at Toe (ft, MLLW)		Design Issue
			Ocean	Channel	Ocean	Channel	
Reach 1 (Stations 40 to 50)	20 to 22	40 to 50	5 to 11.5	0	+2 to +18	0 to +14	Minor frontslope wave attack (1)
Reach 2 (Stations 50 to 75)	20 to 25	20 to 50	11.5 to 22.5	3.5	0 to -8	0 to +2	Major fronstlope wave attack (1), Overtopping (1)
Reach 3 (Stations 75 to 90)	18 to 25	15 to 50	17 to 20	5.5	-8 to -20	0 to -75	Moderate frontslope wave attack (1), overtopping (1), Foundation loss (2)
Reach 4 (Head)	-2 to 20	NA	20	5.5	-15 to -50	-75 to -105	Moderate frontslope wave attack (1), Overtopping (1), Foundation loss (2)

Figure 3-19. Jetty A Design Reaches and Adjacent Bathymetry



3.5.2. Design of Jetty Repair Cross Section

3.5.2.1. Cross Section Intent and Design Philosophy

Cross section development for jetty repairs was guided by the following constraints.

- The repair cross-section must be cost-effective in terms of construction materials as well as quantity of material, to allow the maximum repair within funding limitations. Quarried stone is expected to be used for the majority of the work. The vast majority of the repair stone which will be needed for the jetty repair will be within the easily acquired stone size range. Quarried armor stone is available from numerous sources in the Pacific Northwest. Concrete armor units are considered as an option for only the most extreme part of each structure.

- The repair cross-section must be constructible. In order to limit potential impacts to the surrounding environment, the minimum modification to the jetty footprint is desirable.

- The jetty repair should be structurally consistent with the present jetty configuration and future rehabilitation scenarios. There should be no dissimilar attributes between the present jetty section and the repair cross-section. Areas of the jetty that are repaired, using the repair cross-section, must be able to be augmented later, if necessary. Each action taken should be directed toward improving the long-term reliability of the jetty system and its function to protect the navigation channel.

Historical performance of previous jetty designs, expected and feasible construction techniques, and existing structure configuration were considered when specifying structure design parameters. Table 1-2 through Table 1-4 summarize the design cross section history for the three jetties. Verification of evaluated design cross section elements in the project environment was conducted in the two-dimensional physical model. Due to the extreme wave climate along the northern Oregon Coast, the design of a rubble-mound structure to eliminate overtopping is infeasible. In addition, the crest width and to some extent the crest elevation for these structures is related to construction method. The current method of construction has necessitated a crest width that is wide enough to safely accommodate the necessary construction equipment. In addition, especially for the exposed area of construction, the crest elevation is required to be high enough for the equipment to be safely out of the wave attack area.

3.5.2.2. Design Cross Section Development

Design cross-section attributes are selected to minimize the cost of repairs while achieving sufficient stability and life-cycle restoration for each portion of the jetty. Due to the variability in design climate and repair history, alternatives vary between the three structures and along the length of each structure. Jetty cross-section options examined crest elevation, crest width, and side-slope adjustments. The location along the jetty alignment was important to the degree of robustness needed for each design parameter. In addition, for those jetty reaches where foundation stability was a concern, special designs were developed for the toe area of the cross section in order to stabilize the upper portion of the section over the long term. Above and below water adjustments were made in cross-section design to address both variability in design forcing and accuracy and expected method of construction.

Cross section cross-sections for graduated levels of cross-section design are provided in Appendix A1, Section 14.

3.5.2.3. Two-dimensional Physical Model Study

Two-dimensional physical modeling was used to assess and fine tune the cross-section designs, and then each cross section was tested for long-term reliability in the life-cycle model used for this rehabilitation study (the design input parameters are shown in Tables 3-2, 3-3 and 3-4).

The primary failure modes impacting cross-section design vary along each structure but are generally believed to be a combination of one or more of the following: (1) armor instability due to direct wave impact, (2) armor instability due to overtopping, (3) scour de-stabilization of toe, and (4) static instability of underwater slope. The primary issues from the structural design perspective include: (1) technical viability given the condition of the existing structures and the Pacific Ocean environment, (2) risk and/or robustness of design to achieve a minimum 50-year life under extreme annual loading, and (3) reliable constructability of design.

The USACE Engineering Research and Development Center in Vicksburg, Mississippi was contracted to conduct a two-dimensional physical model of the jetty cross-section design. The range of structural repair types addressed in the model included crest elevation and crest widths variations, side-slope variations, underwater berms, armor stone, and concrete armor unit options. The purpose for the two-dimensional physical model was three-fold:

1. Assist in defining damage initiation and damage progression relationships (damage function) for existing condition and evaluated alternatives to feed into a reliability analysis of the three structures.
2. Conduct a qualitative screening of a wide range of alternatives that will bracket potential structural and material-type options that could be applied on the three structures.
3. Assist in cross section optimization and material type design for the range of alternatives to be assessed in the rehabilitation study.

Both the North and South jetties were tested under low and high water conditions. Incident wave heights up to 35 feet were applied to the jetty cross sections. Armor units tested included quarry stone and dolos concrete armor units. An additional concrete armor unit was tested called a c-roc. More information on the c-roc can be found in Appendix A1. The c-roc armor unit more closely resembles a large rock with interlocking members. Due to its rock-like configuration, it is expected to be less fragile than concrete armor units which have thinner flange-like elements.

Existing condition and potential design alternative cross sections were modeled. The physical model testing of the jetty cross section resulted in a range of graduated design options that achieve varying levels of structure reliability. These design options were carried forward into the life-cycle analysis model of the jetty system. The general categories of plans tested in the physical model included in graduated levels of robustness:

- Existing jetty cross section;
- Interim repair cross section;
- Minimum repair cross section;
- Increased slope and increased toe berm;
- Extended slope cross section;
- Combination berm/side-slope cross sections; and
- Increased crest elevation cross section.

Physical modeling results showed that the primary failure modes for the North and South jetties were high water level wave attack and overtopping. Individual results are summarized below.

1. Armor unit assessment:
   - The majority of the North Jetty can be reliably designed using attainable rock. The seaward head of jetty may require advanced design combination approach.
   - Dolos concrete armor units did not hold up well in the tests. Very flat slopes would be needed to make this armor unit viable.
   - C-roc appeared to hold up well during preliminary testing (concerns regarding c-roc include reliability of one-layer system, not field-tested, elaborate construction control requirements, and uncertainty about interlocking with relic base).
2. Cross section element assessment (preliminary):
   - Heavy overtopping may require special crest and leeside design in some areas.
   - Large toe berm is not needed on the south jetty due to the existing relic stone base.
   - Side slopes from 2h:1v to 3h:1v provide reliable section designs.
3. Damage relationship information is used in the reliability analysis:
   - Existing and Interim damage relationships define base condition.
   - Various alternative damage relationships define alternative reliability.
   - Alternative information interpolated for design based on position on jetty.

Detailed information on each jetty's cross-section design parameters is located in Appendix A1.

3.5.2.4. Graduated Levels of Jetty Cross-section Design

The physical model results, discussed in the previous section, were used to develop a series of design options. These options were run through the SRB Model to identify the most efficient and cost effective design (see Table 1.1 for construction history).

In the following jetty cross-sections (Figure 3-20 through Figure 3-22), the light brown represents sand foundation or land, the dark brown represents existing relic stone (existing rock structure from earlier construction efforts), and the light blue represents new cross section and new rock under evaluation. The border around each cross section is also color coded (pink, yellow, blue, black) to help describe the composite cross section.

Jetty Head Cross Section. The jetty head cross section stays constant regardless of the cross section applied along the trunk of a jetty. All jetty caps are very substantial features designed to withstand wave attack from three sides and significant overtopping forces. Note that primarily to control costs, all of the jetty head cross-sections are designed to be constructed on top of the existing relic stone base.

Minimum Cross-section and Scheduled Repair Cross Section. This cross section rehabilitates both jetties along their current length using a minimum cross section that extends above the waterline and lies essentially within the existing jetty footprint.

Small Cross-section Cross Section. This cross section was only considered for the South Jetty and Jetty A because the minimum and small cross-sections were essentially the same for the North Jetty. This cross section rehabilitates the South Jetty along its current length using a small cross section that only extends above the waterline; however, it is not constrained to fit within the existing footprint of the jetty.

Moderate Cross-section Cross Section. This cross section was considered for the North and South jetties and rehabilitates both jetties along their current lengths using a moderate cross section that encases the existing jetty both above and below the waterline and extends beyond the existing footprint.

Large Cross-section Cross Section. This cross section was considered for the North and South jetties and rehabilitates both jetties along their current length using a large cross section that encases the existing jetties both above and below the waterline, and also places a stabilizing toe berm along key reaches of each structure. The cross section would extend outside of the existing jetty footprint.

Composite Cross Section. This could entail any combination of the above cross-section types tailored to address structure concerns along specific jetty reach sections. Up to four cross sections could be used together over the length of a jetty to make a composite plan.

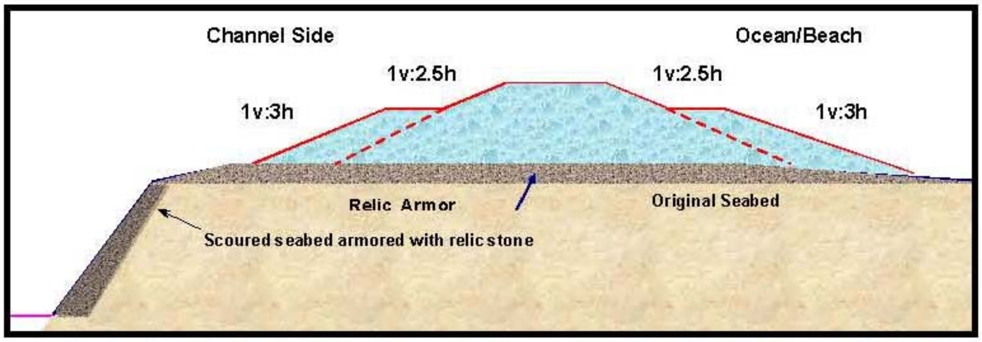
Figure 3-20 through Figure 3-22 are intended to be generic examples of the cross-section types. It is important to realize that the particular cross-section/cross section shown (and the relic stone base it is constructed on) will vary along the full length of each structure.

The top sketch in Figure 3-21 and Figure 3-22 shows the minimum cross-section or scheduled repair approach to the rehabilitation which does not require as much rework of the relic stone as the larger, more substantial designs. The figure showing the minimum cross-section is trying to convey that the repairs conducted will just build off of the existing relic configuration as much as possible. No attempt will be made to modify the back slope for additional stability in that area. The moderate and large cross-sections are more substantial and comprehensive design cross-sections requiring more re-work, more stone, and a larger area of placement.

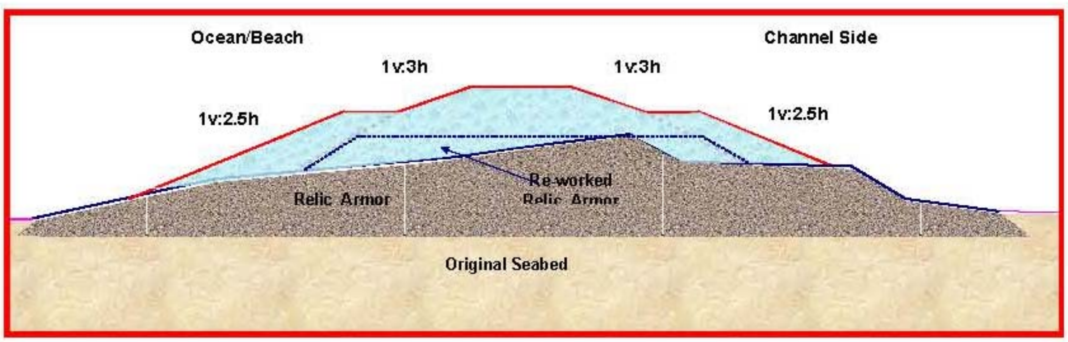
The large cross-section for the North Jetty does not show the gravel and sand area on the backside because, in general, for most of the alternative where this cross-section is used, it is seaward of the lagoon fill area that requires the sand and gravel backfill. The horizontal red lines in the cross sections indicate transitions to different stone sizes within the cross section.

Figure 3-20. Jetty Head Cross-sections

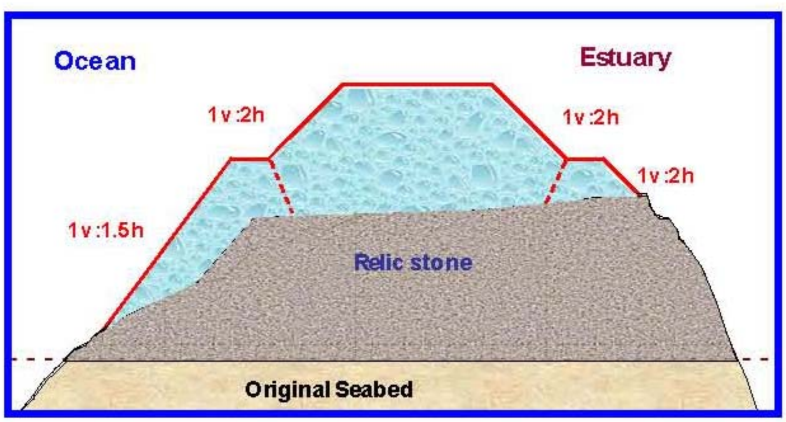
Light brown represents sand foundation or land, the dark brown represents existing relic stone, and light blue represents new cross section and new rock under evaluation. The border around each cross section is also color coded (pink, yellow, blue, black) to help describe the composite cross section.



North Jetty Head Template



South Jetty Head Template



Jetty A Head Template

Figure 3-21. North Jetty and Jetty A Conceptual Cross-sections

Light brown represents sand foundation or land, the dark brown represents existing relic stone, and light blue represents new cross section and new rock under evaluation. The border around each cross section is also color coded (pink, yellow, blue, black) to help describe the composite cross section.

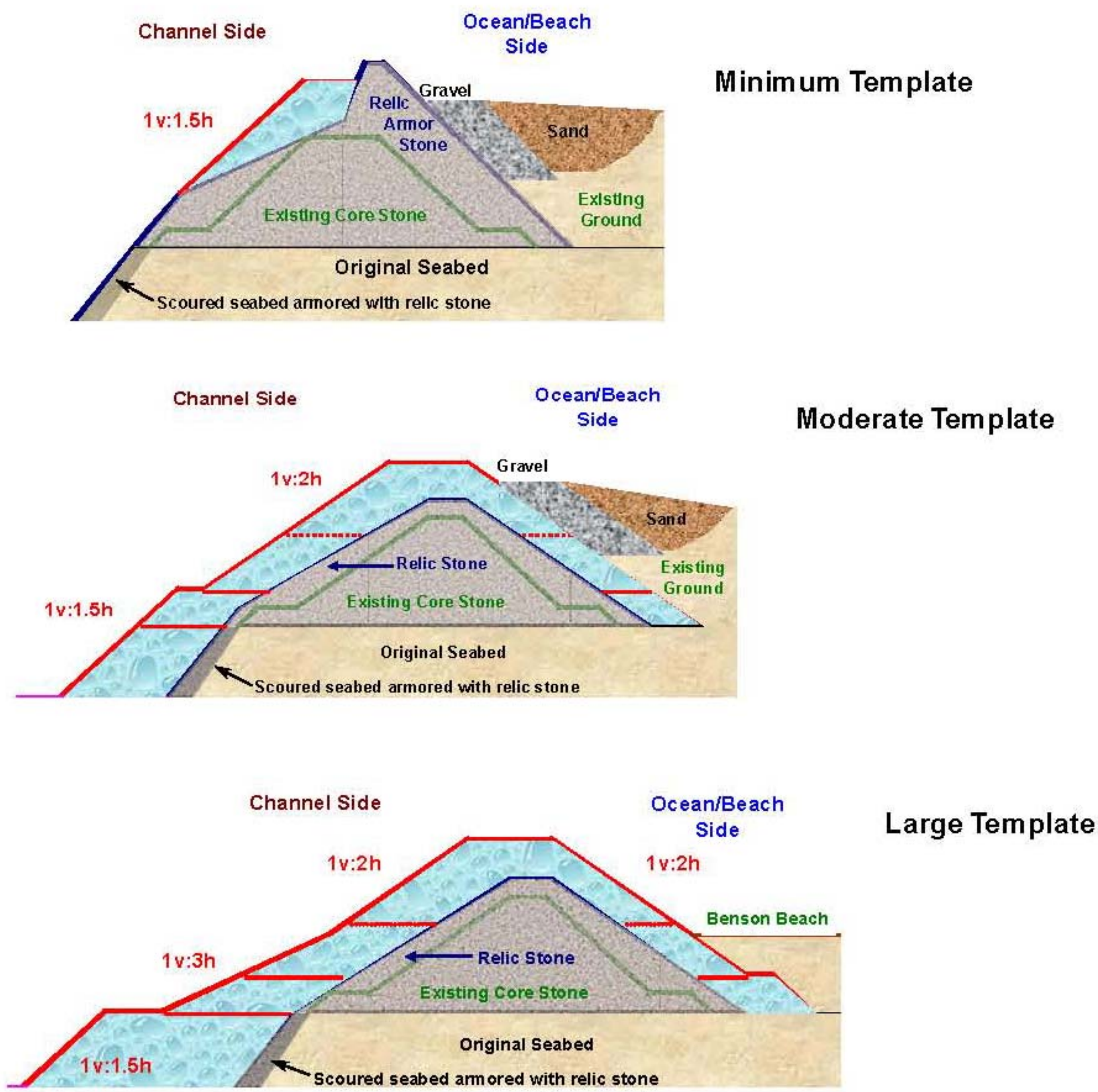
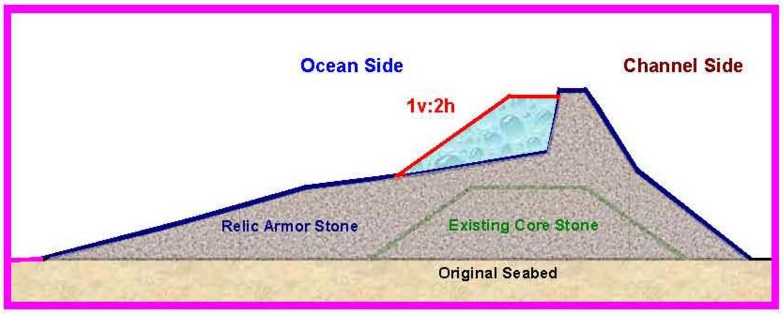
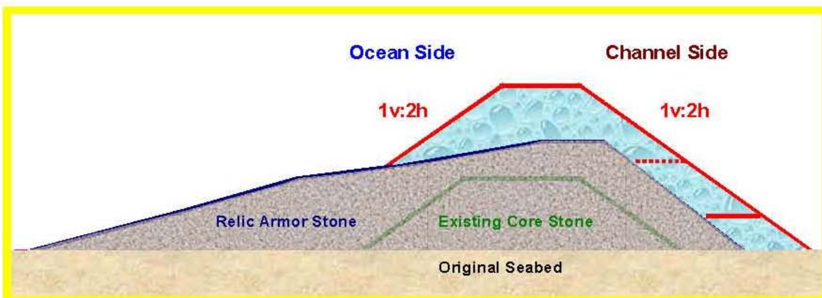


Figure 3-22. South Jetty Conceptual Cross-sections

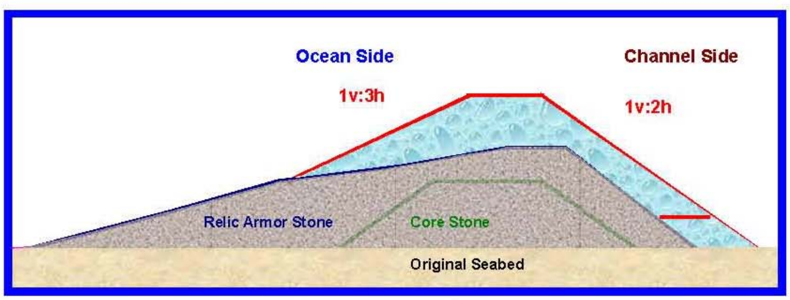
Light brown represents sand foundation or land, the dark brown represents existing relic stone, and light blue represents new cross section and new rock under evaluation. The border around each cross section is also color coded (pink, yellow, blue, black) to help describe the composite cross section.



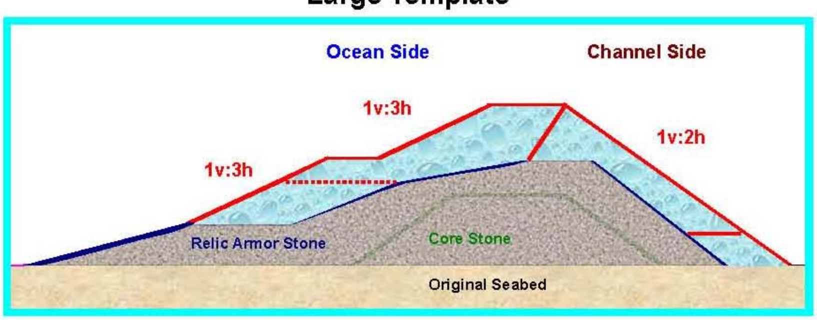
Minimum Template



Moderate Template



Large Template



Largest Template

3.5.2.5. Structural Performance Modes for a Rubble-mound Jetty

Structural performance modes for a rubble-mound jetty can be characterized in terms of its ability to remain stable during wave attack (dynamic stability), and to maintain a stable footprint/slope configuration on the seabed foundation (static stability). These performance modes are described below and are shown conceptually as failure modes in Figure 3-24 and Figure 3-25. Jetty structure reliability can be separated into above and below water areas controlled essentially by wave-driven and erosion-driven processes. An effective and long-term rehabilitation effort needs to address both sets of damage processes.

Dynamic stability affects the upper part of a jetty cross-section as a result of wave action, generally from -5 feet and up to the jetty crest, on the ocean side and channel side of a jetty. On the side of the jetty directly exposed to ocean waves, dynamic stability is manifest by the direct impact of waves on the jetty and the resultant displacement of individual armor units. On the lee side of the jetty, dynamic stability addresses the effect of waves overtopping the jetty crest and displacing armor units down-slope, off of the jetty cross section.

Static stability affects the lower part of the jetty cross-section, generally below -5 feet on the ocean side and channel side of the jetty. Static stability addresses the susceptibility of the jetty toe to wave-current scour, and resistance of the jetty slope to sliding down grade along a slip-plane. Damage due to static stability issues propagates up-slope to affect the upper region of the jetty cross section.

3.5.3. **Engineering Features**

The second phase of the study investigated and evaluated actions to address the larger system-based degradation processes that impact the project as a whole and over the long term. Engineering features included jetty head stabilization through a robust head construction, construction of spur groins at key locations along each jetty to promote foundation stabilization, and lagoon fill behind the North Jetty root. These features were evaluated individually and incrementally in the life-cycle model using the minimum cross section repair plan and are discussed below.

3.5.3.1. Spur Groins

In areas where foundation scour threatens the overall jetty stability, spur groins were considered in some alternatives. If constructed, the spur groins would be perpendicular to the jetty to facilitate stabilization via accumulation of sediment along the jetty foundation. Historical experience and numerical modeling were used to select the type, depth, and length of spur groin necessary to impact the processes causing increased scour at each jetty (e.g., rip currents, eddies). A range of information was utilized in developing a set of possible spur groin applications along the MCR jetties. Furthermore, one set of alternative plans was evaluated within the framework of trying to specify the lowest impact spur groin layouts (size and number of spurs) suitable to achieving the intended long-term stability purpose of the structures. Information utilized included knowledge of problem erosion areas along the three primary jetties, experience of spur groin application at the South Jetty and Yaquina South Jetty, observation of jetty relic stone wing impacts on shoreward sedimentation, other spur groin studies, and numerical hydrodynamic modeling. The effectiveness of the spur groins is evaluated in the model and compared using average annual costs to decide whether it’s more effective to have higher up-front costs by constructing them, or repeated maintenance in those areas to secure the foundation on the jetty trunks without them.

Figure 3-23. Jetty Performance Modes for Dynamic Stability

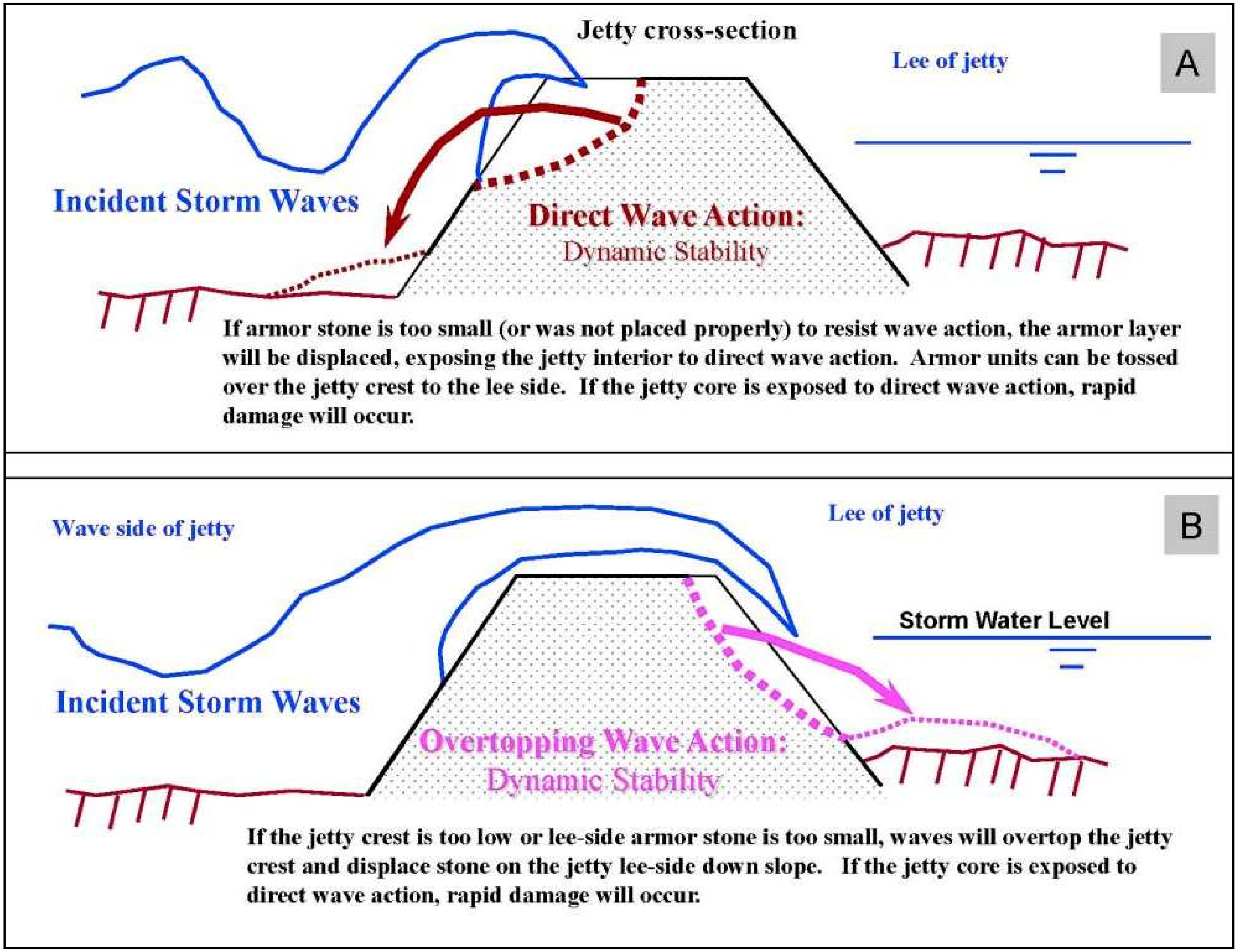
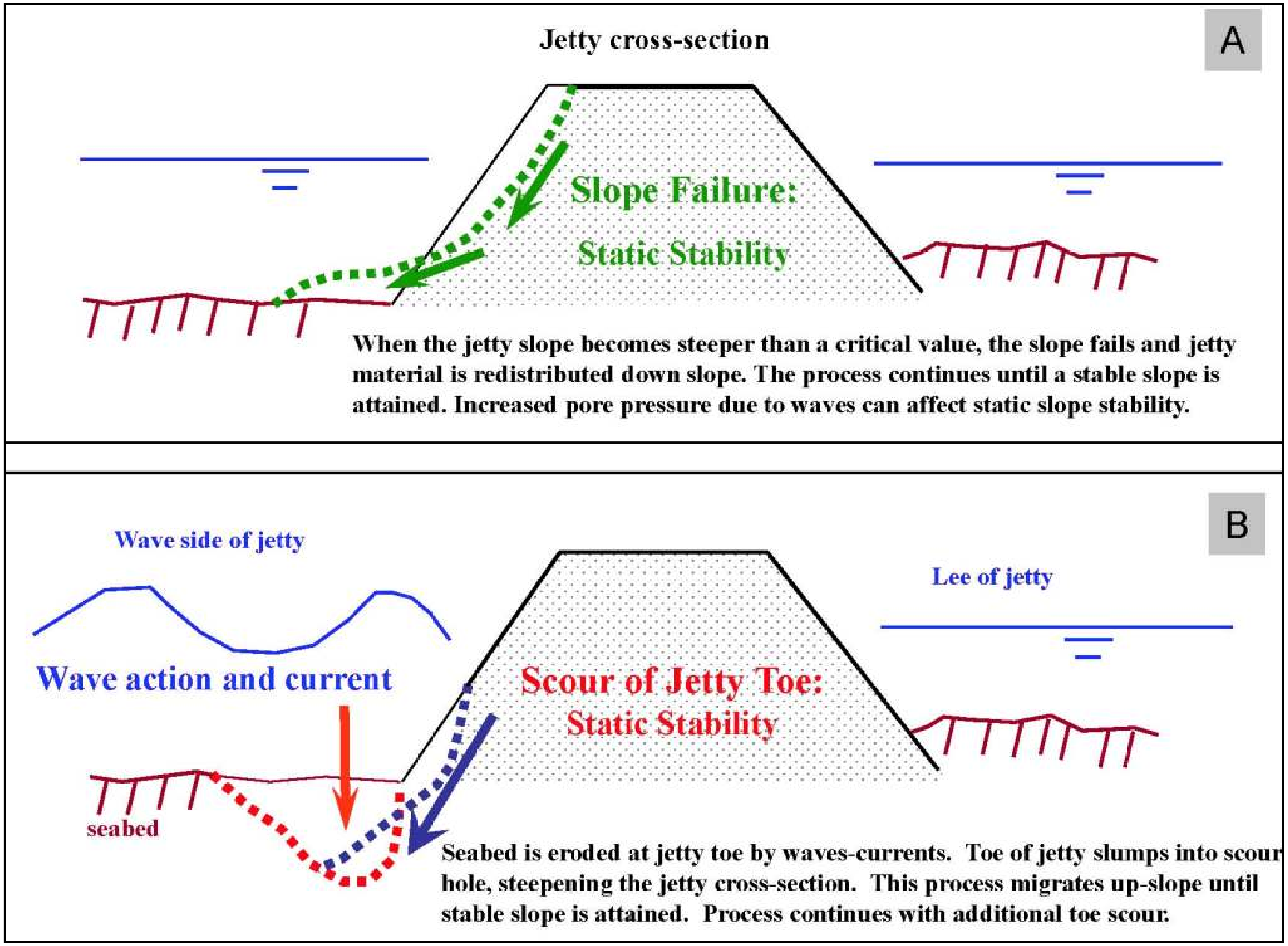


Figure 3-24. Jetty Performance Modes for Static Stability



A jetty spur or spur groin is a relatively short structure (in comparison to jetty length) extending outward from the main axis of a jetty. Spur groins are constructed for a range of reasons dealing with the need to effect currents and sediment transport along the jetty. There are two prominent reasons why spurs are implemented:

1. On the ocean or beach side of a jetty to deflect the long-shore (rip) current and related littoral sediment away from the jetty and prevent littoral sediment from entering the navigation channel (Figure 3-24 and Figure 3-25 illustrate how jetty length recession can also impact shore tie-in erosion conditions).
2. On the channel side of a jetty to divert the tidal or river current away from the channel side toe of the jetty. In this application, spur(s) act to reduce the scour affecting the jetty's foundation, while increasing the current in the navigation channel and thus reducing the deposition in the channel.

The Engineering Research and Development Center (ERDC) analyzed the hydrodynamics and circulation patterns in the MCR entrance, as well as the potential impacts and effectiveness of placing spur groins on the jetties. This analysis was conducted with the coastal modeling system and other models to select the type, depth, and length of spur groins necessary to protect each jetty from the processes causing increased scour (e.g., rip currents, eddies). Each spur groin will have a crest width of about 20 feet and will be constructed using a bedding layer (mixture of gravel and rock) that will be covered with large stone sized for the location and exposure.

Potential locations for jetty spurs were evaluated based on calculated peak ebb and flood currents as simulated with the regional-scale, two-dimensional CMS model. In addition, the length of each of the spur groins was optimized based on the water depth at its evaluated location (i.e., a shallower depth requires a shorter spur groin to have a positive impact). The final approximate location of the spur groins evaluated can be seen on Figure 3-26. A typical spur groin for the North Jetty is shown in Figure 3-27. Table 3-5 summarizes the characteristics for the spur groins evaluated for each MCR jetty. More information on spur groin evaluation can be found in Appendix A1, Section 11.

Figure 3-25. Approximate Locations for evaluated Spur Groins along Each Jetty (one set of alternatives)

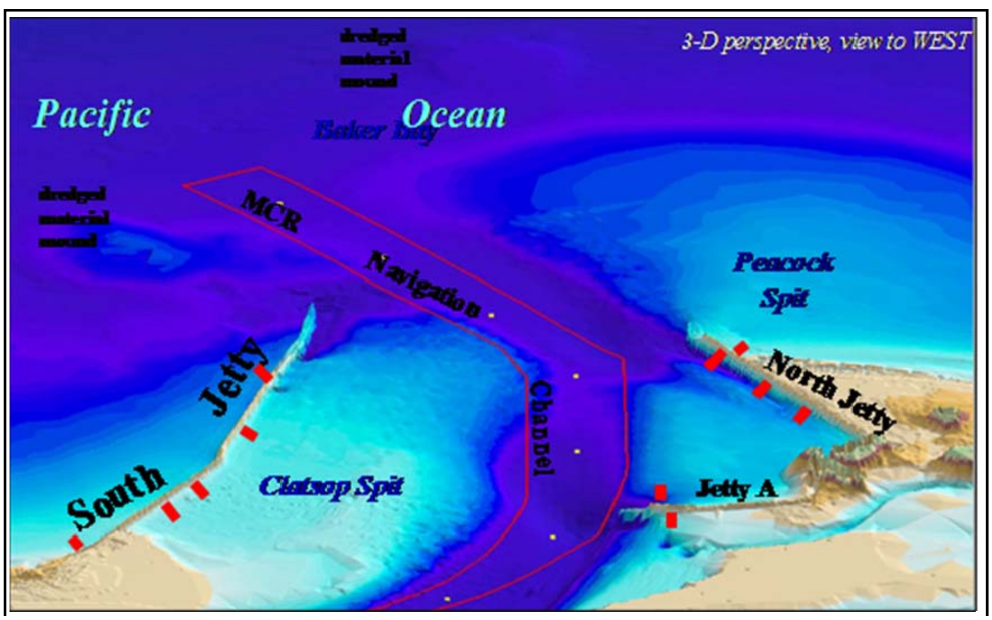


Figure 3-26. Typical Spur Groins along the Channel Side of the North Jetty

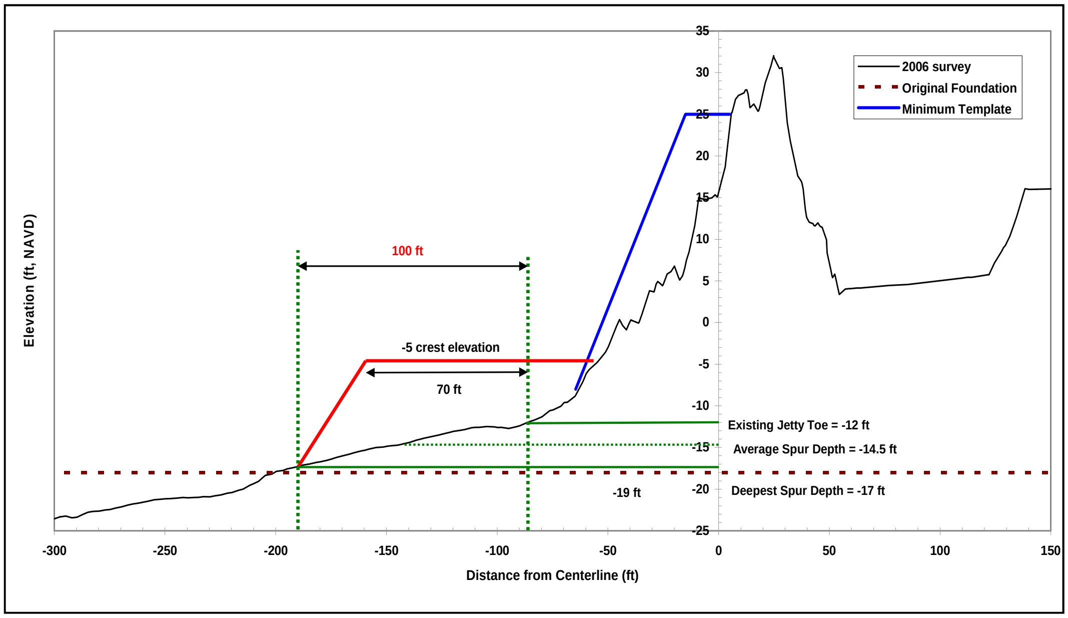


Table 3-5. Characteristics for the Spur Groins Evaluated

Features	North Jetty	South Jetty	Jetty A
Number of spurs on channel side, or downstream for Jetty A	3	3	1
Number of spurs on ocean side, or upstream for Jetty A	1	2	1
Total rock volume per spur	NJ1C: 3,350 tons NJ2C: 11,090 tons NJ3O: 2,010 tons NJ4C: 29,250 tons?	SJ1O: 1,680 tons SJ2C: 2,350 tons SJ3C: 2,350 tons SJ4C: 3,180 tons SJ5O: 18,750 tons	JA1C: 9,650 tons JA2O: 7,330 tons
Total rock volume (all spurs)	45,700 tons	28,310 tons	16,980 tons
Area affected by each spur	NJ1C: 0.18 acres NJ2C: 0.45 acres NJ3O: 0.11 acres NJ4C: 0.80 acres	SJ1O: 0.11 acres SJ2C: 0.13 acres SJ3C: 0.13 acres SJ4C: 0.19 acres SJ5O: 0.55 acres	JA1C: 0.33 acres JA2O: 0.29 acres
Total area affected (all spurs)	1.55 acres	1.10 acres	0.61 acres
Area of spurs above water	NJ1C: 0% NJ2C: 0% NJ3O: 24% NJ4C: 0%	SJ1O: 29% SJ2C: 7% SJ3C: 7% SJ4C: 0% SJ5O: 0%	JA1C: 0% JA2O: 0%
Area of spurs below -20 MLLW	NJ1C: 0% NJ2C: 88% NJ3O: 0% NJ4C: 100%	SJ1O: 0% SJ2C: 0% SJ3C: 0% SJ4C: 0% SJ5O: 92%	JA1C: 1% JA2O: 0%
Dimension of spurs: length x width x height (feet)	NJ1C: 100 x 80 x 10 NJ2C: 170 x 115 x 19 NJ3O: 60 x 80 x 10 NJ4C: 170 x 115 x 19	SJ1O: 60 x 80 x 9 SJ2C: 70 x 80 x 10 SJ3C: 70 x 80 x 10 SJ4C: 90 x 90 x 12 SJ5O: 190 x 125 x 22	JA1C: 135 x 105 x 18 JA2O: 125 x 100 x 15

Two potential construction methods could be used for spur groins, either land-based or marine-based depending on location. Barges or similar equipment could be used to dump the bedding layer rock into place and a clamshell would be used to place larger stone on top of the bedding rock layer in locations with sufficient water depth. Material could also be placed using land-based equipment from on top of the jetty. Land-based construction may require a wide turnout crane placement with over-excavation down to grade as the crane walks back onto the main jetty axis. In addition, the emergent spur groins may be used as turnouts for construction equipment. The land-based construction method could be used for all but the deepest spur groins. See Section 12 of Appendix A1 for a detailed explanation and discussion of the modeling and results.

3.5.3.2. Jetty Head Stabilization and Rebuild

As stated earlier, jetty length recession has various consequences to the stability of the structures and the MCR jetty project. Investigations examining the reconstruction of jetty length focused primarily on maintaining the underwater and adjacent shoals which have proven to be critical for controlling the impinging wave climate and maintaining the current length to provide effective control of sediment movement into the navigation channel. Increased lengths were investigated to determine if those might provide a more sustainable project over the long term.

The U.S. Geological Survey (USGS) Menlo Park assisted the USACE with evaluating potential improvements and impacts of jetty head rebuilds evaluated. The USGS efforts focused on using the Delft-3D model to identify potential changes in circulation, salinity and sediment transport that could result from the offshore re-build of the three jetties. (See section 12. C. Appendix A1)

Based on the several constraints (see discussion in Section 11 of Appendix A1), the rebuild of the South Jetty head (presently located 1,500 feet inshore of the concrete monolith) was not considered a viable rehab option. Constructing the jetty head offshore from the current position of the end of the jetty to its authorized length was deemed infeasible due to the extensive scour hole and depth of water at the authorized south jetty terminus location. The head of the South Jetty was considered to be stabilized at approximately its current location (stations 313-315). Maximum viable rebuild of the North Jetty head was determined to be station 105, which would result in a re-established head position 1,700 feet inshore of the fully authorized length. Maximum viable re-extension of the head for Jetty A was determined to be station 93, which is 500 feet seaward of its current position and 400 feet landward of its full authorized length. Jetty A length is important to controlling erosion along the North Jetty foundation; however, the substantial scour hole south of the Jetty A head limits a cost-effective head rebuild.

Figures 1-24, 1-26, and 1-31 illustrate the original length modeled by USGS and the lengths and head positions of the authorized project. The loss of littoral sediment can be reduced by stabilizing the jetty heads which maintains the overall morphology of the inlet. Because the recommended jetty lengths for the considered alternatives are about the same as existing jetty head locations, it is not expected that these project alternatives will have a negative impact on the hydrodynamics or sedimentation processes of the MCR inlet. It should be noted that a project plan that does not stabilize the jetty heads will more than likely result in erosion of Clatsop and Peacock spits.

3.5.4. **Reliability of Rubble-mound Structures**

A detailed discussion of reliability and risk concepts is provided in Section 2 of Appendix A2. The specific discussion on the reliability of rubble-mound structures concludes that because rubble-mound structures can afford a large degree of resiliency before being functionally compromised, less conservative maintenance strategies can be implemented to manage the structure's life cycle providing that project risk is correctly managed. A less conservative maintenance strategy is essentially a deferred repair condition: the structure is permitted to experience significant degradation before repairs are undertaken. Deferred maintenance can suppress life-cycle expenditures, up to the point at which the structure is on the verge of losing function (failing). When this condition is reached, the damaged structure will require extensive repairs to renew the life-cycle to a point where repairs can once again be deferred.

There are two general elements of reliability: structural and functional. Structural reliability is the likelihood that a structure will not be damaged within a given time interval. If the structure is susceptible to damage, structural reliability indicates the relative degree of damage that could occur. In many cases, a structure can incur damage (or degradation) without affecting the overall function of the structure. The capacity for sustaining damage without failing is called resilience. When a structure sustains cumulative damage (deferred maintenance) to the point of exceeding its resilience, the structure can lose the ability to perform its intended function. At this point the structure fails. Table 3-6 summarizes target reliability indices and corresponding probability function, P(u), for structure performance in reference to major rehabilitation guidance. Note that the values shown in the table indicate the likelihood of a structure to exceed a given performance limit state, or the probability to experience unsatisfactory structural performance P(u). Unsatisfactory structural performance occurs when a structure incurs damage. The values in Table 3-6 are intended to be used only for the MCR jetties.

Table 3-6. Target Reliability Indices for Structure Performance

Values for conventional practice apply to rigid non-compliant steel structures such as bridges, lock gates, or vertical walls. Values and corresponding consequences given for rubble-mound structures are applicable for MCR jetties only and are assumed to have two or more layers of armor units protecting core material.

Expected Performance Level		**Beta (β) Reliability Index**	**Probability of Unsatisfactory Structure Performance P(u)**	**Functional Reliability**	**Potential Structure Consequences to MCR Jetties**
Conventional Practice (steel structures) ETL 110-2-532	**Rubble-mound Structures @ MCR**				
High	Excellent	5	0.0000003	0.0000097	No likelihood of any structure degradation
Good	Excellent	4	0.00003	0.00097	
Above Average	Very High	2	0.023	0.977	Little likelihood of any structure degradation
Below Average	High	1.2	0.10	0.9	Low likelihood for any structure degradation in response to extreme waves
Poor	Good	0.8	0.2	0.8	Low likelihood for minor structure degradation in response to extreme waves
Unsatisfactory	Average	0.5	0.3	0.7	Moderate likelihood for minor structure degradation in response to extreme waves
Hazardous	Below Average	0	0.5	0.5	High likelihood for minor structure degradation in response to extreme waves
N/A	Poor	-0.2	0.6	0.4	Low likelihood for elevated structure degradation
N/A	Unsatisfactory	-0.5	0.7	0.3	Moderate likelihood for elevated structure degradation
N/A	Hazardous	< -0.8	> 0.8	<0.2	High likelihood for elevated structure degradation

**This table and the values presented within are applicable ONLY to the rubble-mound jetties at the MCR. Do not use this table for citation or reference.*

Functional reliability is the likelihood that a structure will satisfactorily perform its intended function within a given time interval. Functional reliability is derived by combining structural reliability metrics with metrics that describe the present structure cross-section configuration. Unchecked degradation of a structure (reduction in structural reliability) leads to reduced functional reliability.

Appendix A2 provides a more detailed discussion of structural and functional reliability.

3.6. LIFE-CYCLE PERFORMANCE ANALYSIS

3.6.1. General

Project life-cycle costs are affected by two risk elements. *Structural risk* is associated with consequences of a structure being damaged and is driven by structural reliability. Consequences of incurring structural risk are realized when the cumulative damage exceeds a given threshold maintenance level, which may initiate repairs to maintain the structure at a minimal level of resilience.

Functional risk is related to a structure's functional reliability and is associated with the consequences of a structure failing to provide its intended function. Functional risk and project risk are synonymous. The cumulative aspect of incurring structural risk (damage) can add significant cost over time to a structure's life cycle and should be considered with the same emphasis as functional risk (breach). These life-cycle risks are discussed further in Section 2 of Appendix A2.

The difference between structural and functional reliability is indicated by the ability of a structure to incur damage (expressing structure unsatisfactory performance) before losing function (functional failure). A structure that has no capacity to incur damage before losing function will express a functional reliability that is the equivalent to structural reliability. Resiliency is the marginal difference between structural and functional reliability.

3.6.2. MCR Project Event Tree

Complex decisions are the result of progressing through a series of sequential choices and evaluating the consequences of each choice to reach a "best" decision (IWR 1992). For example, as the MCR North Jetty is intermittently damaged by progressive foundation scour and wave damage, areas of the jetty become weakened to the point where the structure has an elevated risk of failing. Several choices are available, such as continuing to defer repairs, performing minimal localized repairs, performing jetty rehabilitation, and/or to implement features to address processes affecting chronic damage. Each choice can produce different consequences, such as the consequences of not repairing the jetty, robustness of the repairs, and at what point in time should repair or rehabilitation occur. An event tree can be used to visually portray sequential decision problems and identify critical sequences in the life cycle of a given structural feature or system. Within this reliability analysis, a project event tree was developed and used to link engineering reliability to economic consequence.

An event tree is a schematic diagram that defines all permutations involving relevant structure performance modes and relates reliability-based outcomes to quantifiable consequences. The compilation of all consequence permutations results in an event tree. An event tree consists of decision points, probabilities of event occurrence, and conditional outcomes (composed of consequence and cost assessment).

The project event tree for the MCR jetties is shown in Appendix A2. The event tree diagram summarizes the annual functionality of a jetty in terms of structural performance modes, sustained damages, consequences, and costs. The event tree starts with the initial condition (*year i*); the forcing environment for *year i* is realized through simulation, jetty performance modes are assessed, and jetty damage for *year i* is evaluated. Cumulative damages are determined at *year i* based on the previous years' performance. Finally, the consequences and costs for *year i* jetty damage are calculated, if repair activities are realized in *year i*. The event tree diagram is repeated n-years, until the life-cycle period is completed. As described above, the project event tree provided the basis for evaluating various life-cycle stages for each MCR jetty. Life-cycle stages evaluated in this report included:

1. Hindcast life cycle (original jetty construction to present, 1900s - 2007).
2. Future life cycle (2006-2007 to 2070) for the current jetty condition and current baseline maintenance strategy.
3. Future life-cycle realizations based on alternative maintenance strategies.
4. Future life-cycle realizations based on alternative rehabilitation strategies.

The following sections describe how reliability and risk are expressed within the event tree and incorporated into the SRB model to perform life-cycle analysis of the MCR jetty.

3.6.3. Stochastic Risk-Based Life-cycle Simulation Model

The MCR SRB model was developed to be a statistical tool to assist engineers and project managers in determining the most cost-effective and reliable method of maintaining and repairing the MCR jetties into the future. The SRB model was written for use in MATLAB® (The Mathworks Inc. 2009). A detailed description of the SRB model is provided in Appendices A2 and A3. Described below is a general overview of the intent, operation, and organization of the model, the coastal engineering functions, and an overview of the model inputs and outputs.

MCR SRB Model Intent

The general intent of the MCR SRB model is to predict the lifecycle costs of repairing and maintaining the MCR jetties based on several repair and maintenance alternative plans. The ultimate objective is to utilize the predicted lifecycle cost ranges and reliabilities computed from each modeled plan to select the option that best balances least cost with highest reliability. The SRB model provides estimates, not definitive answers and is useful in comparing alternatives, costs and consequences but is not the only basis for plan selection. At the foundation of the model is a Monte Carlo simulation which comprises numerous model runs (in the hundreds), each with varying random parameter values. The model, therefore, relies heavily on statistical analysis. Random variation of specific parameters is necessary due to the uncertainty involved in predicting the future demand on, and resultant response of, the jetty structures. Also through this analysis, it is possible to observe the parameters that are most sensitive to random variation and have the largest impacts on lifecycle costs and/or reliability. If the impacts of these parameters are understood and their variation can be controlled to a certain degree, it is logical to conclude that the lifecycle costs can likewise be managed to a similar degree.

MCR SRB Model Operation

The SRB model can be operated in two distinct manners, as a *hindcast* model or a *forecast* model. The hindcast mode incorporates historical jetty geometries (e.g., cross-sectional elevations and widths), costs, and other relevant information from the actual repairs that occurred to each structure since original construction (or since a specified historical date in the case of the South Jetty). Generally, if there is good agreement between modeled and measured data, then the model has good skill (predictability) and is deemed to be performing well. In calibrating the SRB model, *historical* costs and repair schedules were compared to *modeled* costs and schedules. Based on analysis of modeled results (i.e., plots of costs and repair schedules), the hindcast predictions for the MCR jetties are judged to have good model skill.

The hindcast model results are also used to initialize the model for operation in the forecast mode. In the forecast mode, the SRB model predicts structural damages (based on randomized storm conditions), implements repairs and rehabilitations, and calculates dredging and stone quantities over an anticipated jetty lifecycle. The forecasting procedure is similar to the hindcast procedure in the model. For simplicity, only the model forecasting procedures will be described below, but the general methods are essentially equivalent.

MCR SRB Model Organization

Within the SRB model, lifecycle runs are facilitated as nested loops (nested indicates that routines are called to run within other routines, in essence creating loops within loops). Models can be setup to run for several years (e.g., life cycles) and damages can be estimated over a range of storms (annual number of storms) on individual jetty segments (100-foot segments).

For each Monte Carlo simulation and for each year in the forecast, each 100-foot jetty segment is analyzed for damages from each storm predicted to occur in that year. This continues sequentially until all jetty segments have been analyzed for all predicted annual storms in a given year. Subsequently, the model year is incremented and loops through the routines again until a complete life cycle has been modeled. This process is repeated for each Monte Carlo simulation (200 simulations) until the total number of simulations has been analyzed. The flowchart in Figure 3-28 graphically depicts the same concept.

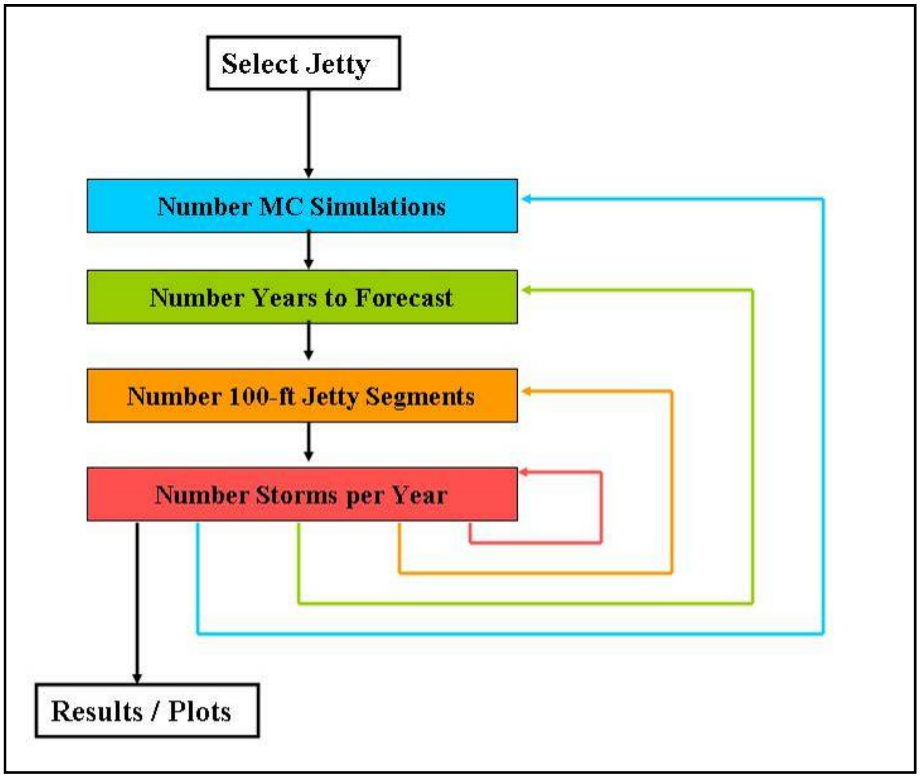
Storm Events

Storm wave heights along the jetties used in the model were generated using a wave propagation numerical model (STWAVE). This model computes nearshore wave heights, periods and directions by propagating offshore wave conditions to the nearshore. A total of 52 observed storm events were selected as representative events to include in the storm database. These are the largest storm events on record, as measured by offshore observation buoys in proximity to the MCR inlet. Each event has impacted the MCR in the recent past, and the potential exists for a similar event to occur and impact the MCR jetty structures in the future.

The storm database used in the SRB model was created prior to any forecast modeling. It comprised near-jetty wave heights at specific along-jetty locations that were predicted by the STWAVE modeling. Each near-jetty wave height correlated directly with an offshore storm condition.

In the SRB model, for each storm predicted to occur in any given model year, a storm event was randomly selected from the database of 52 storms. Subsequently, the corresponding near-jetty wave heights for that particular storm event were extrapolated from the storm database. The wave heights were interpolated along the lengths of the jetties, so that wave heights at each 100-foot jetty station were known and damages calculated at each jetty segment.

Figure 3-27. Simple SRB Model Flowchart



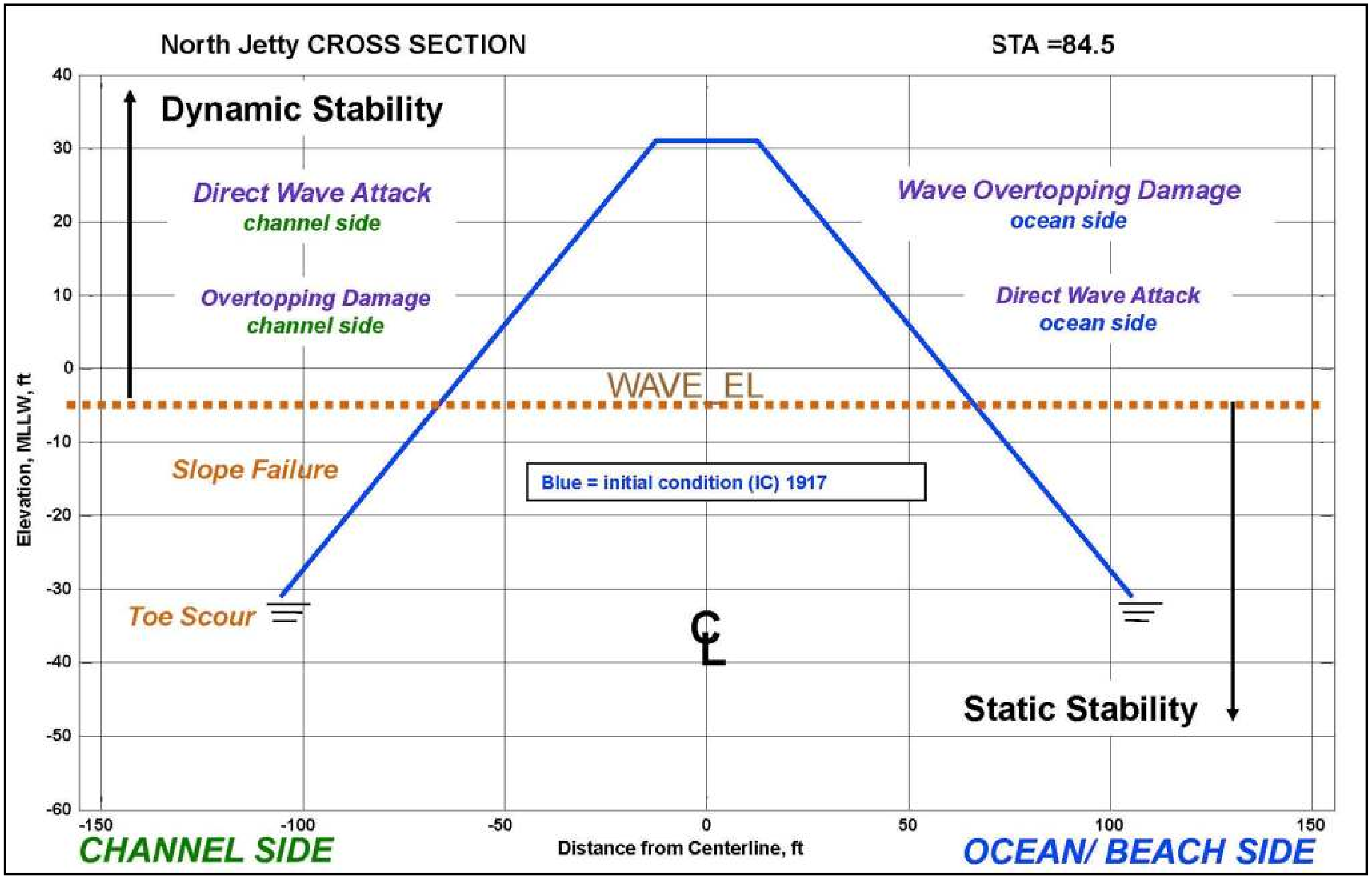
Jetty Damage and Reliability

In the MCR SRB model, both static and dynamic effects contribute to structural damage of the jetties (Figure 3-28). Static damage is attributable to toe scour and side slope failure. Toe scour and resulting toe and slope stone settlement typically results from river and tidal currents scouring the foundation sediments away. Side-slope failure often occurs subsequently because of foundation settlement and may also be a result of scour. The damage associated with static effects are estimated based on historical knowledge of scour and slope failure occurrences. In the SRB model, damages from scour are only applied below the wave elevation surface (defined as the elevation below which wave action does not affect jetty stone).

Dynamic effects are attributable to wave action on the jetty stone (wave breaking and wave overtopping). The damage associated with wave action is computed directly from damage functions attained through physical modeling of various jetty repair alternative designs. The damage functions are simply correlations between wave height and damage. Damage is measured as area damage (square feet) with respect to the jetty cross-section for a particular 100-foot jetty segment (e.g., for a certain wave height at the jetty, a corresponding amount of damage (in square feet) is expected to occur). The damage is combined with any previous damage that has occurred at a particular jetty segment such that cumulative damages are tracked at all stations along a jetty from storm to storm and year to year. The damage thresholds set in the models determine when repairs are implemented and when failures occur.

Figure 3-28. Jetty Breaching Processes and Consequence Emulated within the SRB Model

Representation of a jetty cross-section segment as emulated by the SRB model for every 100 feet of jetty. The jetty is bisected horizontally by the centerline (CL) and vertically by the elevation (WAV_EL) at which wave damage becomes the driving process for structure degradation. Below WAV_EL, scour and static slope stability performance modes govern jetty degradation. Jetty degradation is simulated separately for each side of the jetty.



Within the SRB model, as jetty segments incur damage, the structural and functional reliabilities are adjusted accordingly (decreased). Likewise, when segments are repaired, reliabilities are increased to reflect the increased structural stability of the repaired segments. If a jetty segment fails (e.g., the functional reliability falls below a certain threshold), then emergency repairs may be initiated.

If a jetty segment fails within the trunk or root, the segment is considered breached. If the jetty head or an area within one segment distance landward from the head fails, it is *not* considered a breach. The cost of repairing a breached jetty segment can be significantly higher under emergency conditions as compared to normal repair conditions. Although the likelihood of jetty breach is low, the consequences of jetty breaching can be high. The approach adopted for this rehabilitation study (and SRB model) is to prevent impacts to MCR navigation, should a significant jetty breach occur. To do this, intervention measures such as rapid-reaction jetty repairs are activated if a severe jetty breach occurs.

A series of risk-based calculations are executed within the SRB model to evaluate the consequences of a jetty breach (see Tables A2-7 to A2-9 in Appendix A2 for the unit costs for responding to various MCR jetty breach scenarios). Emergency response actions occur immediately after a jetty breach occurrence and include significant cost escalation for rapid mobilization to the project site and resource acquisition. Deferred and expedited response actions occur during the first construction season (summer) following the breach occurrence and include a modest cost escalation to enable timely jetty breach intervention.

Model Input

The SRB model requires a certain amount of input information in order to complete a Monte Carlo simulation for a specific jetty. This input information includes damage functions, storm events and wave heights, jetty initial geometry, hard-coded variables, and repair cost. These are described further in Appendix A3. During a Monte Carlo simulation, these items are loaded into the model workspace from existing data files or the interactive user interface.

Model Output

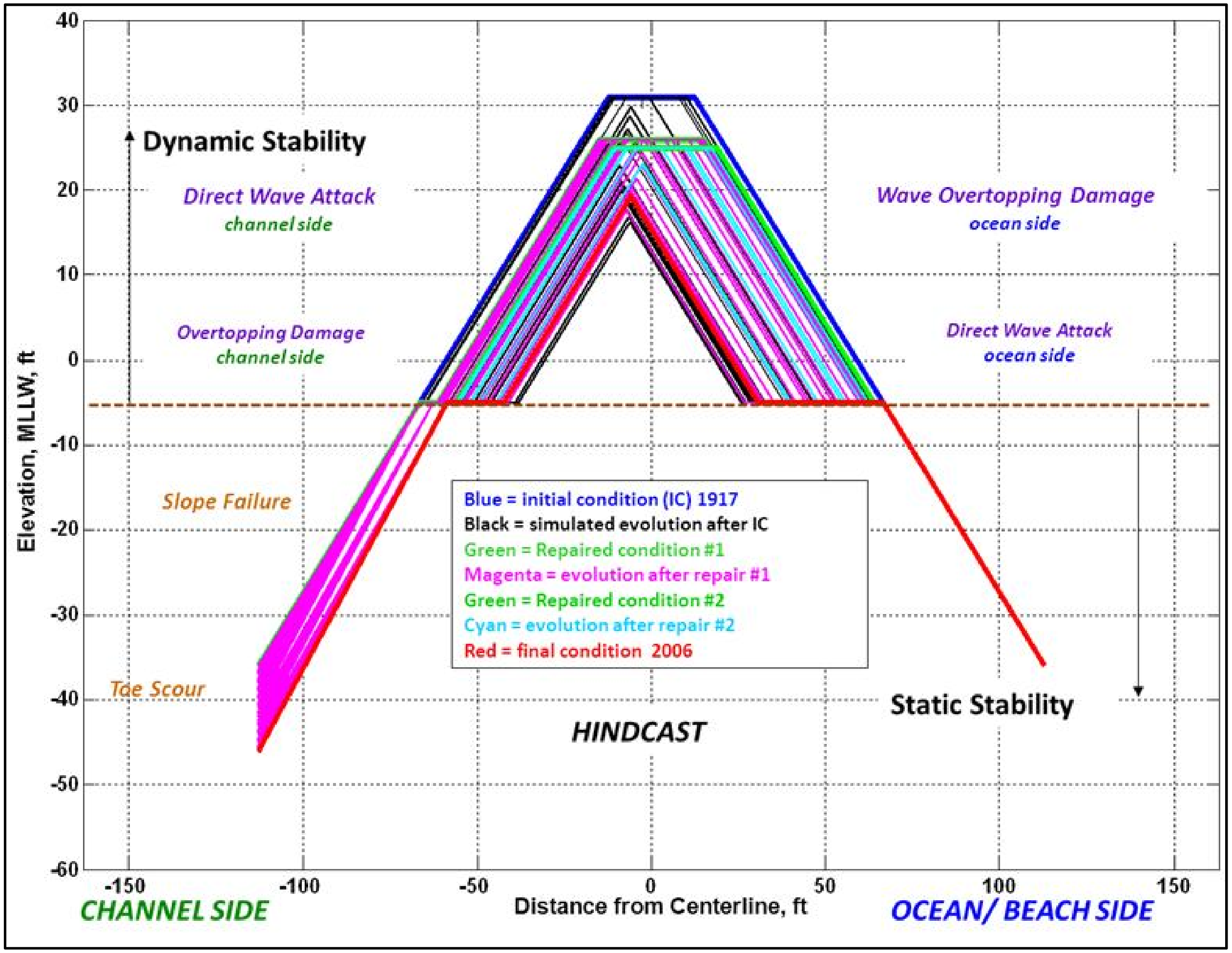
Currently, the MCR SRB model outputs include model variables and files in MATLAB *.mat format, ASCII text files in *.dat format, and various figures illustrating results of the hindcast and Monte Carlo forecast simulation. The lists of the current figures and data files that can be exported from the model can be found in Appendix A3. A description of the modeling results is presented in Section 3.9, *Engineering Evaluation and Life-cycle Model Results for the Range of Alternatives*.

The SRB model evaluates the cumulative structural response of the jetty cross section in 1-year time steps for a given 50-year life cycle. Figure 3-29 illustrates a typical jetty cross section evolution with identified damage zones. The structure is represented as a system of interacting components. Performance modes are used to describe head recession, foundation erosion, slope stability, and wave-induced damage. Considerations used in developing the model include: (1) existing condition of structure, (2) previous repairs of structure, (3) foundation conditions, (4) failure modes, (5) structure function, and (6) exposure to changing morphology and wave conditions.

The model is stochastic in that environmental loading is defined by specific probability density functions and structure response and life-cycle outcomes are expressed as random variables. The risk-based portion of the model portrays the *structural* and *functional* performance in terms of reliability and the life-cycle dredging volumes and stone quantities are based on probabilistic outcomes of negative consequences. The model uses Monte Carlo techniques to stabilize the variance of random variables and stabilize expected value estimates. In short, the model defines the initial conditions, simulates structure response and variable forcing and produces an end-state.

Figure 3-29 illustrates the modeled simulation of cross section evolution at station 79.5 on the North Jetty. The blue outline represents the initial construction and the green outlines represent repair efforts which restored the damaged jetty cross section to an improved condition. The magenta, black and cyan outlines provide estimated cross section evolution that occurs in response to a given year's storm cycle. The red outline is the final condition of the cross section at the end of the simulation. The figure and the model application are divided between dynamic stability modes, direct wave attack and overtopping damages. The static stability modes include scour at the toe and slope failures along the below water portion of the cross section. The representative elevation used to delineate between these two stability categories (dynamic and static) is -5 feet MLLW.

Figure 3-29. North Jetty Cross-section Life-cycle Evolution (1917-2006) at Station 79.5



Typical simulation using the SRB model is as follows:

1. Simulate Structure's Previous Life Cycle – Hindcast: Calibrate model to ensure the model replicates observed life-cycle quantities and timing and location of observed repairs. Key inputs include actual repair history, location, timing, and frequency.
2. Simulate Future Life Cycle – Forecast: Establish base condition to evaluate potential maintenance/rehabilitation scenarios against. A base condition is selected that is most likely to be implemented in a "non-intervention" framework.
3. Simulate Future Life Cycle – Alternative Analysis Forecast: Evaluate alternatives by life-cycle dredging and stone quantities and other metrics.
4. Select the alternative which achieves best reliable life-cycle performance.

For this project, the SRB model provides estimates, not definitive answers and is useful in comparing consequences for alternatives, but is not the only basis for plan selection in that alternatives that were deemed environmentally unacceptable were ruled out.

The SRB model was used to hindcast the life-cycle performance of each jetty from initial construction (early 1910s) to the present (2010). Accurate hindcasting of jetty performance served as a basis for model verification. Metrics provided by the SRB model, which were used to evaluate life-cycle performance include:

- Jetty cross section evolution;
- Time-varying structural and functional reliability and residual risk;
- Jetty repair occurrence – expected frequency and location of jetty repairs;
- Jetty breach occurrence – expected frequency and location of jetty breaches;
- Potential for loss of jetty function to impact navigation function of the inlet; and
- Jetty end-state condition.

The SRB model was used in forecast mode to formulate an optimal plan for rehabilitating each jetty, predicated on the need to minimize life-cycle costs or maximize reliability (see *Components and Processes of the SRB Life-Cycle Model* in Appendix A2 for additional details). Appendix A1 discusses the optimization of various jetty repair and rehabilitation scenarios.

3.6.4. **Calibration of Life Cycle Performance Model**

Before performing hindcast simulations for a given structure, it is essential that a structure's as-built condition be established to match the actual post-construction condition of the prototype. Fortunately, the historical record for the MCR jetties is good and data was available to define the initial conditions for jetty toe elevation, jetty cross-section geometry, armor/core stone attributes, and historical scour rates for MCR jetties. (Refer to Appendix A1 for historical jetty repair details). The SRB model hindcast jetty maintenance strategy was set at "interim repair" to emulate the maintenance conditions actually undertaken during the historical life-cycle of each jetty.

A detailed discussion of the model calibration, including the hindcast calibration parameters and simulated historical performance for the three jetties, is provided in Appendix A2, Section 7. The hindcast modeling results indicate that the SRB model can accurately portray the historical life-cycle for the three MCR jetties in terms of the following performance metrics: jetty repair location, timing, and frequency, and jetty profile end state. Hindcast reliability clearly illustrates the emergent cyclical behavior of each jetty as it is damaged through time, becomes vulnerable, and is then repaired. As such, the SRB model was considered to be calibrated and verified to perform future life-cycle simulations for evaluation of optimal life-cycle investment strategies for the MCR jetties.

3.7. CATEGORIES AND FEATURES OF ALTERNATIVES

Repair and rehabilitation options comprise the general categories of alternatives considered and evaluated for the MCR jetty system, as described below.

3.7.1. Repair Alternatives

Repair alternatives involved adding limited amounts of stone to trunk and root features. Under repair options, stone placement is generally limited to above-water sections and remains within the existing jetty and relic stone structures. Repair alternatives also considered differing degrees of repair. Repair alternatives were considered to occur either on the basis of a scheduled, predetermined time and place, or on an interim basis for which a stochastic model predicted both jetty repair and/or breach scenarios. For the North and South jetties, the repair alternative included repair combined with and without engineering features.

3.7.2. Rehabilitation Alternatives

Rehabilitation alternatives generally incorporate engineering components which may extend beyond the current footprint of jetty and relic stone structures and could entail both above and below-water fill. Certain engineering features were incorporated as common components present in all rehabilitation alternatives considered. These engineering features included stabilization of the jetty heads, constructing additional spur groins. Rehabilitation strategies were evaluated as both immediate and scheduled. The scheduled rehabilitation alternative constructs at specific locations along the jetty at specific time periods in order to maximize the effectiveness of the federal investment.

3.8. EVALUATED REHABILITATION AND REPAIR PLANS

3.8.1. General Alternative Approach

Rehabilitation was considered as an alternative when it could significantly extend the physical life of the feature and could be economically justified. Reliability is a measure of a facility to perform its intended function under specified operating conditions for a given period of time, in this case 50 years. In the case of the MCR jetty system, an adverse event is described as a jetty breach which has the potential to impact navigation at the entrance. Consequences are evaluated in three general categories: jetty repairs, dredging, and potential navigation impacts. In the execution of this major rehabilitation study, the assumption was made that all attempts to avoid navigation impacts would be employed by the USACE. Therefore, navigation impacts were not evaluated quantitatively.

The alternatives investigation was conducted in phases. The first phase involved a detailed analysis and summary of the base condition for the jetty system. This phase is essential and provided the standard to which all of the other plans would be compared. An extensive hindcast analysis was conducted to simulate past performance of each jetty so that future performance could be projected with a level of confidence. Additionally, lagoon fill behind the North Jetty root was analyzed.

The second phase investigated actions for the larger system-based degradation processes which impact the project as a whole and over the long-term. Those actions were discussed in Section 3.5.3. These features were evaluated individually and incrementally in the life-cycle analysis model using the minimum cross section repair plan. Engineering features included head stabilization through a robust jetty head construction, construction of spur groins at key locations along each jetty to promote foundation stabilization.

The third phase evaluated graduated levels of cross section repair or improvements. The conceptual cross sections for the three jetties can be seen in Figure 3-20 through Figure 3-22. Each of these cross sections was applied along the full length of each jetty to identify resiliency and performance of general design concepts along the jetty's length. Variability of segment-by-segment cross section resiliency is typically driven by existing condition of the structure, degree of exposure to wave attack, directions of wave attack, and foundation condition. Each of these plans was also evaluated using the life-cycle analysis model as previously discussed. The fourth and final phase evaluated the feasibility of phasing the jetty repair to minimize project failure and maximize construction efficiency. Through this phase, a plan to conduct a scheduled rehabilitation effort was developed.

Appendix A2 provides further discussion of the key selection criteria, alternative comparison and selection process, and environmental considerations.

3.8.2. Range of Alternatives Considered

The alternatives under consideration ranged from the interim repair approach of the base condition to increasingly higher levels of repair or rehabilitation action to prevent cumulative jetty damage and possibility of jetty failure and impacts to project function. Not all of the plans address the full range of structure and project degradation and each of the plans has varying levels of risk, as well as need for repair and emergency action readiness associated with it. The alternatives considered included scheduled repairs, immediate rehabilitation, and scheduled rehabilitation:

Scheduled Repair

- Scheduled Repair without engineering features (North Jetty, South Jetty, Jetty A)
- Scheduled Repair with engineering features (North and South jetties)

Immediate Rehabilitation

- Using minimum cross section
- Using small cross section (South Jetty and Jetty A)
- Using moderate cross section
- Using large cross section
- Using composite cross section

Scheduled Rehabilitation

- Using minimum cross section (North and South jetties)
- Using composite cross section (North and South jetties)

Each of these repair alternatives were evaluated with the option of retaining the jetty heads at their current locations utilizing the simulated repair alternative or allowing the jetty head locations to fluctuate based on the stability of the jetty heads. The two options with and without stabilizing the head locations were simulated in order to provide guidance on costs for the two options with all other variables being held equal. In addition, as previously discussed, there is a high likelihood that the functional performance of the jetties will be substantially degraded if the head is allowed to recede any further than they already have.

The importance of engineering features (spur groins, jetty head stabilization, lagoon fill) that target damaging long-term degradation processes of the inlet was discussed earlier in this chapter. These features have been incorporated in all of the above plans except for scheduled repair for the North Jetty and Jetty A. For the alternatives where the head locations were maintained at the current locations, the head stabilization feature was not incorporated. In the case of the South Jetty, scheduled repair with engineering features was evaluated. In addition, scheduled repair uses a minimum cross-section repair cross-section that addresses only above-water jetty structure degradation processes.

Two types of repair strategy were used to realistically assess the life-cycle performance of each plan. A great deal of work went into defining the necessary damage threshold which would trigger a repair and/or a failure (additional information on this work is provided in Appendix A2). Two general categories were utilized: (1) interim repair strategy, and (2) scheduled repair strategy (allowing for the programming of the repair). The interim repair strategy, which is only used in the base condition plan, allows the jetty to degrade at each 100-foot segment until only 30-40% of the cross-section is remaining above -5 MLLW. Since the model measures this damage with a probability density function, for purposes of discussion in this report, 30-40% is averaged to 35% (the fix-as-fails probability density function is averaged to 20%). Once that threshold is reached, a repair action is triggered. The repair action does not always repair the structure before a breach happens. The scheduled repair strategy monitors each 100-foot segment for current cross section and degradation rate. When a threshold occurs (calculated separately for each 100-foot segment and for each repair plan), which represents approximately 4 years prior to a failure, a jetty repair action is triggered. This scheduled repair strategy is used for all of the alternative plans.

The intent of a full rehabilitation of the jetties is three-fold: (1) to improve the stability of the foundation (toe) of each jetty affected by scour; (2) to improve the side-slope stability (above and below water) of each jetty; and (3) to improve the stability of each jetty to withstand wave impact. Two different methods were used to apply the full rehabilitation alternatives: immediate and scheduled. Under the immediate rehabilitation, actions would begin at a given year and continue annually until the entire jetty is completed. Under a scheduled approach, the timing of the rehabilitation would be staged throughout time applying the rehabilitation to only the portion of the jetty when it was needed, postponing the federal outlay of funds throughout the 50-year project life.

Full rehabilitation plans would all include the engineering features and would also address, in some manner, the full length of each structure. The sheer size of the MCR jetties along with the limited construction window available at the project would require that any rehabilitation effort would result in scheduling the construction over a number of years. Construction of a full rehabilitation plan on the North and South jetties is projected to take a minimum of 5 and 8 years, respectively. Due to the length of time required to implement a full rehabilitation on the South Jetty and the extent of that jetty's exposure to extreme conditions, scheduling the construction over a broader time window was not found to be effective. On the North Jetty, the scheduling of rehabilitation efforts was assessed due to vulnerability and was spaced out over about a 12 year time frame. Repair strategies that do not include full rehabilitation can be initiated and completed over a shorter period of time, but may have a shorter life span and require additional repairs in the 50 year life cycle timeframe.

The modeling performed to assess the project alternatives assumes that Jetty A is in place and fully functioning. This is because Jetty A, as originally constructed, protects the North Jetty and helps to train the Columbia River main stem. In addition, Jetty A is believed to play an important function for the Columbia River plume. The plume is an important food source for the 13 Columbia River salmonid evolutionarily significant units (ESUs) listed under the Endangered Species Act (ESA). Jetty A will be treated as the first added increment for the North Jetty and because of this, only one plan was developed and analyzed for each of the alternative categories. The three alternatives (scheduled repairs, immediate rehabilitation, and scheduled rehabilitation) for Jetty A will be evaluated against each other in the same manner as the North and South jetties.

The alternatives analyzed are:

1. Scheduled Repair without Engineering Features
2. Scheduled Repair with Engineering Features
3. Immediate Rehabilitation using Minimum Cross Section
4. Immediate Rehabilitation using Small Cross Section
5. Immediate Rehabilitation using Moderate Cross Section
6. Immediate Rehabilitation using Large Cross Section
7. Immediate Rehabilitation using Composite Cross Section
8. Scheduled Rehabilitation using Minimum or Composite Cross Section

A summary of the alternatives evaluated is provided in Table 3-7 through Table 3-9 for the North Jetty, South Jetty, and Jetty A, respectively. These alternatives are described in detail in Section 16 of Appendix A1.

Table 3-7. Future Condition Alternatives for MCR North Jetty

Alternative	Alternative Description
	Alternatives: Allow Head Recession
NJ-01	Base Condition
NJ-02	Scheduled Repair
NJ-03	Scheduled Repair w/ Engineering Features
NJ-04	Scheduled Repair w/ Spur
NJ-05	Minimum Cross-section Rehab - Immediate
NJ-06	Composite 4 Small Rehab - Immediate
NJ-07	Moderate Cross-section Rehab - Immediate
NJ-08	Large Cross-section Rehab - Immediate
NJ-09	Minimum Cross-section Rehab - Scheduled
NJ-10	Composite 3 Small Rehab - Scheduled
NJ-11	Composite 4 Small Modified Rehab - Scheduled
NJ-12	Composite 2 Medium Rehab - Scheduled
NJ-13	Composite 1 Large Rehab - Scheduled
NJ-14	Moderate Cross-section Rehab - Scheduled
NJ-15	Large Cross-section Rehab - Scheduled
	Alternatives: Hold Existing Jetty Head Location
NJ-16	Base Condition (Hold Head)
NJ-17	Scheduled Repair (Hold Head)
NJ-18	Scheduled Repair w/ Engineering Features (Hold Head)
NJ-19	Scheduled Repair w/ Spur (Hold Head)
NJ-20	Minimum Cross-section Rehab - Immediate (Hold Head)
NJ-21	Composite 4 Small Rehab - Immediate (Hold Head)
NJ-22	Moderate Cross-section Rehab - Immediate (Hold Head)
NJ-23	Large Cross-section Rehab - Immediate (Hold Head)
NJ-24	Minimum Cross-section Rehab - Scheduled (Hold Head)

Alternative	Alternative Description
NJ-25	Composite 3 Small Rehab - Scheduled (Hold Head)
NJ-26	Composite 4 Small Modified Rehab - Scheduled (Hold Head)
NJ-27	Composite 2 Medium Rehab - Scheduled (Hold Head)
NJ-28	Composite 1 Large Rehab - Scheduled (Hold Head)
NJ-29	Moderate Cross-section Rehab - Scheduled (Hold Head)
NJ-30	Large Cross-section Rehab - Scheduled (Hold Head)

Table 3-8. Future Condition Alternatives for MCR South Jetty

Alternative	Alternative Description
	Alternatives: Allow Head Recession
SJ-01	Base Condition
SJ-02	Scheduled Repair w/ Engineering Features
SJ-03	Scheduled Repair w/ Head Capping
SJ-04	Scheduled Repair
SJ-05	Minimum Cross-section Rehab - Immediate
SJ-06	Composite 3 Small Rehab - Immediate
SJ-07	Small Cross-section Rehab - Immediate
SJ-08	Moderate Cross-section Rehab - Immediate
SJ-09	Large Cross-section Rehab - Immediate
SJ-10	Composite 4 Medium Rehab - Immediate
SJ-11	Composite 1 Large Rehab - Immediate
SJ-12	Composite 5 Modified 2 Rehab - Immediate
SJ-13	Composite 2 Modified 1 Rehab - Immediate
SJ-14	Minimum Cross-section Rehab - Scheduled
SJ-15	Composite 5 Modified 2 Rehab - Scheduled
	Alternatives: Hold Existing Jetty Head Location
SJ-16	Base Condition (Hold Head)
SJ-17	Scheduled Repair w/ Engineering Features (Hold Head)
SJ-18	Scheduled Repair w/ Head Capping (Hold Head)
SJ-19	Scheduled Repair (Hold Head)
SJ-20	Minimum Cross-section Rehab - Immediate (Hold Head)
SJ-21	Composite 3 Small Rehab - Immediate (Hold Head)
SJ-22	Small Cross-section Rehab - Immediate (Hold Head)
SJ-23	Moderate Cross-section Rehab - Immediate (Hold Head)
SJ-24	Large Cross-section Rehab - Immediate (Hold Head)
SJ-25	Composite 4 Medium Rehab - Immediate (Hold Head)
SJ-26	Composite 1 Large Rehab - Immediate (Hold Head)
SJ-27	Composite 5 Modified 2 Rehab - Immediate (Hold Head)
SJ-28	Composite 2 Modified 1 Rehab - Immediate (Hold Head)
SJ-29	Minimum Cross-section Rehab - Scheduled (Hold Head)
SJ-30	Composite 5 Modified 2 Rehab - Scheduled (Hold Head)

Table 3-9. Future Condition Alternatives for MCR Jetty "A"

Figure No	Alternative Description
	Alternatives: Allow Head Recession
JA-01	Base Condition
JA-02	Scheduled Repair
JA-03	Small Cross-section Rehab (Plan A) - Immediate
JA-04	Small Cross-section Rehab (Plan B) - Immediate
	Alternatives: Hold Existing Jetty Head Location
JA-05	Base Condition (Hold Head)
J-06	Scheduled Repair (Hold Head)
JA-07	Small Cross-section Rehab (Plan A) - Immediate (Hold Head)
JA-08	Small Cross-section Rehab (Plan B) - Immediate (Hold Head)

3.8.3. Base Condition Development

FY 2011 MRR base condition assumed that no action would be taken to slow down the large-scale physical processes that are negatively affecting the structural stability of the MCR jetty system (the current 2012 MRR base condition is discussed in **3.8.4**). Those larger physical processes include landward recession of the jetty head, shrinking of the ebb tidal shoal, foundation erosion, and adjacent shoreline erosion. The heads of each jetty would continue to recede landward with the expected response of the surrounding morphology including continued shrinking of adjacent underwater shoals and the overall shrinking of the ebb tidal shoal. Much of the material eroded from the inlets shrinking shoals would be transported into the MCR inlet, thereby adding the requirement for maintenance dredging. The underwater sand shoals upon which the jetties are built would continue to erode, leaving deeper water depths along the jetties. The deeper water (over the eroded shoals) would allow larger waves to attack the jetties resulting in a greater rate of jetty deterioration and foundation erosion. Wave and current action within the MCR inlet would increase. The eroded lagoon area behind the north jetty would remain, allowing tidal flow and wave surge through the jetty trunk which de-stabilizes the structure and negatively impacts jetty foundation.

Due to the level of construction and the high mobilization costs, the base condition does not include any jetty head re-construction. Only the trunk and the root of the jetty are maintained, and the jetty head is allowed to recede landward. Maintenance of the trunk and root of the jetty is minimized by deferring repair activities into the future for as long as possible. Jetty repairs are initiated only when a failure of the upper portion of the jetty cross section seems to be progressing. For the fix-as-fails base condition, the level of damage that initiates a repair action is measured by the model as a jetty reach having been reduced to 20% of the cross-section remaining above -5 MLLW. A rubble-mound structure can incur a certain level of damage before the whole cross section fails resulting in a functional impact; however, a complete breach through the above water portion of the structure can result in rapid deterioration. The base condition is identified as an interim repair approach because the upper portion of the cross section is allowed to be damaged to approximately 20% remaining prior to repair actions being taken. In this way, the jetty is maintained close to the margin of functional loss.

Depending on the percentage of lost cross section which results from the deferred action, maintenance actions may need to be conducted on an expedited or emergency basis. In some cases, the repair occurs before the complete failure of the upper part of the cross section and in some cases, depending on the severity of the intervening storm climate, an actual failure of the upper cross section occurs resulting in a breach of the jetty. If a jetty breaches, adjacent segments would have a high probability of also breaching or incurring additional damage. In addition, depending on the location of the breach, sediment from adjacent land or underwater shoals can move through the breached jetty toward the navigation channel, requiring an emergency mobilization of dredges to prevent impacts to navigation.

The interim repair approach carries an elevated risk for incurring added costs either through expediting repairs (to prevent functional loss of a jetty) or responding to a breached jetty. Consequently, there is an elevated likelihood that jetty repairs may be more expensive (cost/ton of repair stone placed) when they do occur, In order to maintain navigability of the federal channel, emergency repairs would be performed on the breach and/or emergency dredging of the federal navigation channel would occur.

3.8.3.1. North Jetty Base Condition

The North Jetty has receded approximately 2,100 feet in length since original construction in 1916. The jetty head will continue to deteriorate at a rate of about 20 to 50 feet per year. In 50 years, it is estimated to reach stations 76-90 (or about 1,800 feet lost), in very close proximity to where the existing shoreline is today. Under the base condition, the jetty head is not repaired or rebuilt during the 50-year period. Peacock Spit and Benson Beach are expected to continue to erode shoreward at a similar rate to the jetty length deterioration. Much of the sediment loss associated with shoreline retreat will migrate into the federal navigation channel and routine maintenance dredging of the entrance will increase over time. The maintenance dredging volume could be greater than present by an amount of 0.5 to 1 MCY per year (or by a rate up to 25% greater). The resulting head loss would have moderate effect on wave climate and navigability. Erosion of the surrounding shoal would expose more vulnerable areas of the jetty to increased damages. Continued loss of jetty length (and Peacock Spit) could potentially expose the seaward half of the South Jetty to higher wave conditions.

The trunk of the jetty is expected to degrade by three distinct processes: direct wave impact, wave overtopping (affecting the above water level of the jetty) and scour at the base of the jetty (affecting the below water portion until it fails and destabilizes the above water portion of the jetty).

In the event of a significant breach event, approximately 2-3 MCY of material could move from Peacock Spit and Benson Beach into the navigation channel. A shoal within the navigation channel would begin to form. In the absence of emergency dredging, it is expected that the depth of the navigation channel could be reduced from -55 feet to -40 feet in about 2 to 4 months. In order to maintain navigability of the navigation channel, the USACE would perform emergency repairs on the breach and attempt to mobilize sufficient dredges to maintain the authorized channel depth. During the 50-year project life, approximately 2 to 5 planned repairs would be expected to occur along the North Jetty.

To perform emergency repairs to the breached area, a contractor would truck in readily available stone to the North Jetty, build a haul road on top of the jetty, and place jetty stone in the breached area with a track mounted excavator or similar piece of equipment to stop the volume of material migrating into the navigation channel. Not only will the breach allow for sand to move through the jetty opening, but also sea water may flood low-lying Benson Beach park areas complicating access to the repair. The contractor may need to pioneer a road into a jetty access point for breach repairs.

The Columbia River Bar can only be maintained with the use of a hopper dredge. These types of dredges have two drag arms that extend to the river bottom and hydraulically remove material. The material is temporarily stored within the ship in a hopper, and then transported to a disposal location.

Once at the proper location, doors on the bottom of the ship open or the hull of the ship opens and the material falls from the hopper through the water column to the disposal site. To perform emergency dredging, one or two dredges would be mobilized. Production rates for the dredges would be approximately 20% to 25% of normal due to weather conditions and storm events. The dredges would rely on weather windows and favorable sea conditions to remove as much of the shoal as possible with a goal of maintaining navigation. Due to the physical limitation of the dredges, it is unlikely they could achieve the -55 feet of depth of the outbound lane with swells of 10 to 16 feet.

It should be noted that this course of action would present high risks to the dredges and their crew. Given the winter wave conditions that the dredges would be performing in, it is highly likely that damage would occur to the drag arm of the dredge while working. Environmental concerns regarding loss of hydraulic fluid or oil spills may result if the dredges are damaged. Dredged material will be disposed of at an approved in-water disposal site. Because it is predicted that 2 to 3 MCY of material will enter the navigation channel, the dredges are not expected to be able to remove all of the material that has migrated into the channel; therefore, the following dredging year could require up to three dredges to work the entrance to remove twice the amount of material of a normal maintenance year. During the last 23 years, there were about 7 years when the wave climate would have been too severe to do emergency dredging. Under those circumstances, there would be more risk of not being able to do emergency dredging with the potential impacts to navigation.

3.8.3.2. South Jetty Base Condition

The South Jetty has receded approximately 6,200 feet in length since original construction in 1885-1913. Under the base condition, the jetty head is not capped and no spur groins are constructed to control foundation scour. The jetty head continues to recede back at a rate of 5 to 20 feet per year until the concrete monolith collapses at which point the head recession is projected to be more rapid. In 50 years, it is expected to reach approximately station 292 (or about 2,100 feet lost). The jetty head would not be repaired or rebuilt during the entire 50-year period. Continued loss of the jetty length (and Clatsop Spit) under the base condition would expose the seaward half of the South Jetty to higher wave conditions. Loss of jetty length would contribute to continued loss of the underwater shoal, exposing the jetty to increasing wave action and the shoreline at the root of the jetty to higher wave forces. The shoreline would continue to erode and recede, resulting in a shoreline breach into Trestle Bay in about 8-16 years. Based on the present condition of the concrete monolith, it is expected to slump into the ocean and basically be non-existent within 12-20 years adding additional deteriorating forces to the seaward half of the jetty. The remaining rubble mound portion of the South Jetty would then begin to deteriorate in an accelerated way.

The trunk of the jetty is expected to degrade by three distinct processes discussed above. During the 50-year project life, about 3 to 6 repairs would be expected to occur along the South Jetty. Unlike the North Jetty, emergency dredging would not occur because the material is not anticipated to affect the federal navigation channel in the short term. Increased dredging would occur during the summer maintenance months. The breach would not be repaired by emergency actions; rather repairs would be performed during the following summer.

Shore Area along South Jetty

The shore area along the South Jetty root has experienced profound changes since the time of jetty construction. Before construction, the nearshore area immediately south of the jetty was dominated by a broad shallow ebb tidal shoal, exhibiting relatively shallow water depth. Construction of the South Jetty dissipated this shoal, resulting in a rapid trend of increasing water depth through time. As the water depth along the south side of the jetty increased, wave action along the jetty root and adjacent shore area increased. The increased wave environment motivated rapid deterioration of the entire South Jetty and culminated with the significant breaching event along the jetty root in the late 1920s. During the 1930s, extensive efforts were undertaken to rebuild the South Jetty and re-establish the shore-land interface along the south side root of the jetty. The effort was successful; however, the result has been subjected to an increasingly harsh environment of wave action and related circulation since the 1930s.

Currently, the coastal shore interface along the South Jetty is in a condition of advanced degradation. The foredune separating the ocean from the backshore is almost breached. The backshore is a narrow strip of low elevation, accretionary area, separating Trestle Bay from the ocean by hundreds of yards. The offshore area along the South Jetty (and to the south) continues to erode, promoting larger wave action to affect the shoreline along the jetty root. The shoreline at the jetty root will continue to erode and recede, resulting in a possible shoreline breach into Trestle Bay in approximately 8-16 years. If this sand spit breach occurs, the resulting scenario would be catastrophic. The MCR inlet would establish a secondary flow way from the estuary to the ocean along this area (south of the South Jetty). This condition would profoundly disrupt navigation at the MCR and bring lasting changes to the physical nature of the inlet. Augmentation of the foredune along the South Jetty root is required to prevent the above realization.

Augmentation of the foredune would consist of placing 60,000 to 70,000 cy of cobble material to fortify the toe of the foredune and improve the foreshore fronting to resist wave induced erosion/recession. The augmentation material would be composed of a well graded mixture spanning the size range of large gravel (3-inch diameter) to large cobble (12-inch diameter.). The material would likely be delivered by truck and placed by earth moving equipment. There is the possibility that MCR sand or coarse-grained sand from the lower Columbia River could be hydraulically placed to enhance the foredune augmentation effort. However, use of sand-sized material would require a significantly large volume (200,000 to 400,000 cy) to produce the equivalent resilience as the cobble material augmentation evaluated. The timing of this action is expected to be within first 8 years of jetty rehabilitation. Note that the nearshore placement of MCR dredged material within the evaluated South Jetty Site would mitigate the erosion of the South Jetty root area. The South Jetty Site is a potential nearshore dredged material placement site located in a water depth of 40-50 feet approximately 1 mile south of the South Jetty. This would complement the foredune augmentation evaluated and help ensure balance of the sediment budget south of the South Jetty. However, this action should not be viewed as a replacement for foredune augmentation.

3.8.3.3. Jetty A Base Condition

Jetty A has receded approximately 900 feet in length since original construction in 1939. The head of the jetty will continue to deteriorate at a rate of about 5 to 20 feet per year. In 50 years, it is estimated to reach stations 78-86 (or about 1,500 feet lost). Under the base condition, the jetty head is not repaired or rebuilt during the 50 year period. There will be increases in dredging as Jetty A recedes. Clatsop Spit will prograde northward toward the navigation channel. The bathymetry in front of Sand Island will be cut back, mobilizing that additional material. The shallower area between Jetty A and the North Jetty will also be impacted allowing movement of that material toward the channel. The deepening which will be expected to happen in the vicinity of the North Jetty will further destabilize the foundation of that structure impacting its long-term reliability. The primary purpose of Jetty A is to direct river currents away from the North Jetty. It is expected that a one-time increase in dredging will occur on the order of 800,000 to 1.6 MCY followed by incremental increases in dredging that will depend on changes in channel shoaling patterns and spit movement.

The trunk of Jetty A is expected to degrade by three distinct processes: direct wave impact, wave overtopping (affecting the above water level of the jetty) and scour at the base of the jetty (affecting the below water portion until it fails and destabilizes the above water portion of the jetty). During the 50-year project life, it is predicted that Jetty A will breach, destabilizing more of the jetty and allowing significant amounts of sand to move through the jetty. Breaching typically occurs during severe winter storms. Modeling suggests that during the 50-year project life, breaching will occur between 2 and 5 times along Jetty A. If a segment breaches, adjacent segments have a high probability of also breaching. It is estimated that 2 to 4 repairs would occur along Jetty A. Unlike the North Jetty, emergency dredging would not be needed because the material is not expected to affect the navigation channel in the short term. Increased dredging would occur during the summer maintenance months. Also, repairs to the breach would occur the following summer.

3.8.4. Modification of the Base Condition

In FY 2010-11, a 90% draft of the MRR underwent District Quality Control (DQC) and Agency Technical Review (ATR). The underlying tenets of that report included a base condition involving a fix-as-fails approach where each jetty was allowed to degrade as low as 20% of the originally authorized cross-section remaining above MLLW -5, resulting in forecasted breaches. The hypothetical breaches would release material into the navigation channel, leading to emergency dredging. Breaches were forecasted to primarily occur in the winter, thus emergency dredging was high-risk and very expensive, and reliability of the navigational channel became questionable. Moreover, potential breach volumes entering the navigation channel were difficult to predict. In an attempt to model these effects, the SRB model code became more complex as the analysis was developed and the timing of the runs became very long and the economics was embedded within the model code. NWP also developed a qualitative numeric scoring of alternatives that included several factors beyond average annual cost.

The IEPR was conducted from December 2010 through April 2011. At the same time, the SRB model underwent substantial review, including ATR approval and DDN-PCX model certification in January 2011. This documentation was then forwarded to HQUSACE for final approval where it was disapproved in June 2011 because the IEPR panel raised concerns about the predicted frequency and severity of breaching and sediment transport in the base condition.

After consultation with NWD, it was decided that a Major Maintenance Report (MMR) should be produced for the most critical portions of the North Jetty for inclusion in the FY 2013 budget submission. The MMR included two actions on the North Jetty: lagoon fill between STA 20 to 60 and critical repairs between STA 86 to 99. Both were removed from the MRR alternatives and included in the revised base condition.

The district decided to revise the SRB model, MRR and appendices per the IEPR comments to show compliance with current technology and Corps policy; providing additional documentation.

The new base condition assumes the upper portion of the jetty is allowed to be degraded until approximately 35% of the cross-section is remaining prior to repair action being initiated. This change in the base condition allows for repair actions to take place prior to a breach event, and thereby eliminates breaching and sediment transport through the jetty, affecting the navigational channel and significantly reduces winter emergency dredging.

The above series of events resulted in a change in the selected plans for the three jetties.

3.9. Engineering Evaluation and Model Results for Alternatives

The SRB model allows one to review the simulated future life-cycle dredging and repair stone quantities. Forecasted dredge quantities are associated with incremental dredging requirements, above normal outlays quantities. Metrics provided by the SRB model that can be used to evaluate life-cycle performance include time-varying structural and functional reliability, jetty repair occurrence, jetty breach occurrence, cross-section evolution, and jetty end-state condition. The SRB model is used to help formulate an optimal plan for rehabilitating each jetty, predicated on the need to minimize life-cycle costs or maximize reliability. A detailed description of the SRB model and its application to the MCR jetties can be found in Appendix A2.

The paragraphs and tables below summarize the SRB model results for each base condition and alternative for each jetty. The focus is on the following output parameters:

- Degree to which larger system degradation processes are addressed.
- Final projected position of the jetty head.
- Number of large scale repair efforts expected over the project life.
- Expected jetty repair costs over the project life.
- Initiation and frequency of jetty repairs expected.
- Expected increases in dredging quantities over project life.
- Extent to which emergency dredging may be expected.
- Estimated number of significant breach events with the potential to impact navigation.
- Average projected structural and functional reliabilities.
- Additional comments on expected jetty maintenance program and potential environmental and inlet effects.

3.9.1.1. North Jetty

The base condition takes no action to address the larger system degradation processes. The North Jetty head continues to recede at a rate of 20-50 feet per year. The modified head position at the end of the life-cycle analysis is estimated at station 92 (about 900 feet shorter than current head position). Potential repairs are expected to begin immediately and extend for the life of the project, as needed. The base condition is expected to result in significant changes to the navigation entrance.

Figure 3-30 illustrates the simulated North Jetty crest profile evolution over the project life. In this figure, the blue line depicts the originally constructed North Jetty showing both the authorized length and crest elevation. The green line shows the 2006 condition of the jetty and the red line depicts the changes predicted to occur in the jetty over the next 50 years if the jetty is maintained as described in the base condition. The second graph illustrates the estimated repair and breach frequency per 100-foot segment along the jetty for the base condition. The abbreviation “FF” refers to the fix-as-fails repair scenario. The pink line refers to breach frequency and the blue line refers to repair frequency. The dotted black vertical line identifies the head position at the beginning of the simulation. The solid black line shows the head position at the end of the simulation. The third graph shows the functional and structural reliability over the project life.

Figure 3-30. North Jetty Base Condition

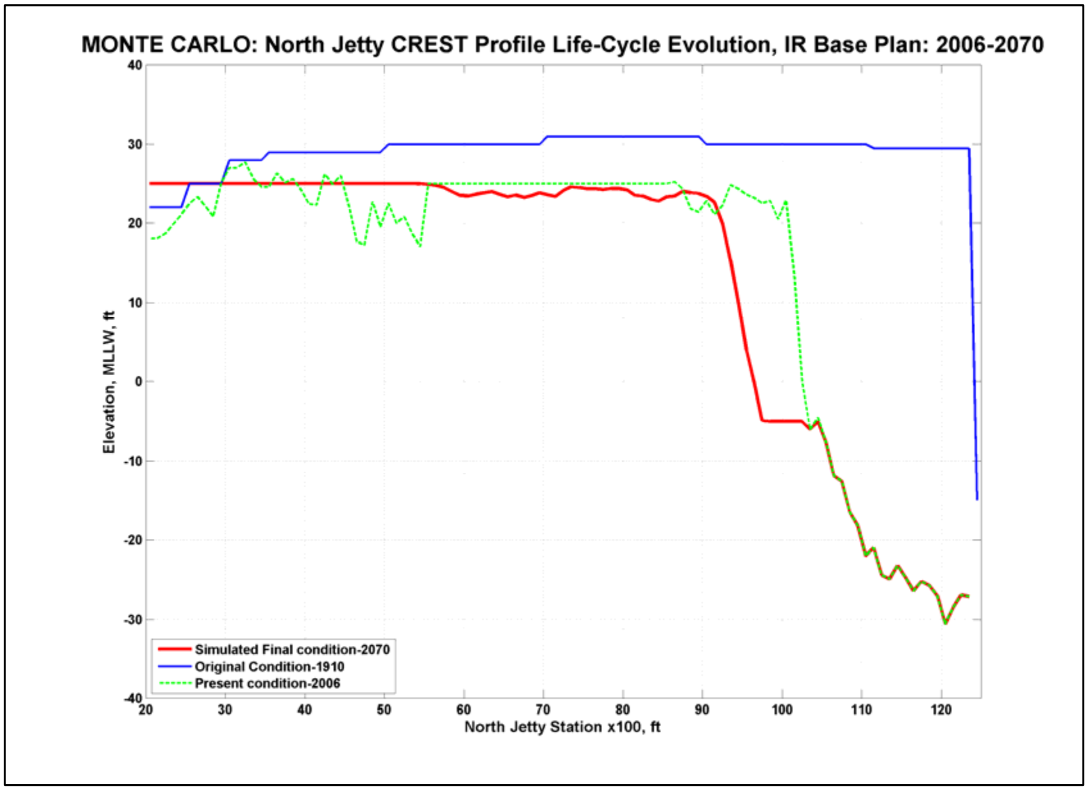
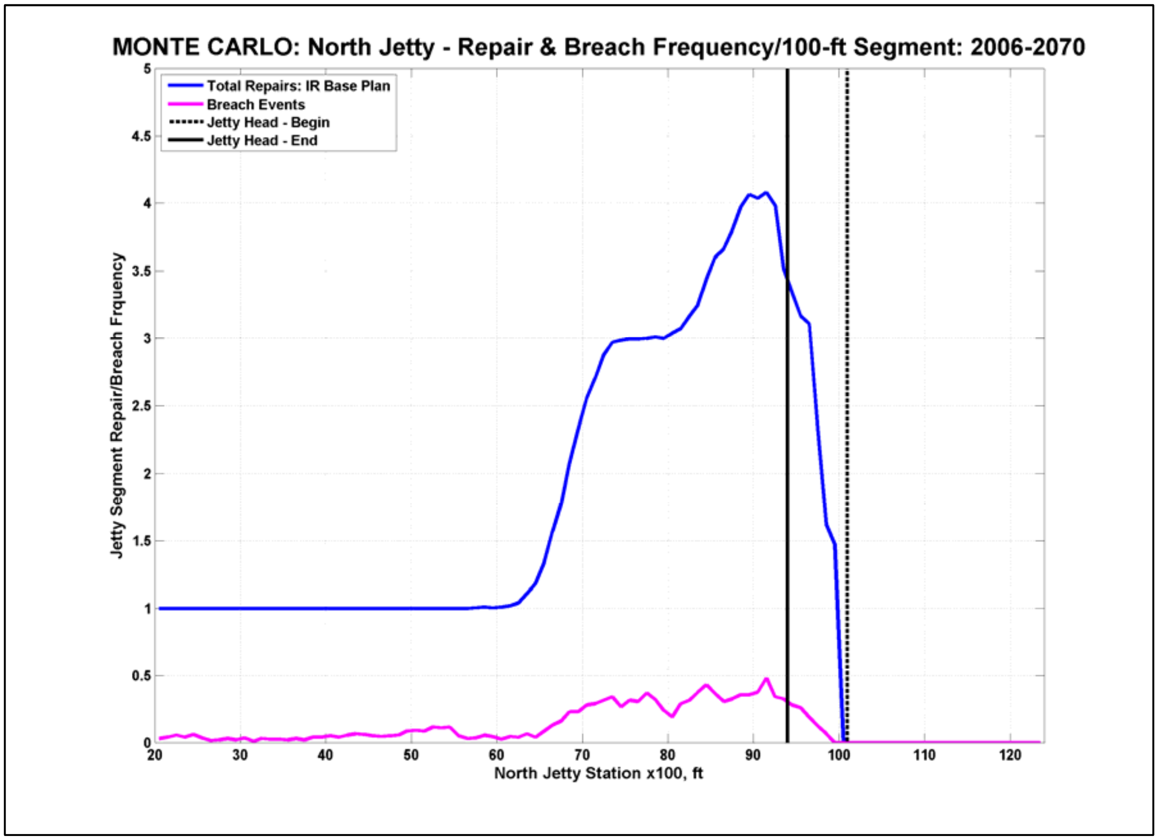
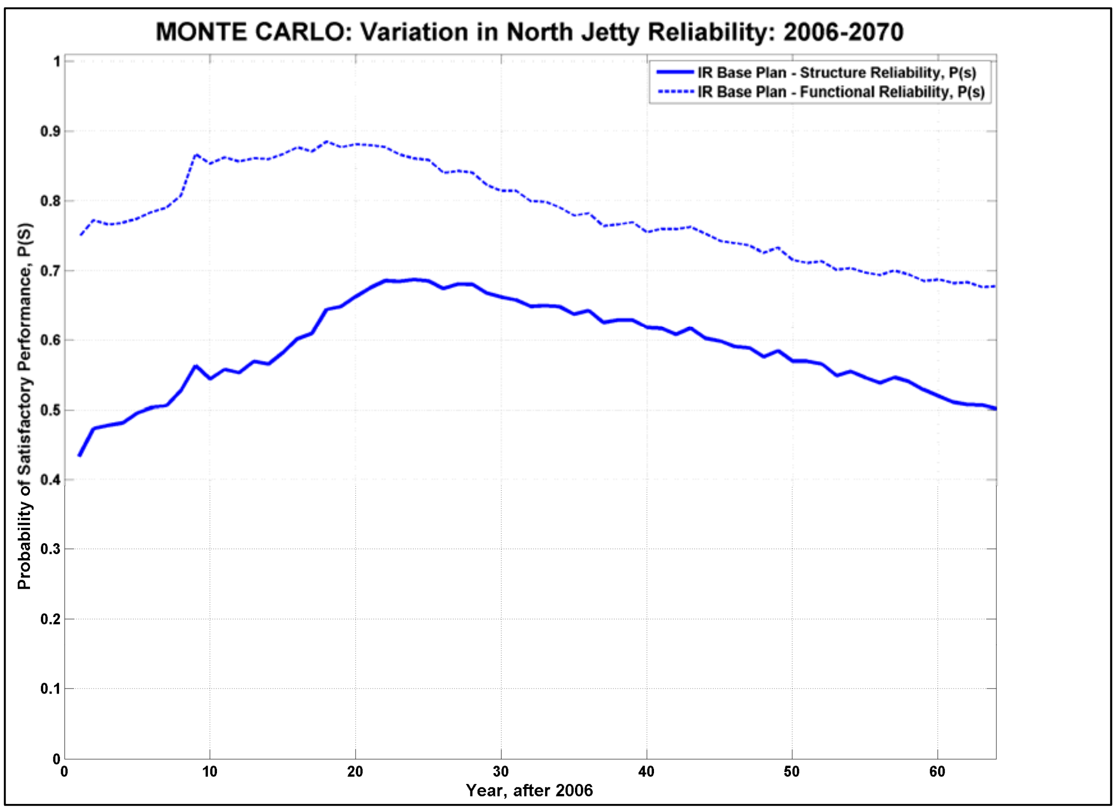


Figure 3-31, continued





3.9.1.2. South Jetty

The base condition takes no action to address the larger system degradation processes except for some shoreline stabilization work at the root of the jetty. Initial construction costs to address the South Jetty root work are estimated at $10 million. The South Jetty head continues to recede back at a rate of 5 to 20 feet per year. The modified jetty head position at the end of the life-cycle analysis is estimated to occur at approximately station 298 (about 1,500 feet shorter than the current jetty head position). The base condition is expected to result in significant changes to the navigation entrance.

Figure 3-32 illustrates the simulated South Jetty crest profile evolution over the project life. In this figure, the blue line depicts the originally constructed South Jetty showing both the authorized length and crest elevation. The green line shows the 2006 condition of the jetty and the red line depicts the changes that are predicted to occur in the jetty over the next 50 years if the jetty is maintained as described in the base condition. The second graph shows the expected breach and repair frequency and the third graph shows the functional and structural reliability over the project life.

Figure 3-31. South Jetty Base Condition

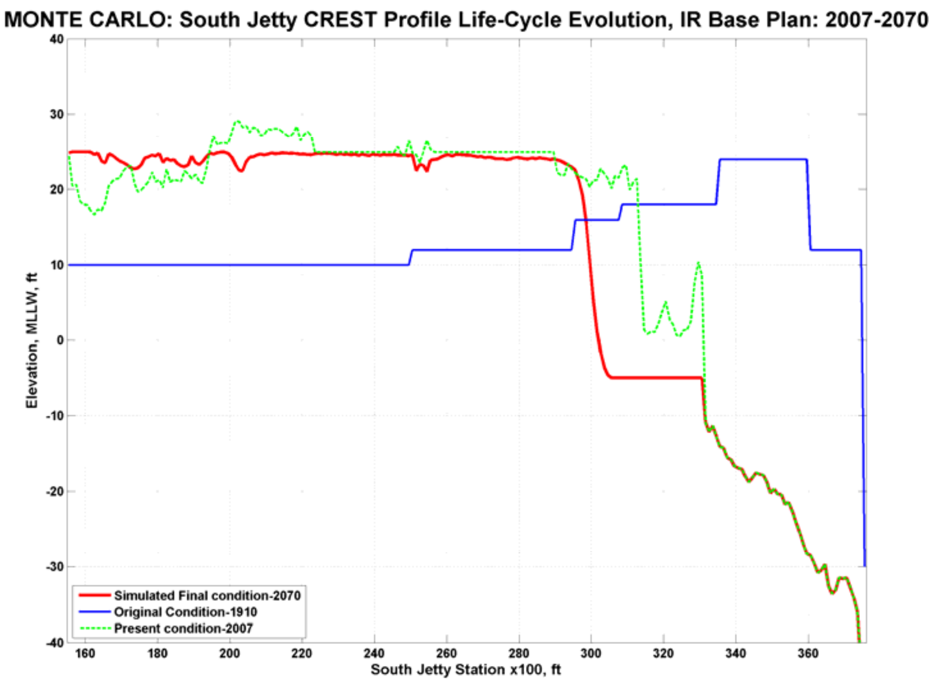


Figure 3-32, (continued). South Jetty Base Condition

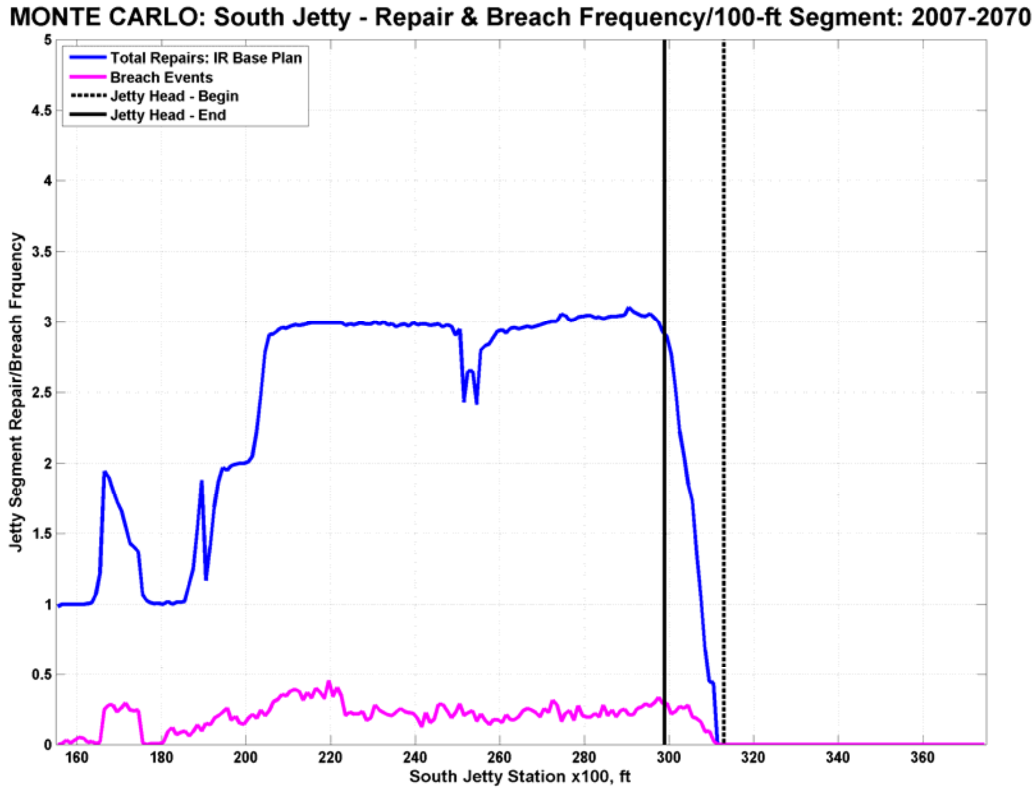
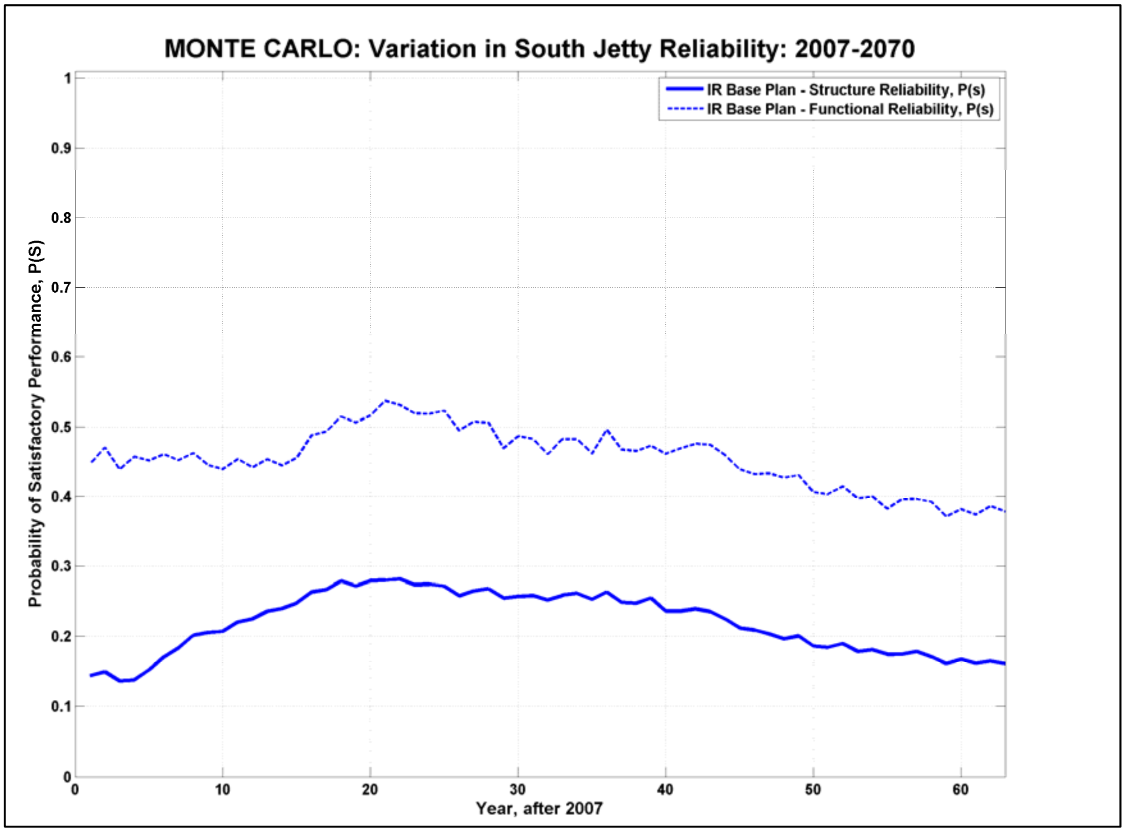


Figure 3-32 (continued). South Jetty Base Condition



3.9.1.3. Jetty A

The base condition takes no action to address the larger system degradation processes. The jetty head continues to recede back at a rate of 5 to 20 feet per year. The modified jetty head position at the end of the life-cycle analysis is approximately at station 82 (about 600 feet shorter than the current jetty head position). The base condition is expected to result in significant changes to the navigation entrance.

In Figure 3-32, the blue line depicts the originally constructed Jetty A showing both the authorized length and crest elevation. The green line shows the 2006 condition of the jetty and the red line depicts the changes that are predicted to occur in the jetty over the next 50 years if the jetty is maintained as described in the base condition.

Figure 3-32. Jetty A Base Condition

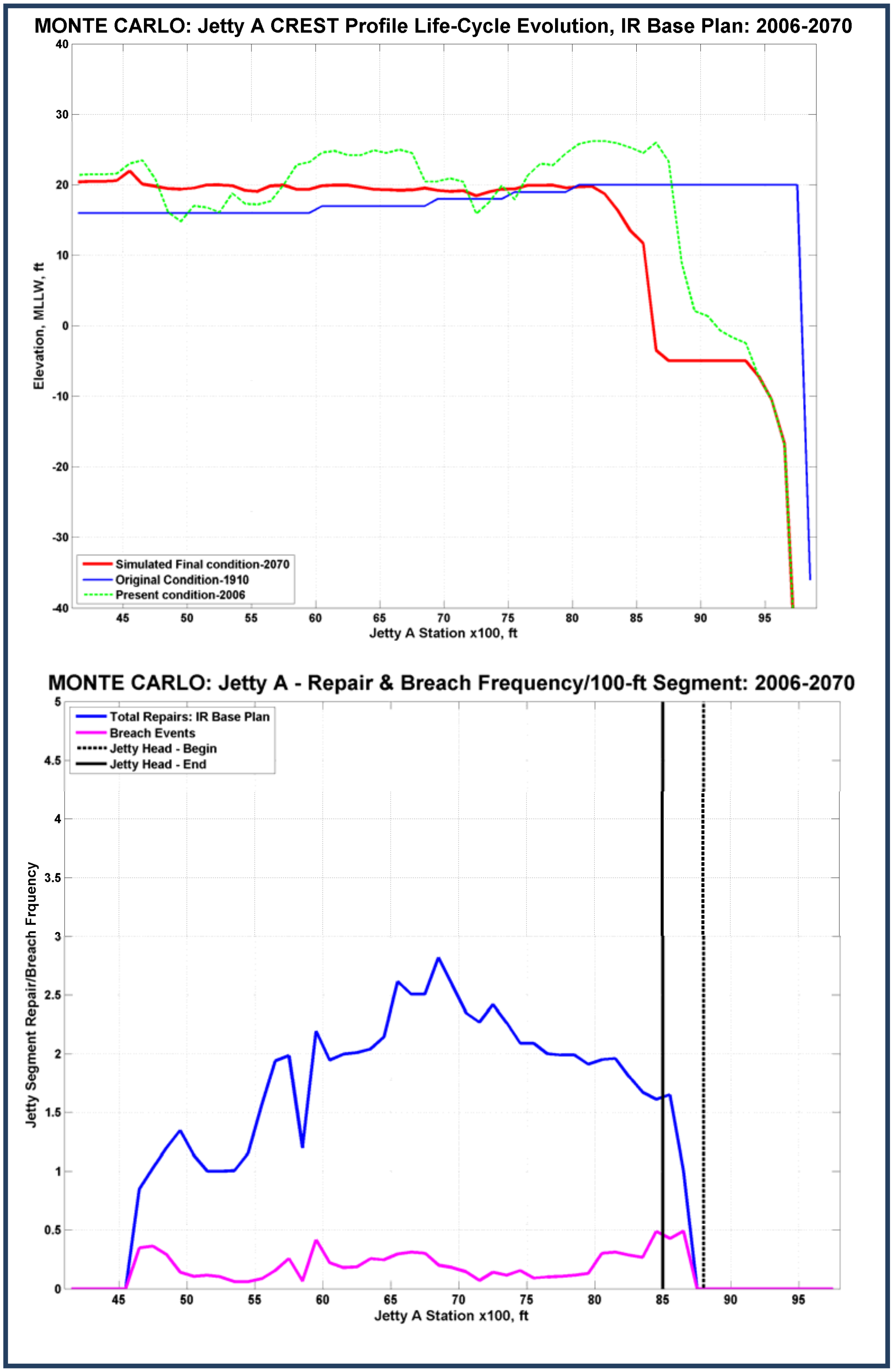


Figure 3-33. (continued). Jetty A Base Condition

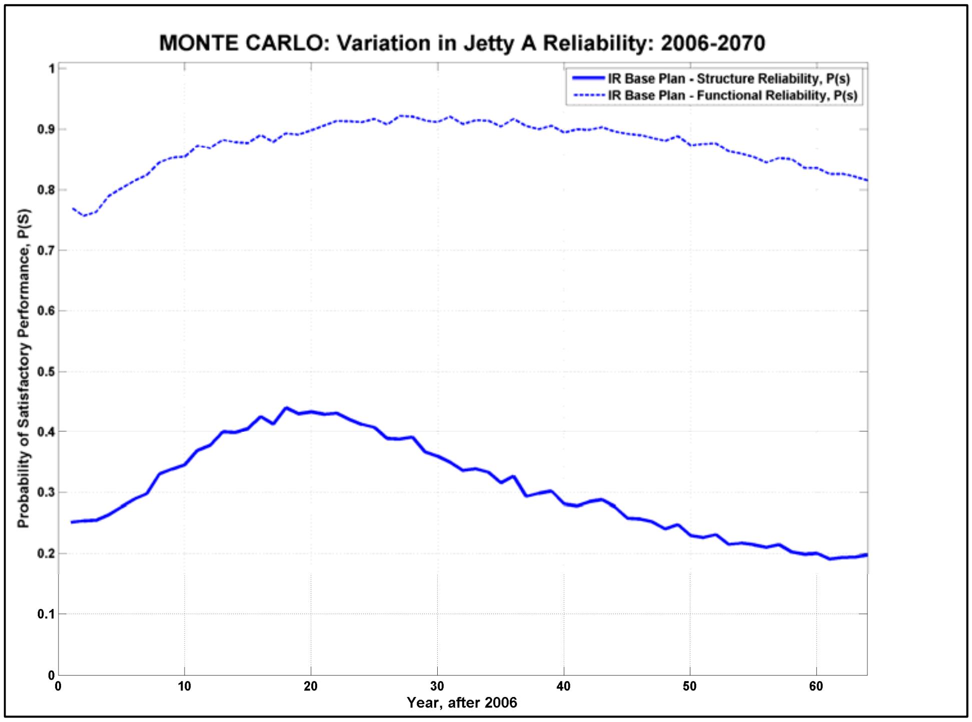


Figure 3-33. Repair tonnage for MCR North Jetty. Projected estimate is based on the project base condition (no action plan) and begins in 2006, which the last time that the north jetty was fully surveyed.

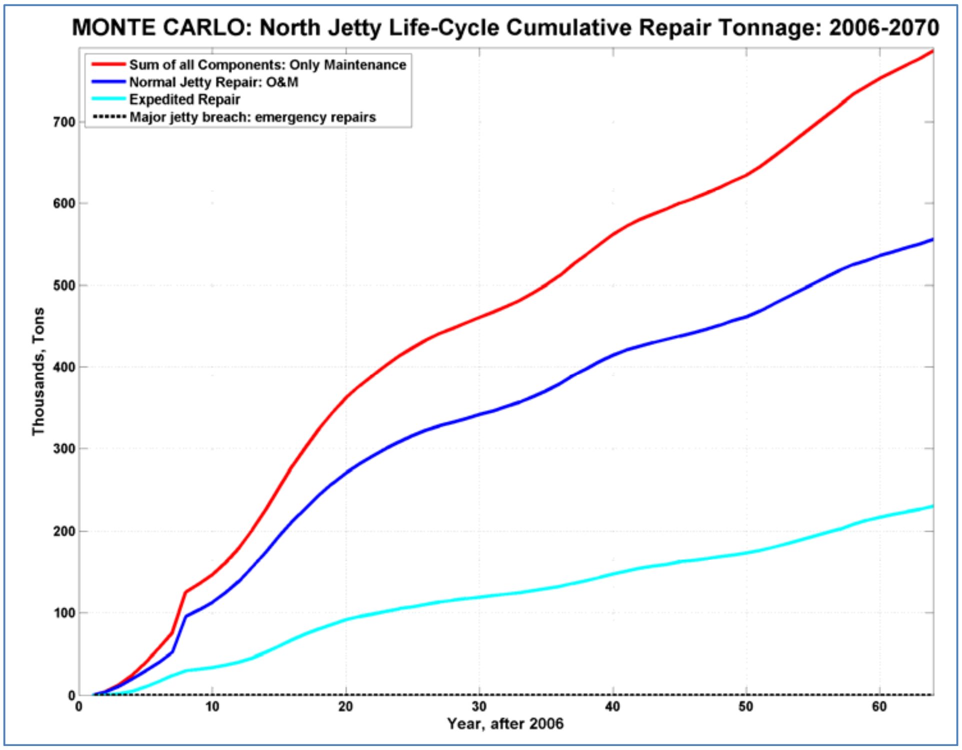


Figure 3-34. Repair tonnage for MCR South Jetty. Projected estimate is based on the project base condition (no action plan) and begins in 2007, which the last time that the south jetty was fully surveyed.

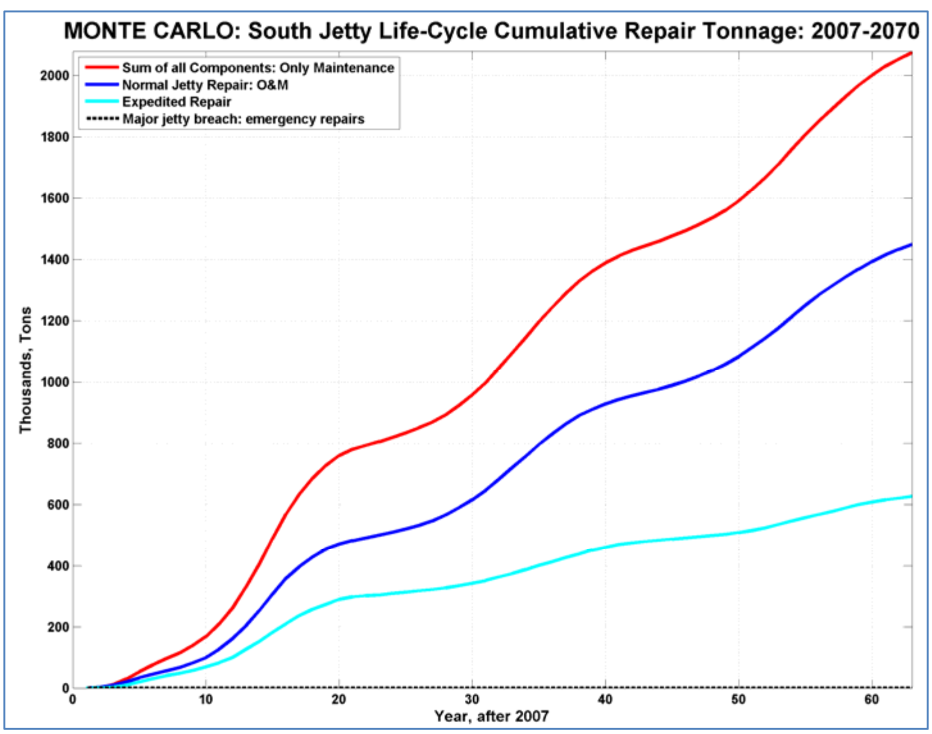
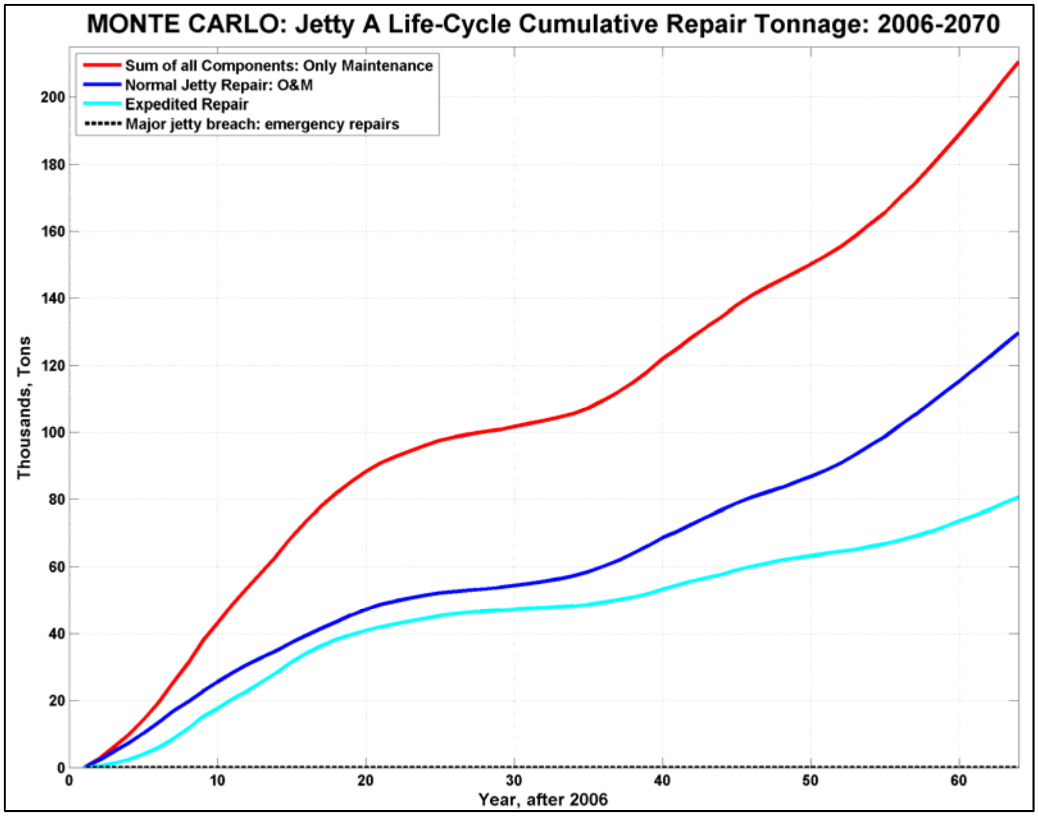


Figure 3-35. Repair tonnage for MCR Jetty "A". Projected estimate is based on the project base condition (no action plan) and begins in 2006, which the last time that jetty "A" was fully surveyed.



3.10. SUMMARY OF ENGINEERING EVALUATION OF ALTERNATIVES

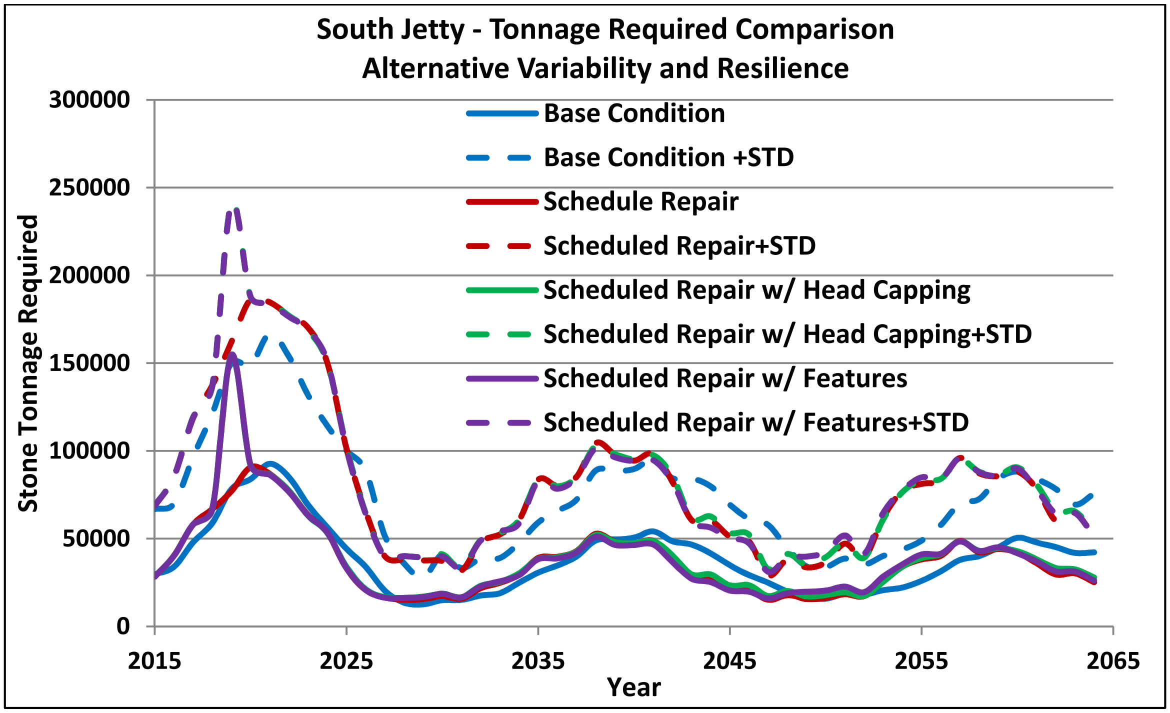
The purpose of this rehabilitation study was to identify and recommend a course of action that would minimize future life-cycle costs and maintain deep-draft navigation for the MCR jetty system. While this was a least cost analysis, various additional elements including project reliability, constructability and access, and potential navigation risk also were considered in the alternative comparisons and rankings. The complexities of major jetty repair in challenging conditions, as well as the feasibility of emergency winter dredging at the MCR, were considered in the final evaluation. Only four contract dredges are capable of dredging at the MCR during winter conditions, and they are normally scheduled for work in milder climates during the winter months. Contract dredges are typically working at projects on the east and gulf coast where work is limited to an environmental window and not expected to be available to mobilize to the west coast. The Corps' dredge ESSAYONS is also generally in repair status and not likely to be available during the winter months.

In short, dredges are typically not available for dredging at the MCR during the winter months when a breach and sudden infill are likely to occur and the risks of dredging at the MCR during that period are very high, so channel depths will likely be lost for an extended period. There typically are two dredges working at MCR for a total of 80-100 days per year to dredge 4-5 MCY during favorable weather each year. The ability to dredge an additional 2-3 MCY (during the winter) is highly unlikely. The best-performing alternative for each jetty was selected by optimizing the initial cost of structure rehabilitation, optimizing future maintenance costs, and considering the time-varying reliability of the jetty.

The alternative plans evaluated spanned the full range of potential actions from the Base Condition which does not include any attempt to slow down the larger, destabilizing processes acting upon the jetties (head recession, toe scour, backside erosion) to a Composite plan rehabilitation, a substantial and robust rehabilitation of the structure in addition to the construction of the stabilizing engineering features. Figure 3-36 through Figure 3-38 below illustrate, using tonnage required over time, how those general types of plans compare over a typical life cycle for the South Jetty, the North Jetty, and Jetty A for the base condition and the 3 least cost alternatives. Results are plotted for the cases with and without holding the jetty heads at their current location. The dashed line shown for each plan indicates the potential variability of the estimate of the mean shown by the solid line. The plans with a lower upfront action (Base Condition and Scheduled Repairs) result in a higher variability for much of the life cycle. The rehabilitation plan, as expected, provides more resilience and less need for repair actions in the near future. These figures combined with the figures that indicate reliability over time for each plan illustrate the trade-offs between a rehabilitation strategy versus a repair strategy.

This section summarizes the results for each MCR jetty and compares the engineering performance of the alternative plans that performed best in each category. Metrics used to assess future jetty performance and compare the alternatives included reliability, constructability and access, potential impacts to larger inlet system, and environmental effects. A summary of the engineering evaluations described above for the best-performing alternatives is provided in the following figures and tables for each MCR jetty.

Figure 3-36. South Jetty – Comparison of variability and resilience of alternative types



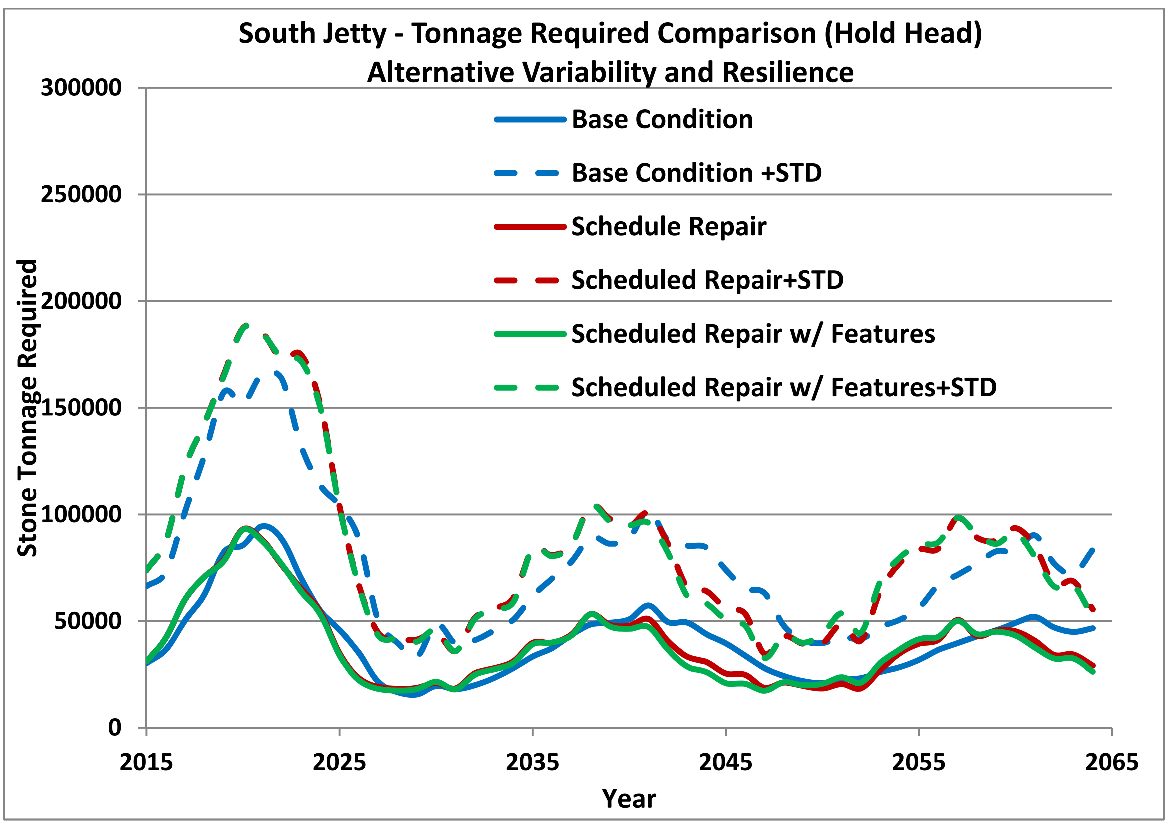
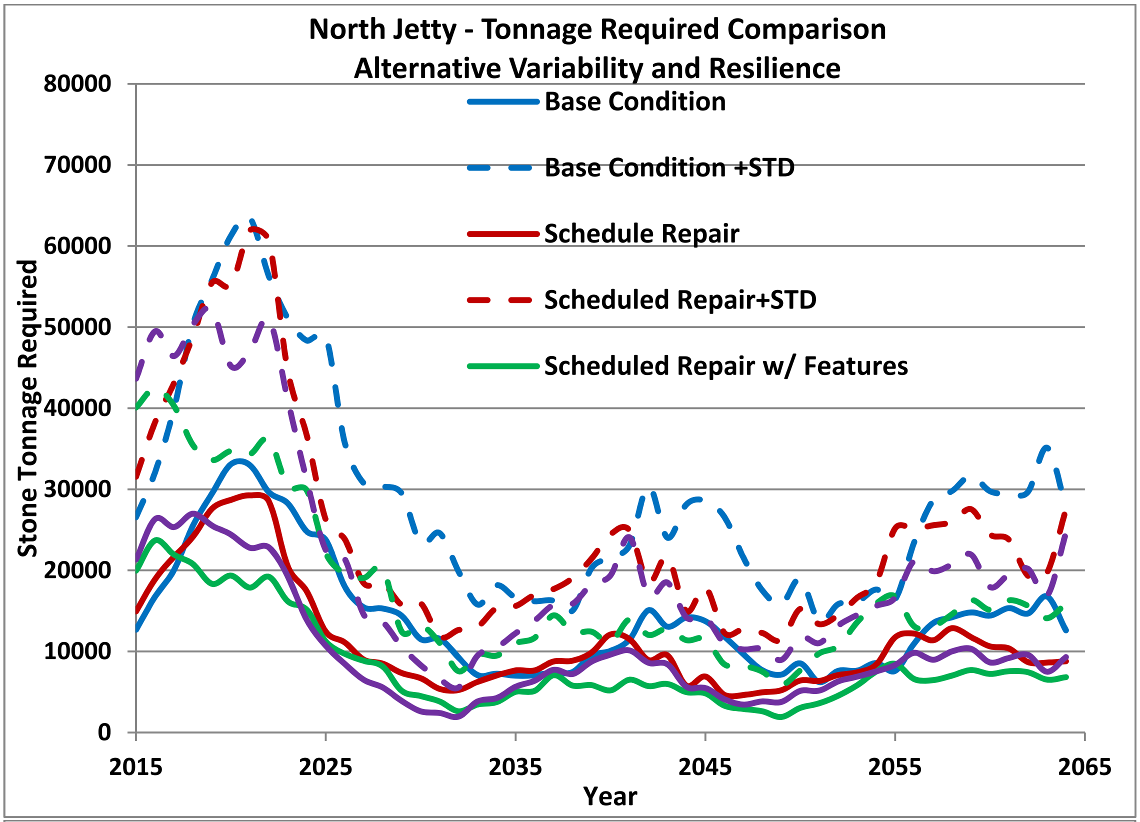


Figure 3-37. North Jetty – Comparison of variability and resilience of alternative types



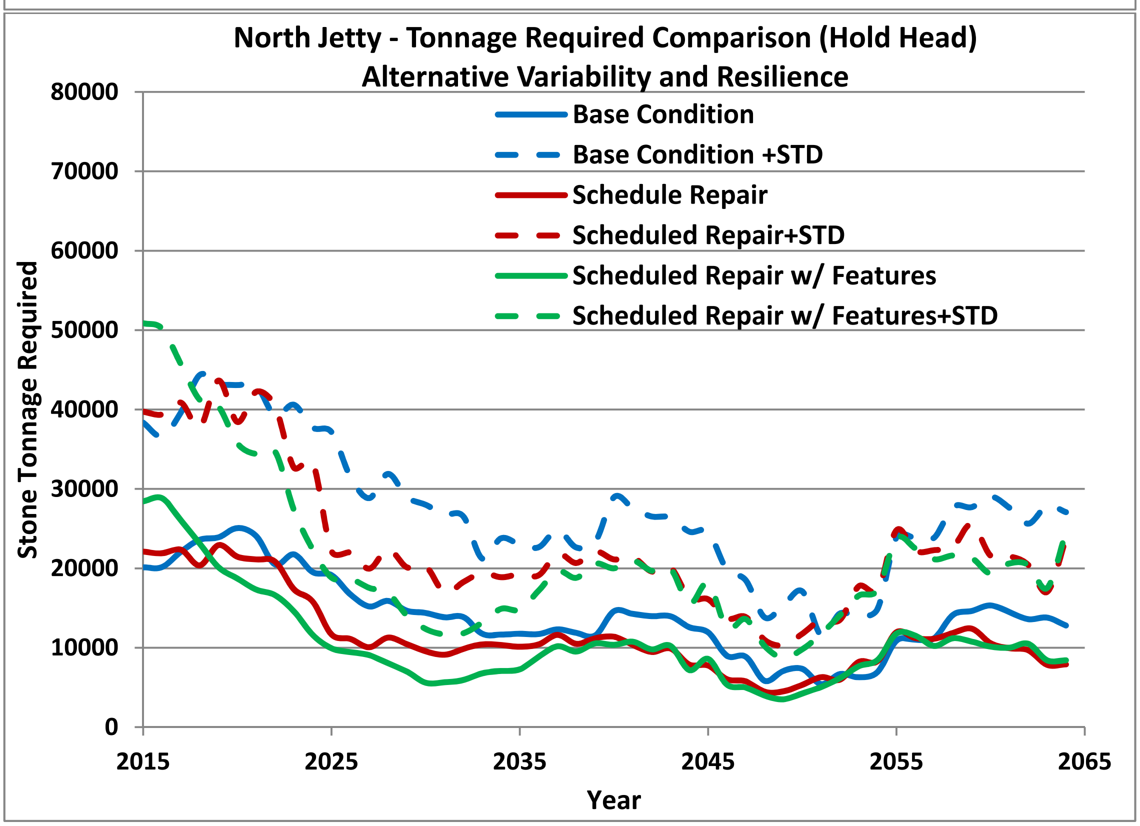
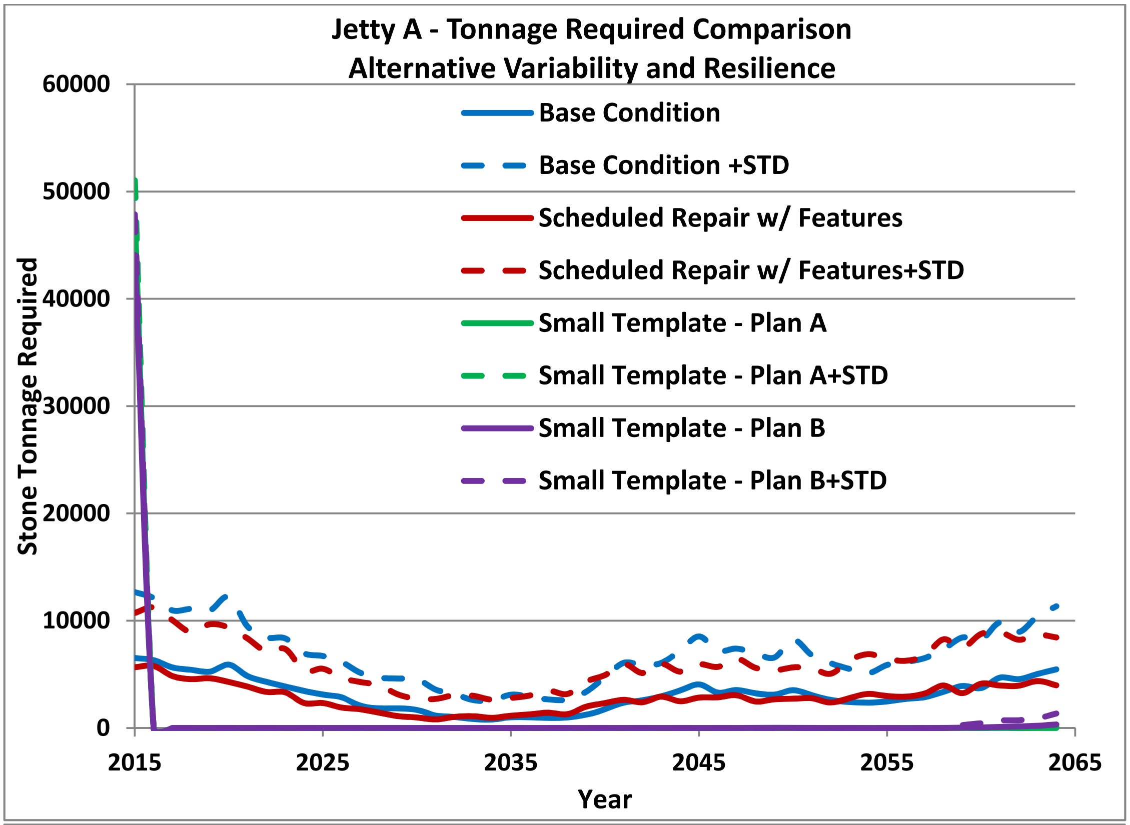
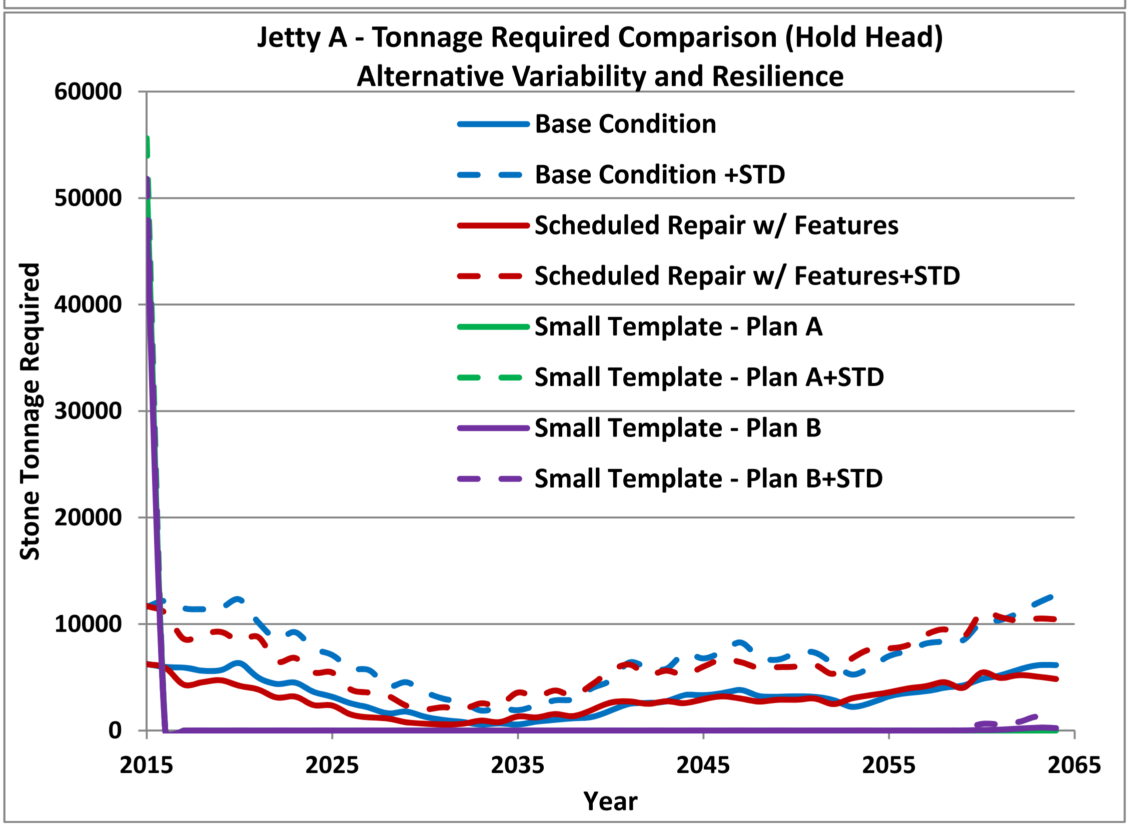


Figure 3-38 Jetty A – Comparison of variability and resilience of alternative types





3.10.1. North Jetty

The North Jetty is distinctive in that it is closest to the navigation channel and serves to hold back very large subaerial and subaqueous sediment features in the form of Benson Beach and Peacock Spit. The existence of this large shoal has served as protection for the ocean side of the North Jetty for a good portion of its life. A major breach along this jetty has the potential to impact navigation if emergency repairs cannot be instituted quickly and/or emergency dredging cannot be conducted for the resulting sediment infill in the channel. For this reason, a major breach along this jetty would result in emergency repairs being instituted immediately, regardless of the time of year or the cost of the repairs. Another significant difference for the North Jetty is the 60- to 80-foot depths on the channel side of the seaward half of the structure, and the rapid loss of jetty length (two to three times the jetty length loss as for the South Jetty and Jetty A).

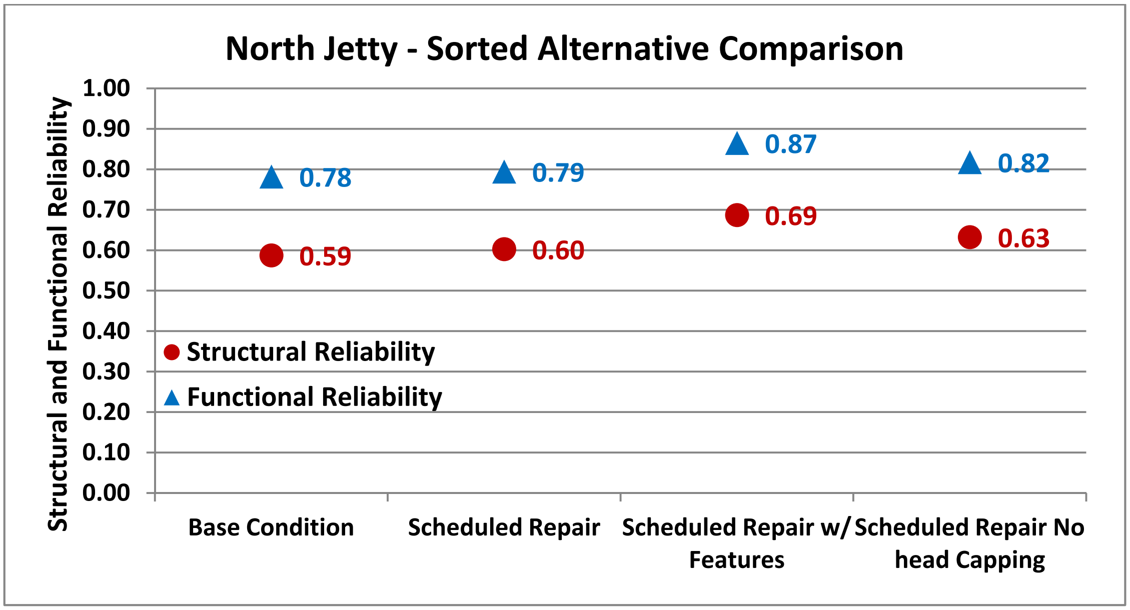
Figure 3-39 summarizes the best performing alternatives in terms of cost, which will be economically evaluated in Section 4, in comparison to the base condition. Structural and functional reliabilities are plotted as black and orange markers, respectively. All of these plans include jetty head stabilization, lagoon fill, and spur groin construction. Figure 3-40 shows the estimated structural and functional reliability over the period of analysis of the project for the best performing alternatives.

Should the repair alternative not be executed, the identified reliabilities and project performance would be impacted. The scheduled-repair-with-features alternative and the minimum cross-section alternative address the stability of the cross section only above water.

On the other end of the spectrum are the full rehabilitation composite plans that address above and below water damage processes along the full length of the North Jetty (composite 3 and composite 4). Each of these attempted to optimize resilience and cost using the graduated levels of cross-section repair along the jetty length. Cross section application increases toward the seaward end of the structure to address the increased forces. All of the plans utilize the minimum cross-section cross section (above-water repair only) for the landward half of the jetty. This portion of the jetty has the lowest exposure to waves in addition to a lower potential impact if failure occurs. All engineering features are included in these plans. Composite 4-small modified applies a more robust cross section from approximately stations 55 to 98 due to increasing damaging wave exposure, increasing foundation depths, and the potential damaging effects of a breach.

The functional and structural reliability scores of the top economic performing alternatives are presented in Figure 3-40.

Figure 3-39. North Jetty Sorted Alternative Comparison



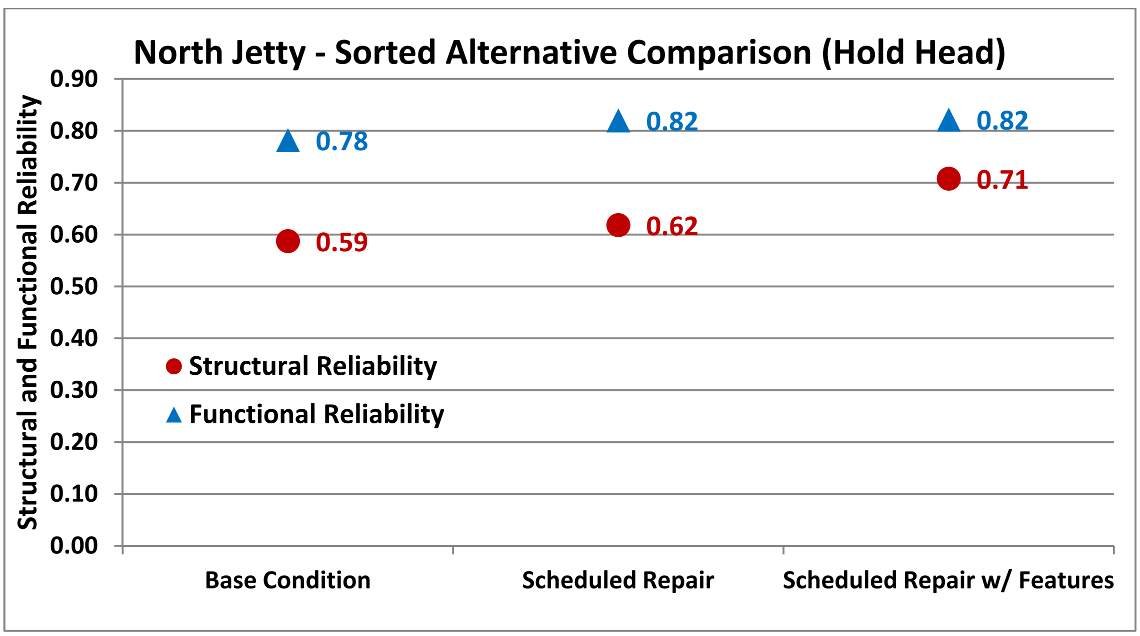
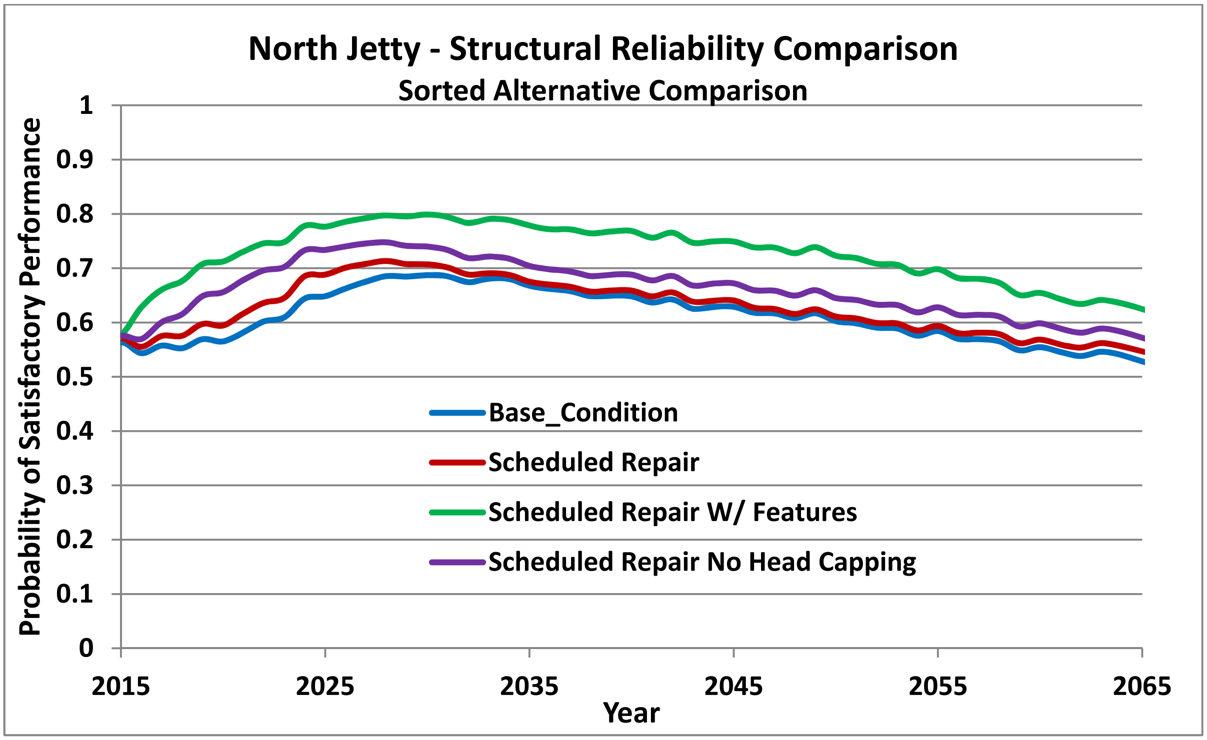
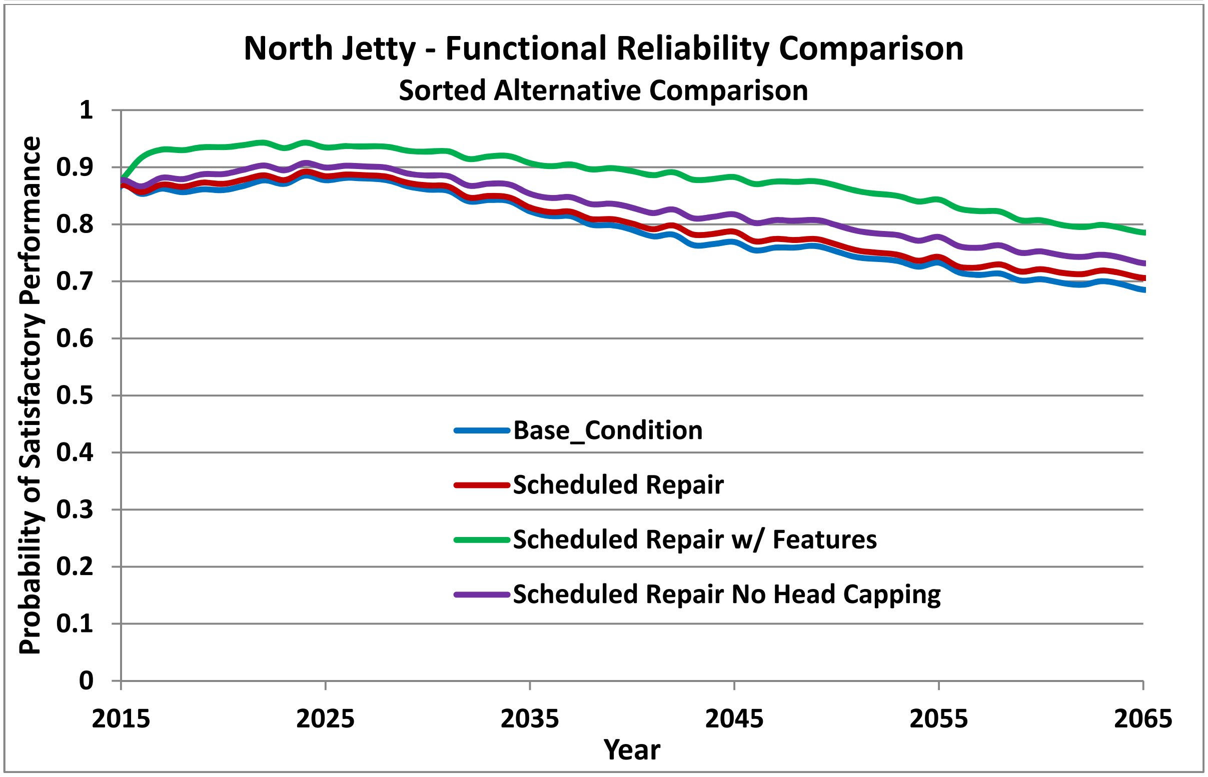
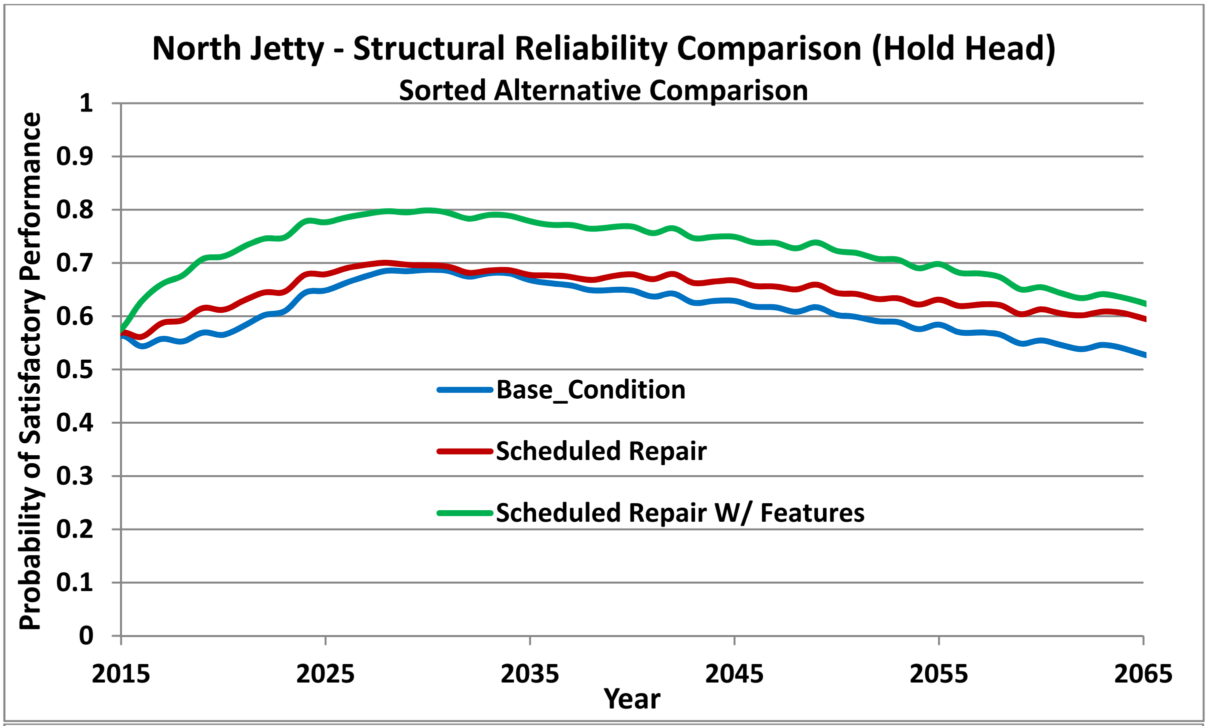
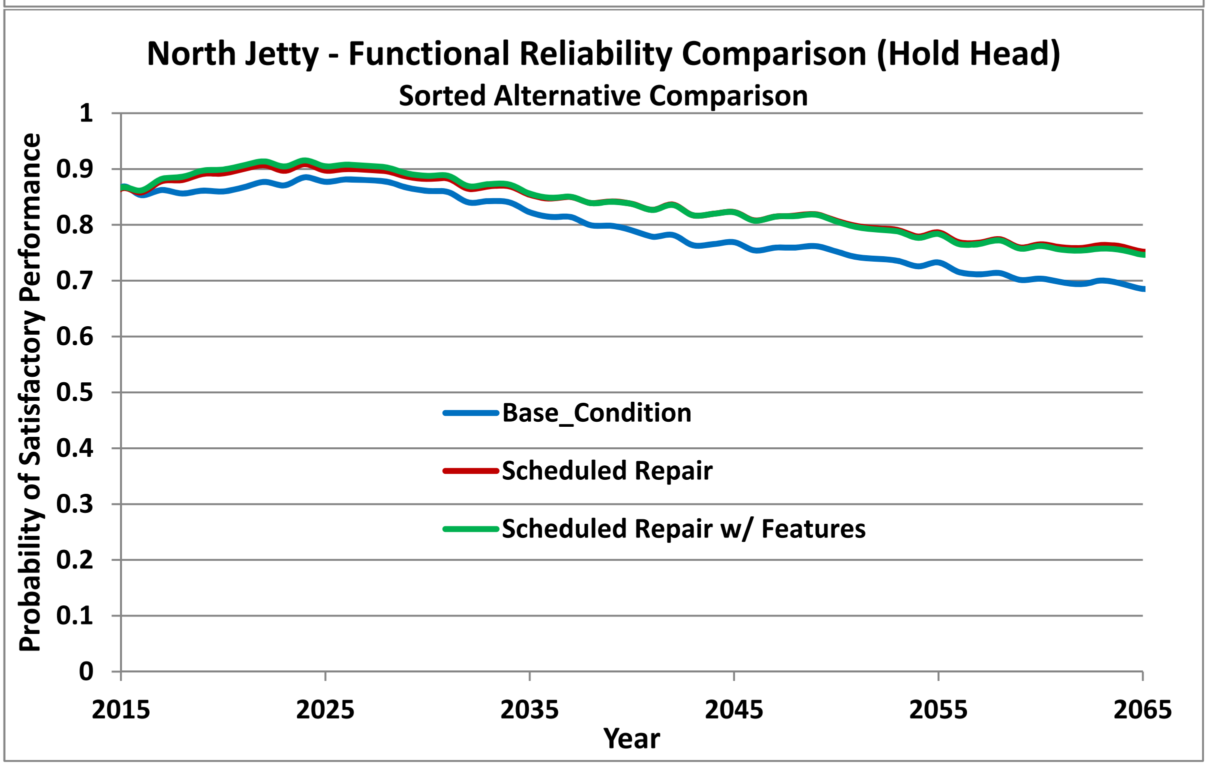


Figure 3-40. North Jetty Reliabilities for Sorted Alternative Comparison






North Jetty - Structural Reliability Comparison (Hold Head)
Sorted Alternative Comparison
Probability of Satisfactory Performance
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
2015
2025
2035
2045
2055
2065
Year
Base_Condition
Scheduled Repair
Scheduled Repair W/ Features


North Jetty - Functional Reliability Comparison (Hold Head)
Sorted Alternative Comparison
Probability of Satisfactory Performance
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
2015
2025
2035
2045
2055
2065
Year
Base_Condition
Scheduled Repair
Scheduled Repair w/ Features

3.10.2. **South Jetty**

The South Jetty is very important to the MCR inlet by serving as a type of anchor to aid in controlling the overall shape of the ebb tidal shoal which ultimately impacts sediment pathways as well as wave approach patterns. The South Jetty is also distinctive in that it extends for over 4 miles out into the ocean and is exposed to the greatest wave forces of any of the structures. The exposed nature of the South Jetty makes it difficult to repair quickly since fall through spring construction on the jetty is too hazardous. Access to the outer half of the jetty is particularly problematic and results in extreme exposure of any equipment being used. The South Jetty is located further from the navigation channel than the North Jetty and a major breach would not immediately impact the channel. Due to a slower potential impact to navigation response and the hazardous access, the South Jetty would not be repaired following a major breach until the following summer.

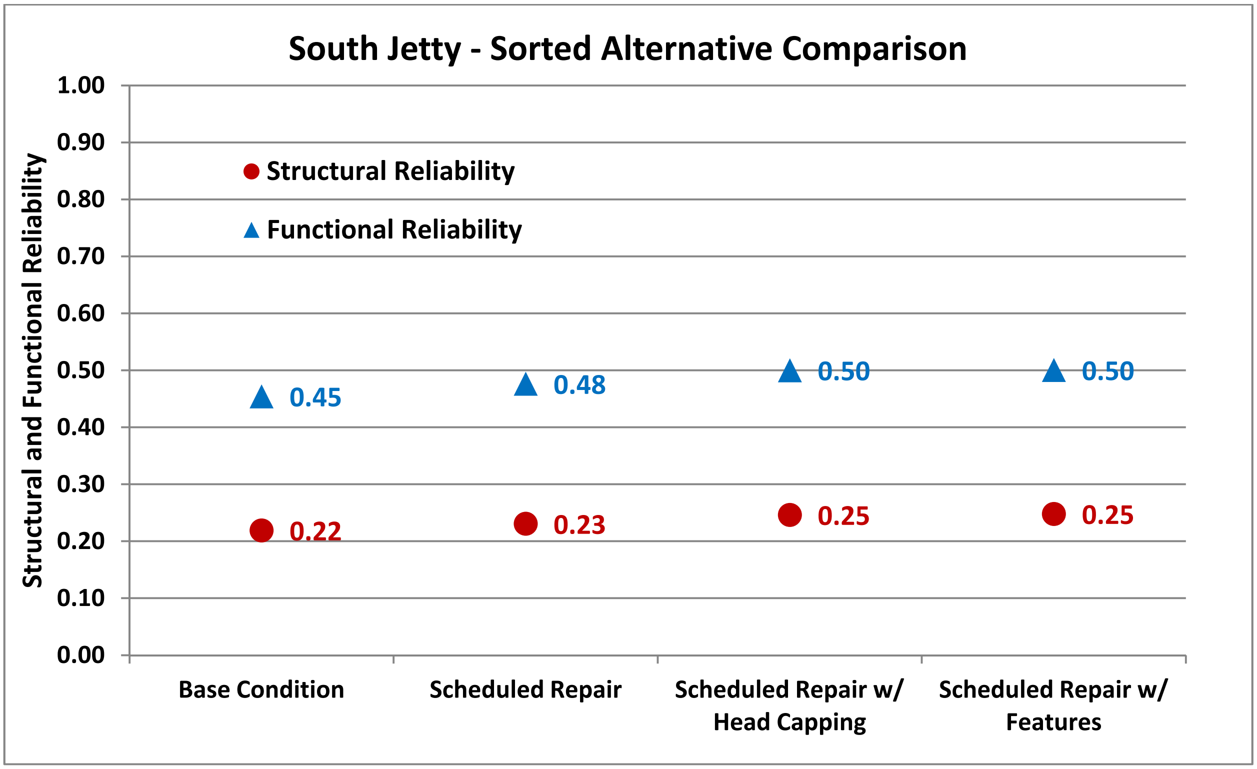
Figure 3-41 summarizes the South Jetty results for the best performing alternatives. These alternatives illustrate the key differences in approach to long-term jetty maintenance. Scheduled repair with features achieves a structural and functional reliability of 0.3 and 0.5, respectively (Figure 3-42).

The two composite alternatives are ranked next. Each of these attempted to optimize resilience using the graduated levels of cross section repair along the jetty length. These alternatives are between the low action plans and the larger full rehabilitation plans.

Because the South Jetty has such extreme exposure and challenging construction conditions, a more robust application of repair/rehabilitation has the potential to optimize life-cycle performance. Two composite alternatives, composite 1-large and composite 4-medium performed over the period of analysis with functional reliabilities of 0.72 and 0.68.

Both composite alternatives utilize the minimum cross section (above water repair only) for the portion of the jetty out to approximately station 175. This portion of the jetty has the lowest wave exposure and a lower potential impact if failure occurs. Composite 1-large applies the largest cross section repair along the jetty length. The small cross-section is placed out to station 180. From stations 180 to 260, the more resilient moderate cross section is constructed. From station 260 to the head, the larger cross section is constructed. The moderate and large cross sections provide a more resilient seaward slope and the large cross section provides a robust toe berm feature. Since the outer half of the South Jetty is most exposed to extreme wave conditions and is the most difficult to access for repair, some discussion centered around the practicality or reasonableness of implementing a smaller cross section along that reach, which would result in multiple repair actions over the life of the structure. All engineering features are included in these alternatives. The top economic performing alternatives are presented in Figure 3-41 and Figure 3-42 in terms of functional and structural reliability. None of the full rehabilitation alternatives were economically competitive, see chapter 4.

Figure 3-41. South Jetty Sorted Alternative Comparison



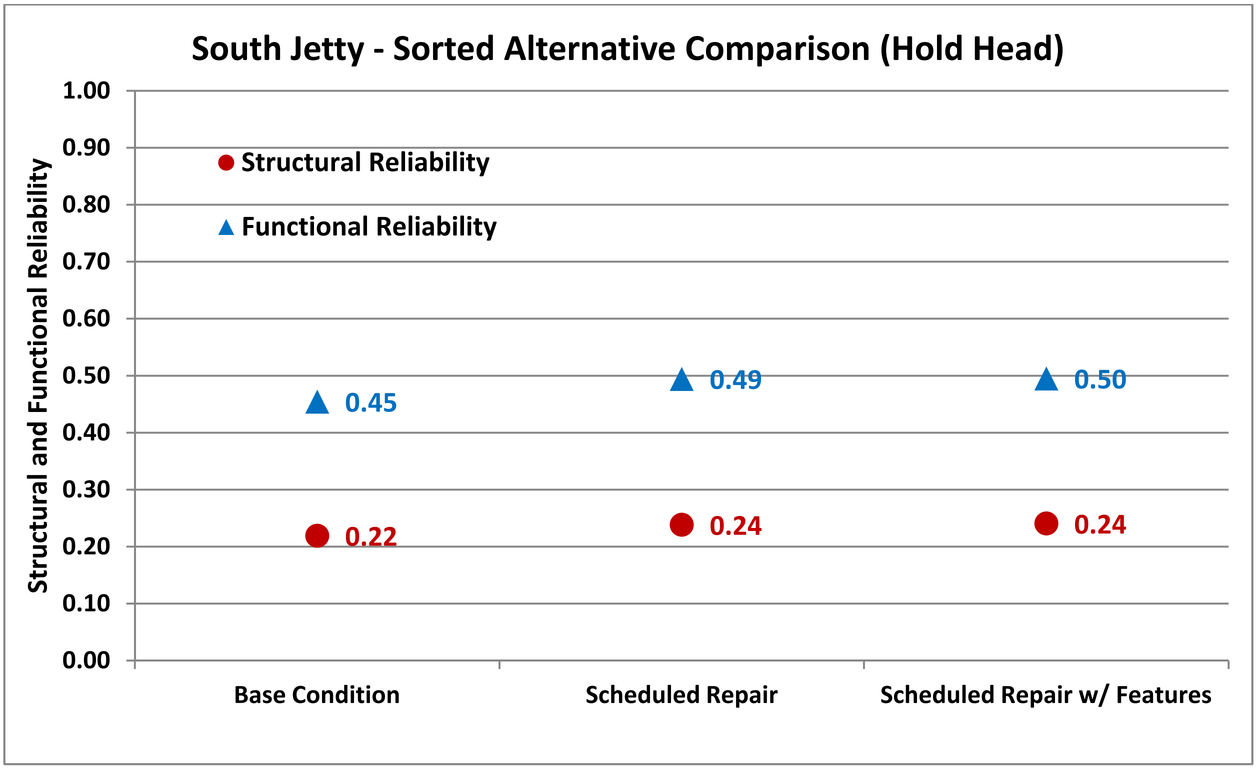
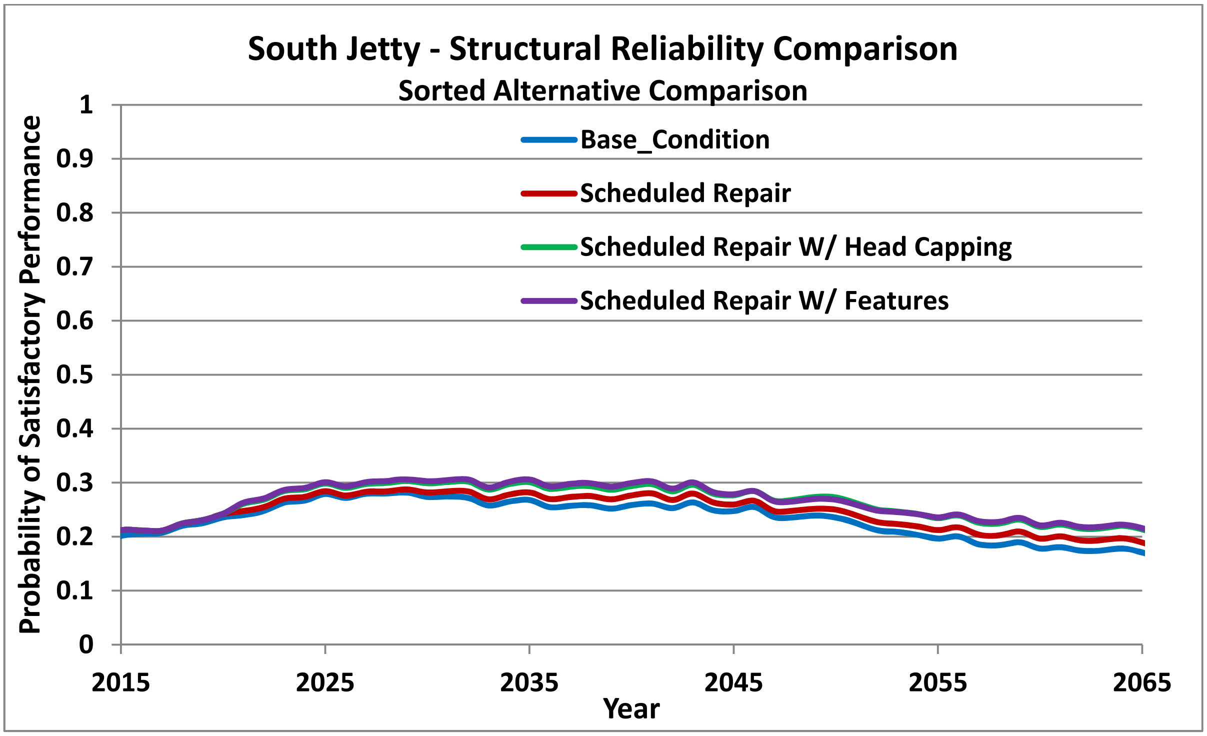


Figure 3-42. South Jetty Reliabilities for Sorted Alternative Comparison



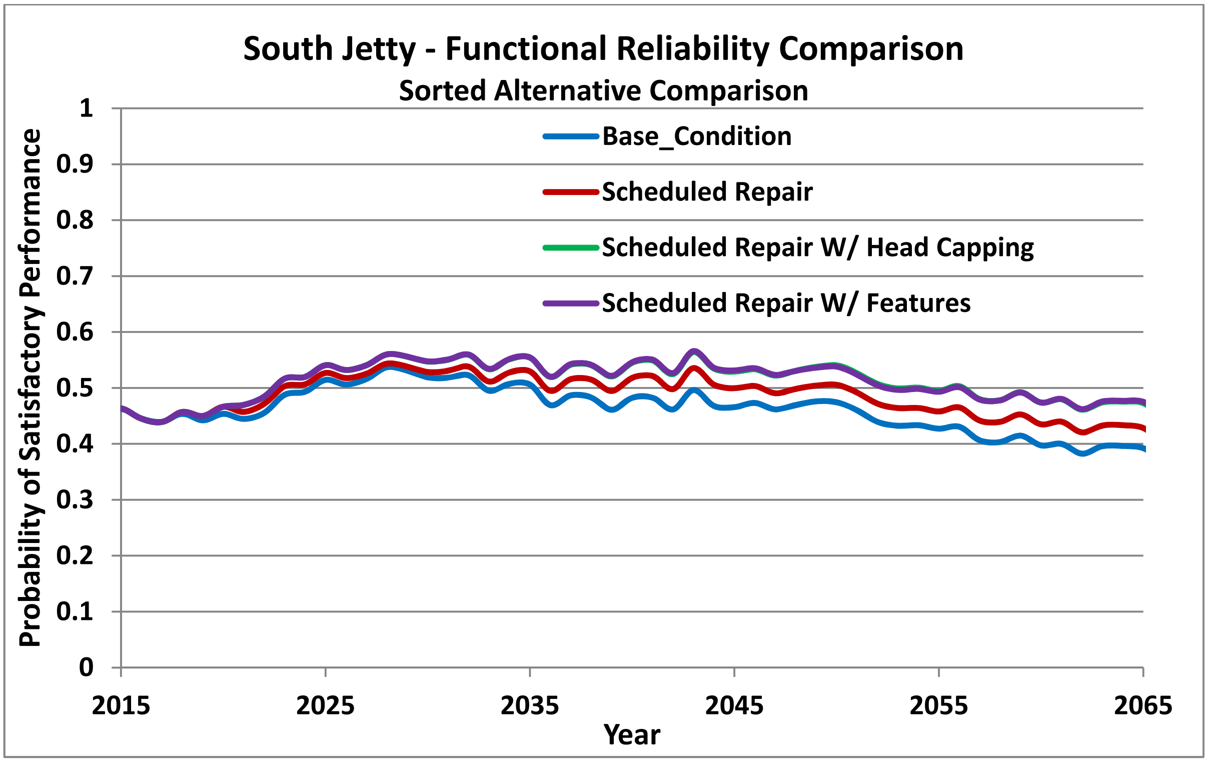
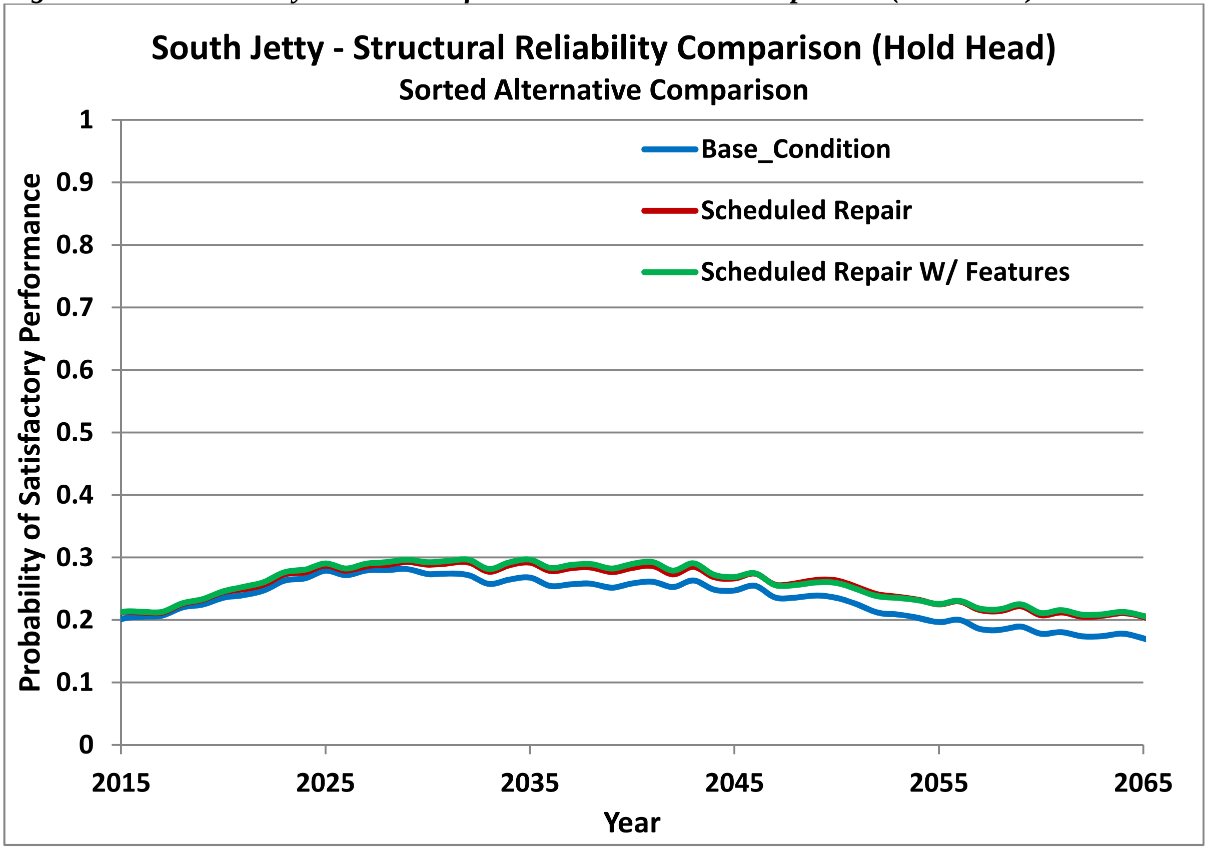
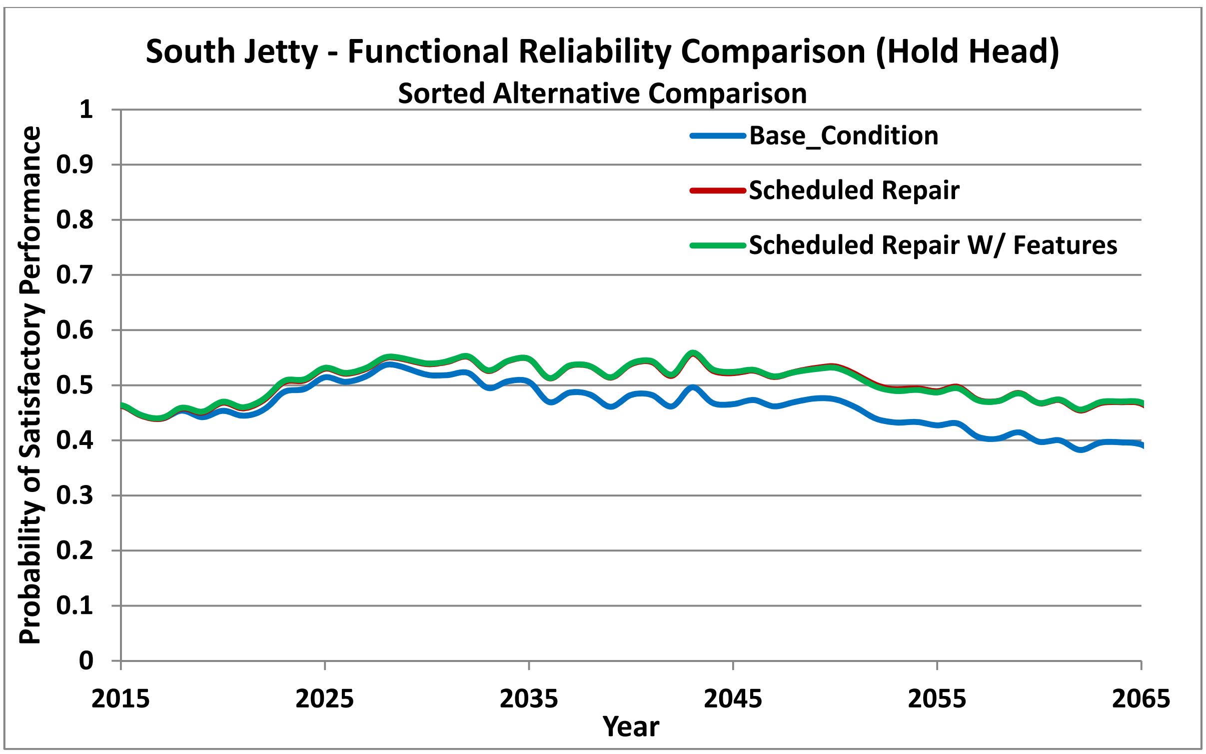


Figure 3-42. South Jetty Reliabilities for Sorted Alternative Comparison (Continued)



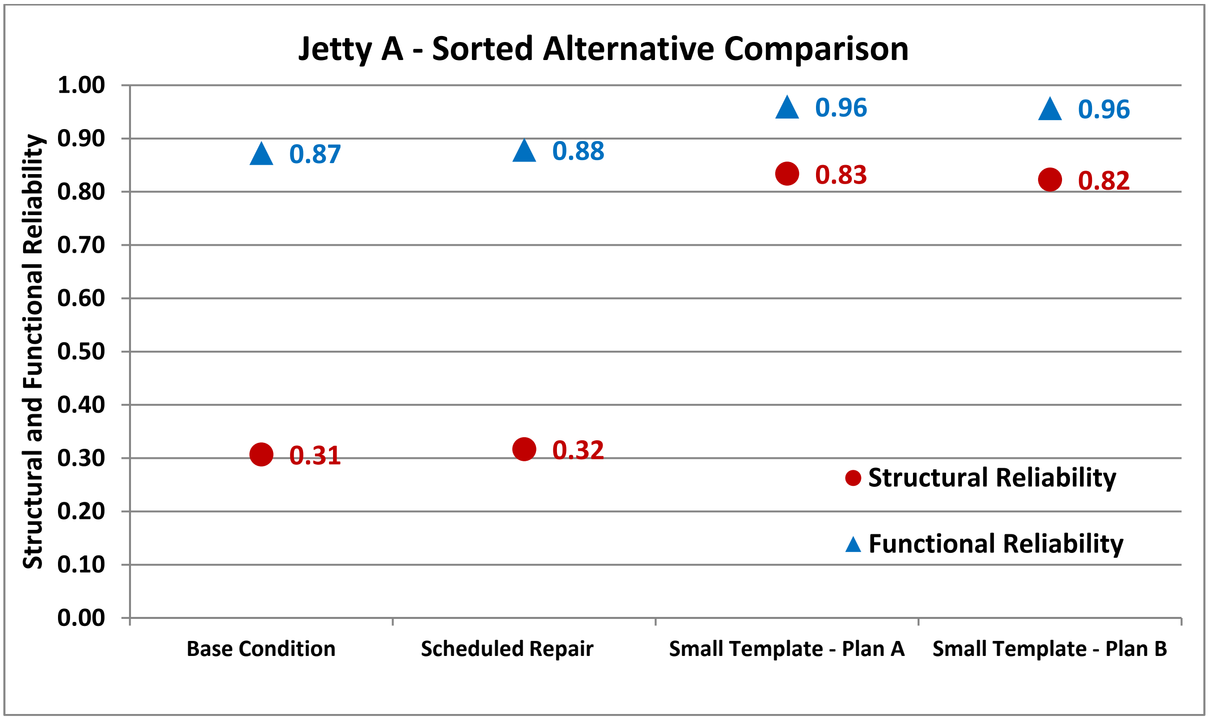


3.10.3. **Jetty A**

Jetty A is less exposed to storm waves than either the North Jetty or the South Jetty. It also is oriented perpendicular to the navigation channel, making a breach in Jetty A less likely to have an immediate impact on the navigation channel. The evolution of Jetty A over time, however, has been impacted by a large +100-foot-deep scour hole that developed off of the south end of the jetty head. The rehabilitation/repair of Jetty A is primarily to maintain a robust cross section and stable jetty length, so that the forces along the length of the North Jetty are controlled and the alignment of the navigation channel remains centered in the inlet.

Figure 3-43 summarizes the Jetty A results for the best performing alternatives. Both the functional and structural reliability values decrease from immediate rehabilitation to scheduled repair to base condition (Figure 3-44). Structural reliability decreases from 0.87 to 0.44 from immediate rehabilitation to scheduled repair, and functional reliability decreases from 0.98 to 0.92. The immediate rehabilitation plan was shown to provide the best life-cycle results for Jetty A.

Figure 3-43. Jetty A Sorted Alternative Comparison



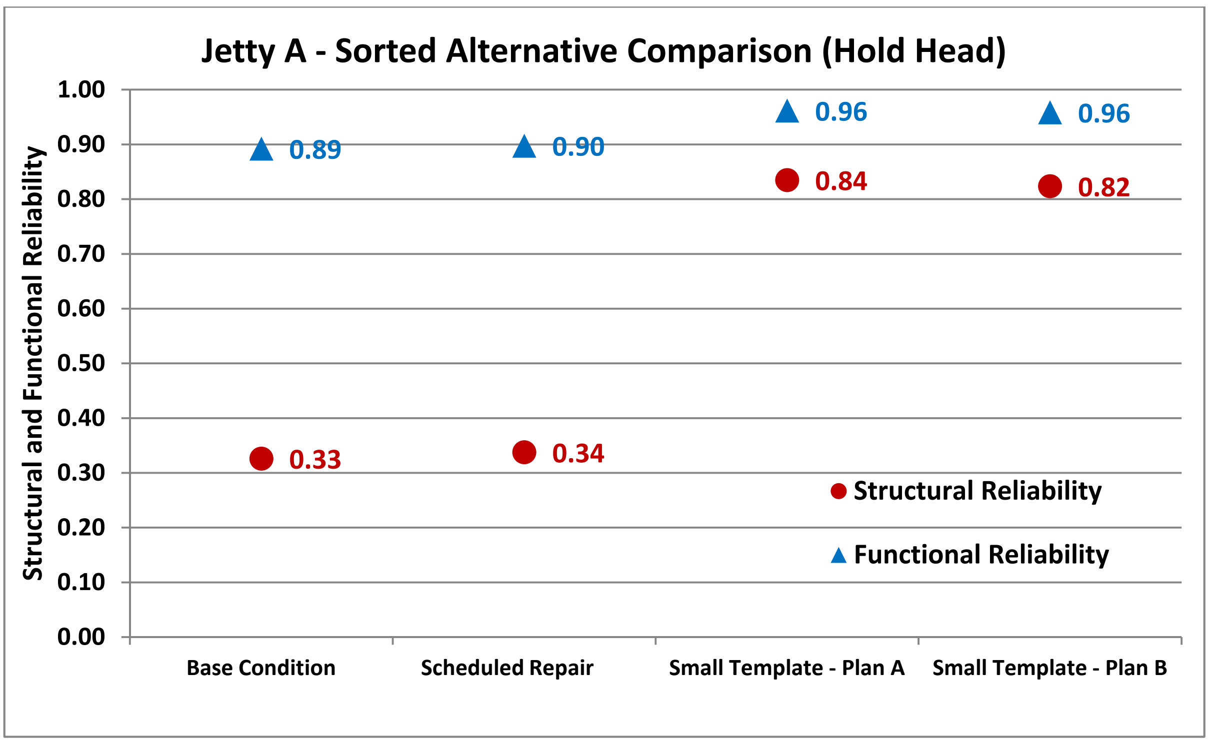
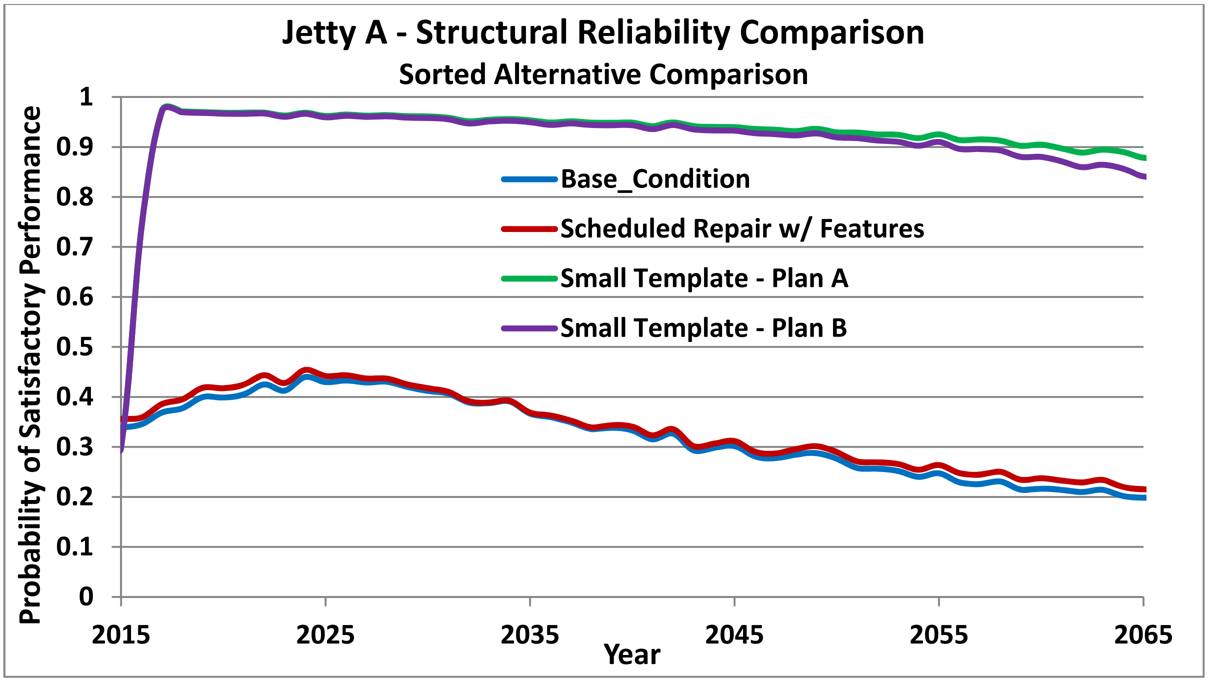


Figure 3-44. Jetty A Reliabilities for Sorted Alternative Comparison



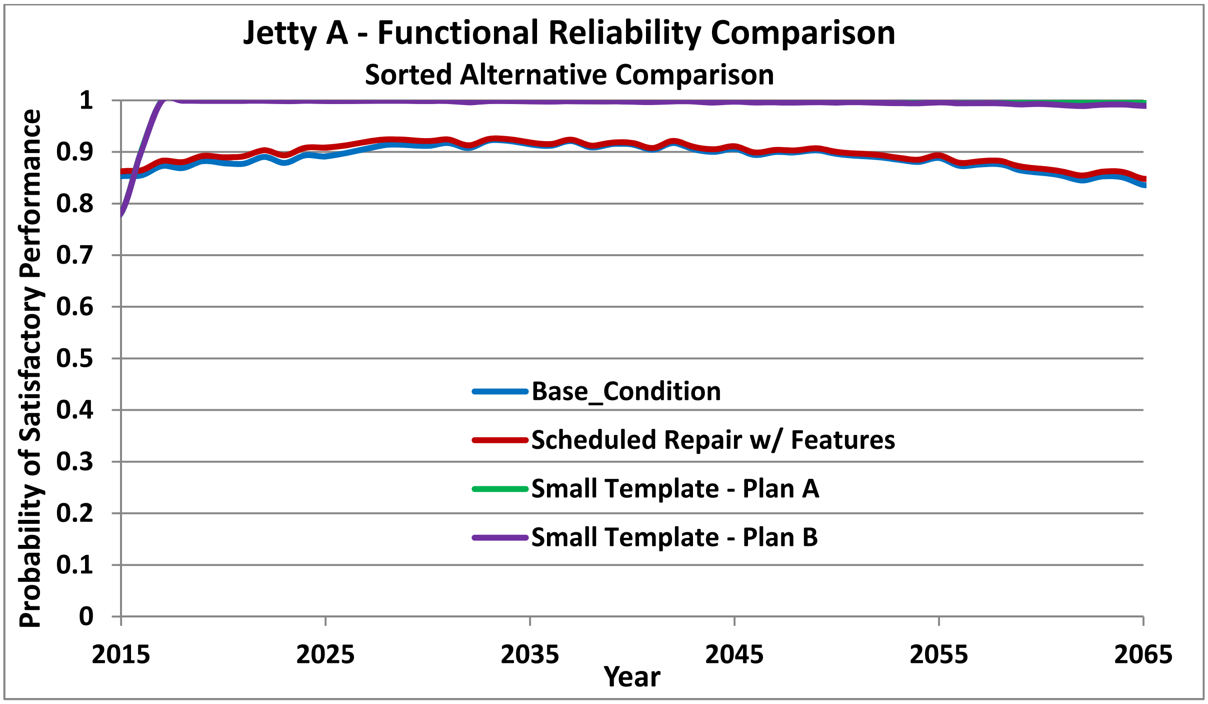
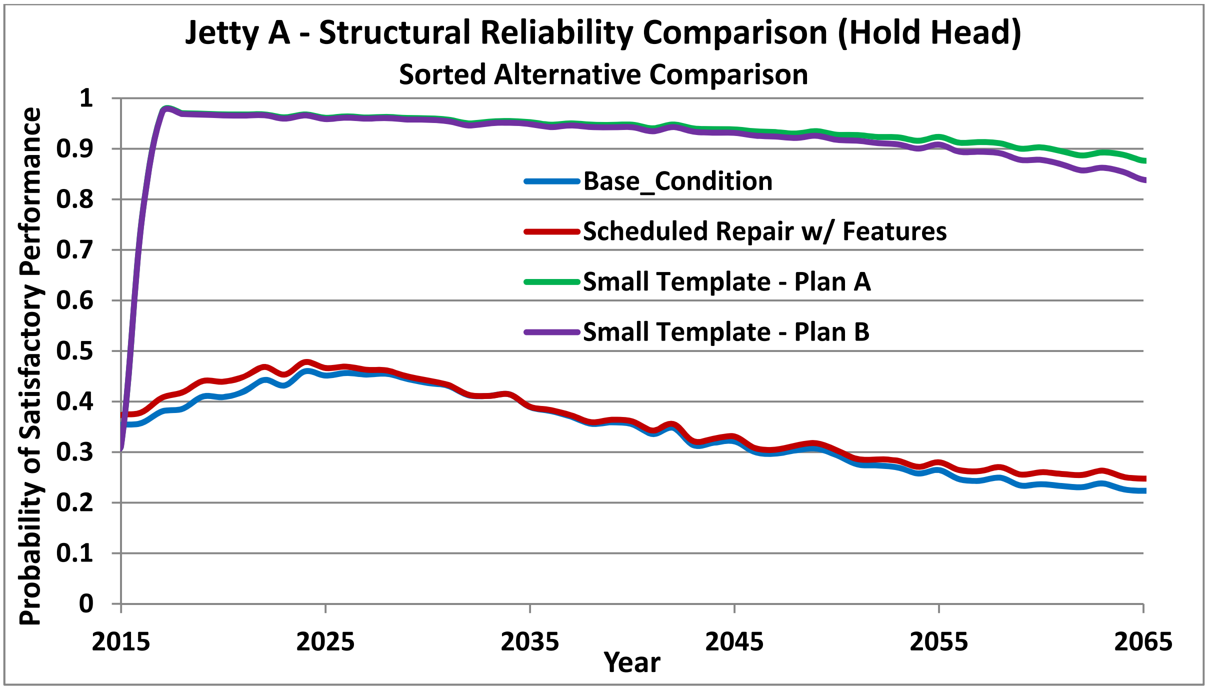
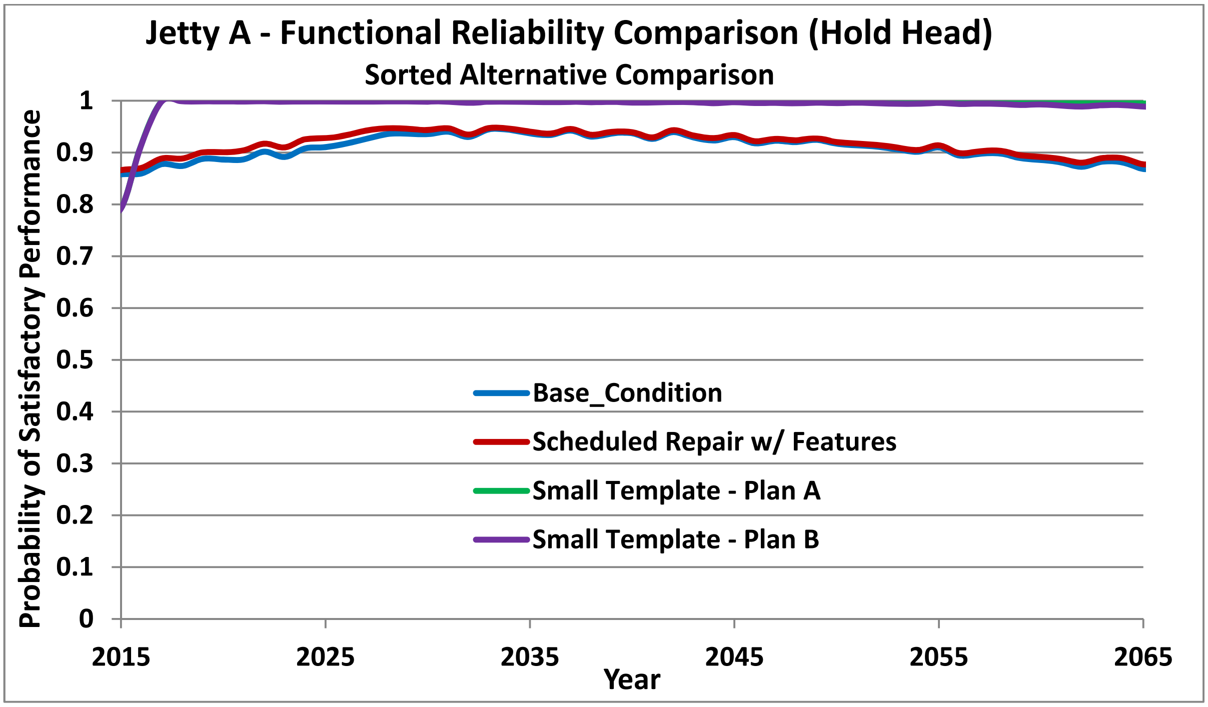


Figure 3-44. Jetty A Reliabilities for Sorted Alternative Comparison (Continued)





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4. ASSESSMENT OF ALTERNATIVES

4.1. INTRODUCTION

This chapter builds upon the previous two chapters to provide a comparison of the alternatives based on initial and life-cycle costs, reliability, and environmental considerations. Based on these comparisons, a recommended plan for each jetty is developed.

The primary function of the MCR project is to maintain the navigation channel for deep draft shipping. The secondary function evaluated in the structure rehabilitation effort is to significantly extend the life and reliability of the jetties in order to reliably maintain the primary function.

An analysis and optimization of the alternatives was performed using a stochastic (probability) risk-based (SRB) life-cycle model developed for the MCR jetties. Each jetty was analyzed separately. The evaluation addressed the following study objectives:

- Maintain deep-draft navigation at the MCR.
- Minimize jetty life-cycle costs.
- Extend the functional life of each jetty, as a system of structural elements.
- Improve the reliability of the three MCR jetty structures.

Analyses were performed pursuant to the following applicable guidance for life-cycle analyses and rehabilitation of coastal navigation infrastructure:

- Coastal Engineering Manual (2006). Engineering Manual 1110-2-1100. U.S. Army Corps of Engineers, Washington, D.C.
- Engineering and Design: Life-Cycle Design and Performance (1997). Engineering Regulation 1110-2-8159. U.S. Army Corps of Engineers, Washington, D.C.
- Engineering Regulation ER-1105-2-100 (2000). Planning Guidance Notebook. U.S. Army Corps of Engineers, Washington, D.C.
- Guidelines for Risk and Uncertainty Analysis in Water Resources Planning, Volume I and II (1992). U.S. Army Corps of Engineers, Institute for Water Resources, Report 92-R-1. Ft Belvoir, VA.
- Reliability and Risk Engineering for Existing Infrastructure (2008). Chapter 3: Basic Features and Methodologies for Reliability Analyses. Engineering Circular 1110-2-6062. U.S. Army Corps of Engineers, Washington, D.C.

4.2. DISCUSSION OF BASE CONDITION AND ENGINEERING CONSIDERATIONS

The MRR base condition reflects three separable actions:

(a) The previous (FY 11) base condition involved a fix-as-fails approach where each jetty was allowed to degrade to as low as 20 percent of the originally authorized cross section and therefore breaches were forecasted. An IEPR comment stated that this assumption was not consistent with historic maintenance practices. As a result, the district changed the base condition to reflect the most likely future jetty maintenance strategy, one that did not allow breaches: interim repair, with the jetty head receding. This assumption reflects that an effective jetty monitoring program can reasonably be expected to recognize any substantial loss of cross section, and that the process of failure, in the case of a large rubble-mound jetty, occurs over a period of years, rather than months.

Due to the level of construction and the high mobilization costs, the revised (FY 12) base condition does not include any jetty head re-construction. Only the trunk and the root of the jetty are maintained, and the jetty head is allowed to recede landward. Maintenance of trunk and root of the jetty is minimized by deferring repair activities into the future for as long as possible. Jetty repairs are initiated only when a failure of the upper portion of the jetty cross section is progressing. The base condition is identified as an interim repair approach because the upper portion of the cross section is allowed to be damaged to approximately 35 percent remaining prior to repair actions being taken. In this way, the jetty is maintained close to the margin of functional loss without breaching.

(b) The South Jetty dune augmentation and stabilization at its root is part of the without-project condition and is funded in the FY 13 Presidential budget for $5.5M.

(c) North Jetty Major Maintenance Report (MMR) actions: Lagoon fill between STA 20 to 60; and critical repairs between STA 86 to 99.

A more detailed discussion of the Base Condition is in Section 3.8.3 and Section 16 of Appendix A2.

4.3. KEY ASSUMPTIONS

The purpose of this rehabilitation study was to identify and recommend a course of action which minimizes the future life-cycle costs and maintain deep-draft navigation for the MCR jetty system. The starting point for this evaluation was to formulate alternatives that met the project purpose, and met acceptable levels of project reliability, constructability, and potential navigation risk. Alternatives varied by jetty geometry, including crest-width and -height, side slope, benching, and whether or not they included engineering features (spur groins and capping). The alternatives were further distinguished by holding the head location through reconstruction of cross-section, or through capping. These alternatives were evaluated using the SRB model providing required repair volumes through time and by reach. The required repair volumes were converted to life-cycle cost and ultimately to an average annual cost for each alternative. The life-cycle costs included initial construction cost, repair cost, and their timing after rehab. The average annual cost of each alternative was put in ranked order and the recommended plan was chosen based on least-cost.

Alternatives including rebuilding submerged sections of each jetty were screened out in the early phases of the study. These alternatives included rebuilding up to the full authorized length, constructing jetty heads on currently submerged relic stone, rebuilding the cross-section off of the existing footprint, and realigning the jetties. Hence, these alternatives were unacceptable and eliminated from further consideration because they were either outside of the authorized project, or deemed unacceptable from a constructability standpoint. The current length of each jetty is generally deemed to result in an acceptable level of navigation access and maintenance dredging, meaning that rebuilding submerged sections of the jetty would have limited potential benefit. Although it was conclusively demonstrated that use of extremely large, dense stone in larger cross sections will reduce future maintenance costs, none of the rehabilitation alternatives proved to be cost effective.

The recommended plan will identify the optimum investment both in terms of proposed actions and timing of proposed actions, given the risk and uncertainty identified during the study. This plan will offer the greatest benefit to the project with respect to cost while still meeting the project goals.

4.4. ALTERNATIVE PLAN SELECTION SCREENING

4.4.1. Screening Level 1

The Corps began looking at applying a system approach to the MCR entrance in 1999, had an interruption from study to conduct interim repairs on the North Jetty in 2005, and the South Jetty in 2006 and 2007. In 2006 the major rehabilitation study continued, evaluations began with an analysis of where the end of each of three jetties should be at the mouth of the Columbia River and developed three jetty length options:

- rebuild the jetties beyond their authorized lengths
- rebuild the jetties to their authorized lengths
- rebuild the jetties to the midpoint between the authorized length and the existing jetty end station
- rehabilitating the jetties to the current end stations

Consideration was given to alternatives that re-aligned the jetties off of the existing footprint and alternatives that included cross-sections that extended well beyond the relic stone. Table 4-1 displays the alternatives that were formulated and removed from further consideration and reasons why these alternatives were screen out.

Table 4-1 Alternatives Formulated and Removed From Further Consideration

Alternative	Currently Authorized	Environmental Concerns	Justification for Removal
Jetty Lengths			
Extending Jetties beyond their authorized length	No	Numerous	Not brought forward due to cost and authorization.
Rebuilding Jetties to their authorized length	Yes	Some	Not brought forward due to high cost, concerns on constructability due to scour holes at the end of N. and S. Jetties; and therefore not cost effective.
Rebuilding Jetty head at midpoint between authorized length and existing length	Yes	Some	Numerical modeling did not conclude a change to circulation patterns; therefore, it was determined there was no benefit to the navigation channel for the investment cost.
Jetty Alignment			
Reconstruct North and South Jetty alignment to improve inlet conditions, reduce O&M dredging	No	Not likely to be acceptable to the resource agencies and the public	Not brought forward due to authorization issues and significant environmental concerns. The improvements to the navigation channel were uncertain and not justified when compared to cost of construction.
Cross-section			
Increasing the cross-section of the jetty beyond the relic stone for foundation and structural stability	No	Numerous	Not brought forward due to authorization issues and numerous environmental concerns. The improvements to the navigation channel were uncertain and not justified when compared to cost of construction.

4.4.2. Screening Level 2

Based on this screening effort project alternatives were developed on the basis that the end of the jetties would not extend past their existing length. The alternatives developed in Chapter 3 were compared using the SRB model with the results being displayed below for each of the three jetties. Alternatives in Table 4-2, 4-3 and 4-4 are those that remain for consideration. The table displays average annual costs (AAC) and demarcated based on benefit to cost ratios (BCR) greater than unity and for the South Jetty near unity, because the South Jetty had no alternatives above unity when costs are compared to the base condition. Those alternatives that are shaded in the table were removed from further consideration.

Table 4-2 North Jetty Alternatives Remaining For Consideration

Alternative	Alternative Description	Average Annual Cost ($1,000)	Benefit Cost Ratio	Rank
NJ-17	Scheduled Repair (Hold Head)	2,891	1.09	1
NJ-02	Scheduled Repair	2,948	1.07	2
NJ-04	Scheduled Repair w/ Spur	2,964	1.06	3
NJ-16	Base Condition (Hold Head)	2,985	1.05	4
NJ-18	Scheduled Repair w/ Engineering Features (Hold Head)	3,036	1.04	5
NJ-19	Scheduled Repair w/ Spur (Hold Head)	3,036	1.04	5
NJ-01	Base Condition	3,143	-	7
NJ-03	Scheduled Repair w/ Engineering Features	3,200	0.98	8
NJ-14	Moderate Cross-section Rehab - Scheduled	4,762	0.66	9
NJ-29	Moderate Cross-section Rehab - Scheduled (Hold Head)	4,872	0.65	10
NJ-10	Composite 3 Small Rehab - Scheduled	4,872	0.65	11
NJ-11	Composite 4 Small Modified Rehab - Scheduled	4,977	0.63	12
NJ-07	Moderate Cross-section Rehab - Immediate	5,007	0.63	13
NJ-26	Composite 4 Small Modified Rehab - Scheduled (Hold Head)	5,017	0.63	14
NJ-22	Moderate Cross-section Rehab - Immediate (Hold Head)	5,036	0.62	15
NJ-21	Composite 4 Small Rehab - Immediate (Hold Head)	5,051	0.62	16
NJ-06	Composite 4 Small Rehab - Immediate	5,090	0.62	17
NJ-25	Composite 3 Small Rehab - Scheduled (Hold Head)	5,141	0.61	18
NJ-09	Minimum Cross-section Rehab - Scheduled	5,279	0.60	19
NJ-05	Minimum Cross-section Rehab - Immediate	5,297	0.59	20
NJ-12	Composite 2 Medium Rehab - Scheduled	5,385	0.58	21
NJ-13	Composite 1 Large Rehab - Scheduled	5,441	0.58	22
NJ-28	Composite 1 Large Rehab - Scheduled (Hold Head)	5,491	0.57	23
NJ-24	Minimum Cross-section Rehab - Scheduled (Hold Head)	5,605	0.56	24
NJ-20	Minimum Cross-section Rehab - Immediate (Hold Head)	5,649	0.56	25
NJ-27	Composite 2 Medium Rehab - Scheduled (Hold Head)	5,649	0.56	26
NJ-15	Large Cross-section Rehab - Scheduled	6,889	0.46	27
NJ-30	Large Cross-section Rehab - Scheduled (Hold Head)	6,936	0.45	28
NJ-23	Large Cross-section Rehab - Immediate (Hold Head)	7,338	0.43	29
NJ-08	Large Cross-section Rehab - Immediate	7,395	0.43	30

Table 4-3 South Jetty Alternatives Remaining For Consideration

Alternative	Alternative Description	Average Annual Cost ($1,000)	Benefit Cost Ratio	Rank
SJ-01	Base Condition	9,567	-	1
SJ-04	Scheduled Repair	9,650	0.99	2
SJ-16	Base Condition (Hold Head)	9,652	0.99	3
SJ-18	Scheduled Repair w/ Spur Groins (Hold Head)	9,701	0.99	4
SJ-17	Scheduled Repair w/ Engineering Features (Hold Head)	9,744	0.98	5
SJ-19	Scheduled Repair (Hold Head)	9,786	0.98	6
SJ-03	Scheduled Repair w/ Spur Groins	10,082	0.95	7
SJ-02	Scheduled Repair w/ Engineering Features	10,116	0.95	8
SJ-10	Composite 4 Medium Rehab - Immediate	10,817	0.88	9
SJ-25	Composite 4 Medium Rehab - Immediate (Hold Head)	10,862	0.88	10
SJ-13	Composite 2 Modified 1 Rehab - Immediate	11,171	0.86	11
SJ-11	Composite 1 Large Rehab - Immediate	11,208	0.85	12
SJ-28	Composite 2 Modified 1 Rehab - Immediate (Hold Head)	11,211	0.85	13
SJ-26	Composite 1 Large Rehab - Immediate (Hold Head)	11,248	0.85	14
SJ-12	Composite 5 Modified 2 Rehab - Immediate	11,433	0.84	15
SJ-27	Composite 5 Modified 2 Rehab - Immediate (Hold Head)	11,473	0.83	16
SJ-15	Composite 5 Modified 2 Rehab - Scheduled	11,523	0.83	17
SJ-30	Composite 5 Modified 2 Rehab - Scheduled (Hold Head)	11,544	0.83	18
SJ-08	Moderate Cross-section Rehab - Immediate	11,671	0.82	19
SJ-07	Small Cross-section Rehab - Immediate	11,703	0.82	20
SJ-23	Moderate Cross-section Rehab - Immediate (Hold Head)	11,705	0.82	21
SJ-22	Small Cross-section Rehab - Immediate (Hold Head)	11,858	0.81	22
SJ-09	Large Cross-section Rehab - Immediate	12,605	0.76	23
SJ-24	Large Cross-section Rehab - Immediate (Hold Head)	12,642	0.76	24
SJ-06	Composite 3 Small Rehab - Immediate	12,699	0.75	25
SJ-21	Composite 3 Small Rehab - Immediate (Hold Head)	12,737	0.75	26
SJ-05	Minimum Cross-section Rehab - Immediate	13,480	0.71	27
SJ-14	Minimum Cross-section Rehab - Scheduled	13,502	0.71	28
SJ-29	Minimum Cross-section Rehab - Scheduled (Hold Head)	13,673	0.70	29
SJ-20	Minimum Cross-section Rehab - Immediate (Hold Head)	13,692	0.70	30

Table 4-4 Jetty A Alternatives Remaining For Consideration

Alternative	**Alternative Description**	**Average Annual Cost ($1,000)**	**Benefit Cost Ratio**	**Rank**
JA-06	Scheduled Repair (Hold Head)	913	1.42	1
JA-05	Base Condition (Hold Head)	1,000	1.30	2
JA-08	Small Cross-section Rehab (Plan B) - Immediate (Hold Head)	1,086	1.19	3
JA-04	Small Cross-section Rehab (Plan B) - Immediate	1,114	1.16	4
JA-07	Small Cross-section Rehab (Plan A) - Immediate (Hold Head)	1,164	1.11	5
JA-02	Scheduled Repair	1,192	1.09	6
JA-03	Small Cross-section Rehab (Plan A) - Immediate	1,200	1.08	7
JA-01	Base Condition	1,297	-	8

No alternatives were screened at this level using the level 2 methodology of removing all alternatives with BCRs lower than unity.

4.4.3. Screening Level 3

This section takes the above-the-line portion from screening level 2 for the North and South Jetties and Jetty A from Tables 4-2, -3 and -4 respectively.

Additional screen will be applied, with the actions bulletized below each table for screening level 3.

Table 4-5 North Jetty Alternatives Remaining For Consideration

Alternative	Alternative Description	Rehab Cost ($1,000)	O&M Repair ($1,000)	Expedited Repairs ($1,000)	Dredge Costs ($1,000)
NJ-17	Scheduled Repair (Hold Head)	0	52,625	8,227	1,263
NJ-02	Scheduled Repair	0	52,578	5,687	5,059
NJ-04	Scheduled Repair w/ Spur	6,529	50,833	4,564	1,756
NJ-16	Base Condition (Hold Head)	0	45,581	17,239	1,297
NJ-18	Scheduled Repair w/ Engineering Features (Hold Head)	6,529	52,657	5,917	1,080
NJ-19	Scheduled Repair w/ Spur (Hold Head)	6,529	52,657	5,917	1,080
NJ-01	Base Condition	0	43,483	18,294	5,745

Level 3 Screening occurred as below:

- Alternatives NJ-0 4, NJ-18 and NJ-19 were removed from consideration because the upfront rehabilitation costs did not appreciably reduce O&M repair costs over time as compared with North Jetty alternatives.
- Alternatives NJ-01 and NJ-16 were removed from further consideration due to their high expedited repair costs and the higher inherent risk to life safety and channel function.

Table 4-6 South Jetty Alternatives Remaining For Consideration

Alternative	Alternative Description	Rehab Cost ($1,000)	O&M Repair ($1,000)	Expedited Repairs ($1,000)	Dredge Costs ($1,000)
SJ-01	Base Condition	0	124,369	65,319	15,825
SJ-04	Scheduled Repair	0	155,249	38,803	13,263
SJ-16	Base Condition (Hold Head)	0	133,035	70,856	3,448
SJ-18	Scheduled Repair w/ Spur Groins (Hold Head)	3,560	159,571	44,264	1,005

Level 3 comparison occurred as below:

- SJ-08 was removed from consideration because the upfront rehabilitation costs did not appreciably reduce O&M repair costs over time as compared with South Jetty alternatives.

Table 4-7 Jetty A Alternatives Remaining For Consideration

Alternative	**Alternative Description**	**Rehab Cost ($1,000)**	**O&M Repair ($1,000)**	**Expedited Repairs ($1,000)**	**Dredge Costs ($1,000)**	**Added Costs to NJ ($1,000)**
JA-06	Scheduled Repair (Hold Head)	0	15,289	4,078	251	0
JA-05	Base Condition (Hold Head)	0	11,674	9,551	249	0
JA-08	Small Cross-section Rehab (Plan B) - Immediate (Hold Head)	23,034	188	127	-5	-8
JA-04	Small Cross-section Rehab (Plan B) - Immediate	26,994	113	112	164	22
JA-07	Small Cross-section Rehab (Plan A) - Immediate (Hold Head)	24,721	165	123	-5	-8
JA-02	Scheduled Repair	0	14,806	4,058	5,717	1,022
JA-03	Small Cross-section Rehab (Plan A) - Immediate	28,868	93	109	164	22
JA-01	Base Condition	0	10,981	9,948	5,884	1,053

Jetty A was constructed to help train the Columbia River as well as provide added protection to the channel side foundation of the North Jetty. As a result, Table 4-7 has a column labeled “Added Costs to the North Jetty” to account for this relationship as measured in the model.

Level 3 comparisons occurred as below:

- Jetty A alternatives 1, 2, 3 and 4 were removed from consideration because they put the North Jetty at risk; therefore, not satisfying Jetty A’s purpose.

4.4.4. Alternative Selection

All of the remaining alternatives maintain deep-draft navigation at the MCR, extend the functional life of each jetty as a system of structural elements, and improves the functional reliability of the three MCR Jetty structures. The final objective is to minimize jetty life cycle costs.

Table 4-8 Comparison of Remaining Alternatives for North Jetty, South Jetty and Jetty A

Alternative	Alternative Description	Structural Reliability	Functional Reliability	AAC
NJ-17	Scheduled Repair (Hold Head)	0.62	0.82	2,891
NJ-02	Scheduled Repair	0.60	0.79	2,948
SJ-01	Base Condition	0.22	0.45	9,567
SJ-04	Scheduled Repair	0.23	0.48	9,650
SJ-16	Base Condition (Hold Head)	0.22	0.45	9,652
JA-06	Scheduled Repair (Hold Head)	0.34	0.90	913
JA-05	Base Condition (Hold Head)	0.33	0.89	1,000
JA-08	Small Cross-section Rehab (Plan B) - Immediate (Hold Head)	0.82	0.96	1,086
JA-07	Small Cross-section Rehab (Plan A) - Immediate (Hold Head)	0.84	0.96	1,164

Table 4-8 displays the structural and functional reliability with the AACs for each of the alternatives remaining. Table 3-6 defines acceptable levels of reliability for a rubble-mound structure the functional reliabilities shown for the North Jetty and Jetty A show a low likelihood for minor structural degradation in response to extreme waves.

ER 1105-2-100, Appendix G (pp. 7-8), states: "Identification of the NED plan is to be based on consideration of the most effective plans for providing different levels of output or service. Where two cost-effective plans produce no significantly different levels of net benefits, the less costly plan is to be the NED plan, even though the level of outputs may be less."

It is important to note that the purpose of the authorized project is to maintain a reliable, functioning, deep-draft navigation channel through the Columbia River entrance. It is not to compare the structural components of each of the alternatives so that if two alternatives still result in no impact to the navigation channel, their benefit is treated as the same. Therefore, the alternatives were evaluated based on least cost as long as they still provided for a usable channel.

Alternatives are selected as below:

- Both plans for the North Jetty have acceptable levels of Functional Reliability. Alternative NJ-17 was selected over alternative NJ-02 because holding the head stabilizes the adjacent geomorphology, protects Benson Beach from further erosion and is least cost. Because NJ-17 has a lowest AAC it is the selected alternative.
- All three plans for the South Jetty have similar values for structural and functional reliability. Because SJ-01 has a lowest AAC it is the selected alternative.
- The high functional reliability and comparatively low structural reliability for JA-06 and JA-05 indicate that the jetties will continue to function with degradation. Structural reliability is

not the determining factor for Jetty A; the functional reliability ranges from 0.89 to 0.96 for all Jetty A alternatives in Table 4-8. Increased AACs provide no benefit to the channel. Because JA-06 has a lowest AAC it is the selected alternative.

4.5. DESCRIPTION OF NED RECOMMENDED PLANS

As discussed in Chapter 2, the National Economic Development (NED) plan compares the average annual costs (AAC), net benefit, and the benefit-to-cost ratio (BCR) for the alternatives developed for each jetty structure. Each alternative was compared to the base condition. Based on this comparison, the NED plan for each jetty structure is shown below:

- **North Jetty** (BCR: 1.09) – Scheduled repair with head stabilization at or near STA 101, (less extensive than the previously proposed capping). These repairs will be conducted after the base condition maintenance repairs to stations 86-99 and lagoon fill to stop erosion of the jetty root. It does not include spur groin construction.

- **South Jetty** (BCR: 1.00) – Base condition (interim repairs) allowing head recession. It does not include spur groin construction. Dune augmentation near the jetty root will be implemented in FY 13 as a separate action and not included in the cost estimate. Although the base condition is the NED plan, the interim repair, hold head alternative is very close in AAC, differing by 0.9 percent. When conditions are appropriate (i.e., repairs of the South Jetty allow for a haul road to be established to the end of the jetty approximately FY 2019), head stabilization could be re-evaluated—using parameters such as least cost, environmental acceptability and engineering feasibility.

- **Jetty A** (BCR: 1.42) – scheduled repair and head stabilization at approximately STA 89. It does not include spur groin construction.

The project has a combined BCR of 1.1 for the system (all three jetties).

The NED plan for each jetty structure was selected as the recommended plan for the MCR jetty system. Additional information on the recommended plan is provided in Chapter 5, *Environmental Considerations*, in Chapter 6, *Construction and Cost Estimate*, and in Appendix A1, *Coastal Engineering*.

4.6. FUTURE DESIGN CONSIDERATIONS

During the DDR phase, the district will develop the least cost head-stabilization plan for the North Jetty and Jetty A. While the South Jetty NED plan is the base condition—allowing head recession—the average annual costs only vary by 0.9% from the base condition alternative holding at STA 313. Consequently, during the DDR phase, the district will also analyze head stabilization alternatives for the South Jetty. The district will survey all three jetties and adaptively manage each. Furthermore, spur groins will be reassessed to prevent ongoing erosion to the surrounding shoals.

It should be noted that this a planning analysis used to support the selected plan. In practice the following will be done to assess actual locations for repair: a biennial monitoring program where photogrammetric surveys of each of jetties will be executed to track cross-sectional degradation and head recession; annual visual inspections; and reporting by the Coast Guard and commercial ship traffic. Consequently, actual jetty repairs may not follow the exact locations identified by the predictive planning model used to develop the seven-year construction sequence on all three jetties.

5. ENVIRONMENTAL CONSIDERATIONS

This section summarizes the anticipated environmental effects of the proposed rehabilitation of the MCR jetty system, and the coordination undertaken related to environmental compliance issues. The associated EA provides a full evaluation of the project and associated environmental compliance considerations. Additional discussion and pertinent correspondence is included in Appendix D, *Environmental Documentation.* Any citations in this chapter can be found in the References section of the EA.

The following discussion is pulled directly from the EA which evaluates the effects of the Major Rehabilitation actions, the Major Maintenance Report actions, and South Jetty dune augmentation actions.

5.1. ENVIRONMENTAL EFFECTS

5.1.1. Physical Characteristics

The proposed action will enable the jetty structures to continue protecting the MCR inlet, adjacent morphology, shore lands, and side channels from becoming destabilized by the intense forces of waves and currents. The proposed action would have no calculable effect on nearshore or shore land areas beyond 1-2 miles north or south of the MCR inlet. Stabilizing the jetty heads would stop the migration of littoral sediment into the navigation channel. Because jetty lengths will be about the same as the existing jetty head locations, a negative impact on the sediment budget in the littoral cell, or on Clatsop or Peacock spits is not expected. Likewise, there would be no changes to salinity or plume conditions.

5.1.2. Water Quality

Effects of the proposed action to water quality could occur by increasing suspended sediments, increasing the potential occurrence of spills and leaks, and increasing the potential for contamination. However, the Corps expects these effects to be negligible.

Placement of rock by heavy equipment, jetty access road construction, dredging, disposal, and pile installation and removal could all cause temporary and local increases in suspended sediment. This is expected to have minimal and limited effects on the environment. Previous tests have confirmed that material to be dredged will be primarily sand with little or no fines, which does not stay suspended in the water column for an extended length of time. During infrequent and limited duration dredging and disposal which could occur for a few days annually or less often, depending on use of the facilities, suspended sediments may increase locally for a short time. These increases will dissipate quickly due to the sandy nature of the sediment, and inwater activities will be further constrained to conditions in the State 401 Water Quality Certification that limit the duration of such exceedences. Light attenuation and water quality effects from increased suspended sediments are expected to be minimal and fleeting. Pile driving is also expected to occur in sand and therefore have similar transient and minimal effects to water quality. Jetty roads could also contribute suspended sediments that would create turbidity during stormy seasons or overtopping events, but since they are above MHHW this will likely be an infrequent occurrence. When erosion of roads does occur, the background turbidity and wave climate is likely to also be in a state of increased turbulence and turbidity such that any additional roadway runoff will be a minimal contribution to the dynamic ocean and channel-forming processes churning the waters during overtopping events. Small increases in turbidity from construction activities on the jetties will likely occur on a nearly daily basis but will be of limited extent and duration, as rock placement will involve clean fill of large, individual boulders with a majority of the placement actions occurring above MLLW. Turbidity monitoring and compliance with expected likely conditions of the 401 State Water Quality Certification would also ensure protection of aquatic life and other beneficial uses in the vicinity of the inwater work. Wave and current conditions in the action area naturally contribute to higher background turbidity levels; and such conditions also preclude the effective use of isolating measures to minimize turbidity. However, other BMPs described for the proposed action would further reduce effects of turbidity from the proposed action. Effects from potential stormwater runoff were addressed in the Construction Staging and Stockpile section. Therefore, impact from suspended sediments should be inconsequential.

The Corps will require the contractor to provide a spill prevention and management plan that will include measures to avoid and minimize the potential for spills and leaks and to respond quickly to minimize damages should spills occur. Good construction practices, proper equipment maintenance, appropriate staging set-backs, and use of a fast fueling system would further reduce the likelihood of leak and spill potential and exposure extent and its associated effects.

Test results on dredge material described earlier further indicated that materials in the area are approved for unconfined in-water disposal and do not contain contaminants in concentrations harmful to organisms occupying the action area. The prohibition of treated wood will also avoid contamination from the migration of creosote and its components (e.g., copper and PAHs) from treated wood in the lotic environments.

Temporally, effects to water quality from suspended sediment and turbidity could occur on a daily basis, but are not expected to be continuous throughout the day. Clean, large boulders are not expected to create much discharge, and the substrate on which they are being placed also includes large, weathered boulders. Any other inwater work such as construction or dredging of offloading facilities will involve sandy materials that settle out very quickly. Turbidity levels and durations will be limited to conditions required in the State Water Quality Certifications which will likely include exceedence windows that are protective of beneficial uses such as salmonids and other aquatic life. Spills or leaks are expected to be infrequent and unlikely. Although the repetition of disturbance may be greater, it is still expected to remain within safe ranges that would not have long-term or deleterious effects. Furthermore, effects are expected to be geographically limited, short term, and minor.

5.1.3. Anadromous and Resident Fish Species

5.1.3.1. Federally Listed Fish Species

The threatened and endangered fish species listed under the Endangered Species Act (ESA) that may occur in the MCR project area are shown in Table 5-1. A description of these species is provided below.

Anadromous Salmonids

Adult salmonids use the MCR area as a migration corridor to spawning areas throughout much of the Columbia River Basin. They are actively migrating and are not expected to use the area for resting or feeding, although they would spend time in the MCR to physiologically acclimate to freshwater.

Chum, coho and Chinook salmon and steelhead populations spawn in tributaries to the Columbia River, and chum and Chinook salmon spawn in the mainstem Columbia River in appropriately sized gravels. No spawning would occur in the vicinity of the MCR for these species because of the lack of tributaries and appropriate spawning substrate.

Juvenile salmonids occur in the MCR area during their out-migration to the ocean. Juveniles that have already become smolts are present in the lower river for a short time period. Juveniles that have not become smolts, such as Chinook salmon subyearlings, spend extended periods of time rearing in the lower river. They normally remain in the lower river or estuary until summer or fall, or even to the following spring when they smoltify and then migrate to the ocean. Rearing occurs primarily in shallow backwater areas. Most juveniles out-migrate in late spring and early summer, although fall Chinook salmon typically have a more extended outmigration period and commonly out-migrate in late summer.

Table 5-1. Federally Listed Anadromous Fish Species

Listing status: 'T' means listed as threatened; 'E' means listed as endangered. FR = Federal Register

Species	Listing Status	Critical Habitat	Protective Regulations
Chinook salmon (*Oncorhynchus tshawytscha*)			
Lower Columbia River	T 6/28/05; 70 FR 37160	9/02/05; 70 FR 52630	6/28/05; 70 FR 37160
Upper Willamette River	T 6/28/05; 70 FR 37160	9/02/05; 70 FR 52630	6/28/05; 70 FR 37160
Upper Columbia River spring-run	E 6/28/05; 70 FR 37160	9/02/05; 70 FR 52630	ESA section 9 applies
Snake River spring/summer run	T 6/28/05; 70 FR 37160	10/25/99; 64 FR 57399	6/28/05; 70 FR 37160
Snake River fall-run	T 6/28/05; 70 FR 37160	12/28/93; 58 FR 68543	6/28/05; 70 FR 37160
Chum salmon (*O. keta*)			
Columbia River	T 6/28/05; 70 FR 37160	9/02/05; 70 FR 52630	6/28/05; 70 FR 37160
Coho salmon (*O. kisutch*)			
Lower Columbia River	T 6/28/05; 70 FR 37160	Not applicable	6/28/05; 70 FR 37160
Oregon Coast	T 2/11/08; 73 FR 7816	2/11/08; 73 FR 7816	2/11/08; 73 FR 7816
S. Oregon/N. California Coasts	T 6/28/05; 70 FR 37160	5/5/99; 64 FR 24049	6/28/05; 70 FR 37160
Sockeye salmon (*O. nerka*)			
Snake River	E 6/28/05; 70 FR 37160	12/28/93; 58 FR 68543	ESA section 9 applies
Steelhead (*O. mykiss*)			
Lower Columbia River	T 1/05/06; 71 FR 834	9/02/05; 70 FR 52630	6/28/05; 70 FR 37160
Upper Willamette River	T 1/05/06; 71 FR 834	9/02/05; 70 FR 52630	6/28/05; 70 FR 37160
Middle Columbia River	T 1/05/06; 71 FR 834	9/02/05; 70 FR 52630	6/28/05; 70 FR 37160
Upper Columbia River	T 1/05/06; 71 FR 834	9/02/05; 70 FR 52630	2/018/06; 71 FR 5178
Snake River Basin	T 1/05/06; 71 FR 834	9/02/05; 70 FR 52630	6/28/05; 70 FR 37160
Green sturgeon (*Acipenser medirosris*)			
Southern	T 4/07/06; 71 FR 17757	10/09/09; 74 FR 52300	P 5/21/09; 74 FR 23822
Eulachon (*Thaleichthys pacificus*)	T 3/18/10; 75 FR 13012	Not applicable	Not applicable
Columbia River Bull Trout	T 6/10/98; 63 FR 31647	10/18/10; 75 FR 63897	Not applicable

In 2005, critical habitat was designated for all Columbia River steelhead and Columbia River salmon evolutionarily significant units (ESUs), with the exception of lower Columbia River coho salmon ESU. General run-specific life history descriptions for the salmonid ESUs are provided below.

<u>Snake River Spring and Summer Run Chinook Salmon</u>. Fish from this ESU occur in the mainstem Snake River and subbasins including the Tucannon, Grande Ronde, Imnaha, and Salmon Rivers. Adults migrate in late winter to spring and spawn from late August to November. Spawning occurs

in tributaries to the Snake River. Juveniles remain in freshwater from 1-3 years and outmigrate from early spring to summer.

<u>Snake River Fall Run Chinook Salmon</u>. Fish from this ESU occur in the mainstem Snake River and sub basins including the Tucannon, Grande Ronde, Imnaha, and Salmon Rivers. Adults migrate from mid-August to October and spawn from late August to November. Spawning occurs in the Snake River and lower reaches of tributaries to the Snake River. Juveniles rear in freshwater from 1-3 years and out-migrate from early spring to summer.

<u>Lower Columbia River Chinook Salmon</u>. Fish from this ESU occur from the MCR upstream to Little White Salmon River, Washington and Hood River, Oregon and including the Willamette River upstream to Willamette Falls. Adults migrate in mid-August through October (fall run) and late winter to spring (spring run). Spawning occurs from late August to November in the mainstem Columbia River to upper reaches of tributaries. Juveniles out-migrate from early spring to fall.

<u>Upper Columbia River Spring Run Chinook Salmon</u>. Fish from this ESU occur in Columbia River tributaries upstream of the Rock Island Dam and downstream of Chief Joseph Dam in Washington, excluding the Okanogan River. Adults migrate from late winter to spring and spawn from late August to November. Spawning occurs in the mainstem Columbia River to upper reaches of tributaries. Juveniles out-migrate from early spring to summer.

<u>Upper Willamette River Chinook Salmon</u>. Fish from this ESU migrate upstream from late winter to spring and spawn from late August to November. Juveniles migrate from early spring to summer, some rearing in the Columbia River estuary and some in freshwater.

<u>Lower Columbia River Coho Salmon</u>. It is believed that the majority of fish from this ESU return to the lower Columbia River to spawn between early December and March. Spawning occurs in tributaries to the Columbia River. Young hatch in spring, rear in freshwater for one year, and out-migrate to the ocean the following spring. Most juveniles out-migrate from April to August, with a peak in May. Coho salmon occur in the Columbia River estuary as smolts and limited estuarine rearing occurs (more extensive estuarine rearing occurs in Puget Sound).

<u>Oregon Coast Coho Salmon</u>. Fish from this ESU are found in Oregon coastal streams south of the Columbia River an North of Cape Blanco. They generally migrate up spawning streams from August through November, and spawning takes place from late September through January in shallow tributaries with gravel bottoms. Fry emerge from redds in May or June and remain in fresh water from one to four winters before going to sea. Coho salmon smolts tend to stay close to shore at first, feeding on plankton. As they grow larger, they move farther out into the ocean and switch to a diet of small fish. Coho salmon can stay at sea for 2 to 3 years.

<u>Southern Oregon/N. California Coasts Coho Salmon</u>. The SONCC coho ESU includes all naturally spawned populations of coho salmon in coastal streams between Cape Blanco, Oregon, and Punta Gorda, California. Spawning runs occur throughout the year, varying in time by species and location. Depending on temperatures, eggs incubate for several weeks to months before hatching. Juveniles may spend from a few hours to several years in freshwater before migrating to the ocean. En route to the ocean the juveniles may spend from a few days to several weeks in the estuary. Juveniles and subadults typically spend from 1 to 5 years foraging in the ocean before returning to freshwater to spawn.

Columbia River Chum Salmon. Fish from this ESU are distributed from Bonneville Dam to the MCR. Adults migrate from early October through November and spawning occurs in November and December. Spawning habitat includes lower portions of rivers just above tidewater and in the side channel near Hamilton Island below Bonneville Dam. Juveniles enter estuaries from March to mid-May and most chum salmon leave Oregon estuaries by mid-May. Most juveniles spend little time in freshwater and rear extensively in estuaries.

Snake River Sockeye Salmon. Fish from this ESU occur in the Salmon River, a tributary to the Snake River. This population migrates in spring and summer and spawning occurs in February and March. Spawning occurs in inlets or outlets of lakes or in river systems. Juveniles rear in freshwater and out-migrate in spring and early summer, out-migrating primarily between April and early June. They spend little time in estuaries as smolts and are guided to ocean waters by salinity gradients.

Snake River Basin Steelhead. Fish from this ESU occur in all accessible tributaries of the Snake River. Upstream migration occurs in spring and summer and spawning occurs in February and March. Spawning habitat includes upper reaches of tributaries. Juveniles spend from 1-7 years (average 2 years) in freshwater and out-migrate during spring and early summer.

Middle Columbia River Steelhead. Fish from this ESU are distributed from Wind River, Washington and Hood River, Oregon upstream to the Yakima River, Washington. These fish migrate in winter and summer and spawning occurs in February and March. Spawning habitat includes upper reaches of tributaries. Juveniles spend from 1 to 7 years (average 2 years) in freshwater and out-migrate during spring and early summer.

Upper Willamette River Steelhead. Fish from this ESU are a late-migrating winter group, rearing 2 years in freshwater and 2 years in the Pacific Ocean before returning to spawn. The run timing appears to be an adaptation to ascending Willamette Falls at Oregon City.

Lower Columbia River Steelhead. Fish from this ESU are distributed from Wind River, Washington and Hood River, Oregon downstream to the MCR. They migrate in winter and spring/summer and spawning occurs in February and March. Spawning habitat includes upper reaches of tributaries. Juveniles spend from 1-7 years (average 2 years) in freshwater and out-migrate during spring and early summer.

Upper Columbia River Steelhead. Fish from this ESU are distributed from the Yakima River upstream to the Canadian border. These fish migrate in spring and summer and spawning occurs in February and March. Spawning habitat includes upper reaches of tributaries. Juveniles spend from 1-7 years (average 2 years) in freshwater and out-migrate during spring and early summer.

Green Sturgeon

Green sturgeon is a widely distributed, marine-oriented sturgeon found in nearshore waters from Baja California to Canada. They spawn in the Sacramento, Klamath and Rogue rivers in the spring. Spawning occurs in deep pools or holes in large, turbulent river mainstreams. Critical habitat for southern DPS green sturgeon includes all tidally-influenced areas of the Columbia River to approximately RM 46 and up to MHHW and includes adjacent coastal marine areas. Green sturgeon congregate in coastal waters and estuaries, including non-natal estuaries, where they are vulnerable to capture in salmon gillnet and white sturgeon sport fisheries.

Information from fisheries-dependent sampling suggests that green sturgeon only occupy large estuaries during the summer and early fall in the northwestern United States. Commercial catches of green sturgeon peak in October in the Columbia River estuary, and records from other estuarine fisheries (Willapa Bay and Grays Harbor, Washington) support the idea that sturgeon are only present in these estuaries from June until October. Green sturgeon enter the Columbia River at the end of spring with their numbers increasing through June. The greatest numbers are caught in the estuary in July through September. The majority of green sturgeon were caught in the lower reaches of the Columbia River based upon harvest information from 1981-2004. There are no known spawning populations in the Columbia River and its tributaries.

Eulachon

The southern DPS of Pacific eulachon (smelt) consists of populations spawning in rivers south of the Nass River in British Columbia, Canada, to and including the Mad River in California. The Columbia River and its tributaries support the largest known eulachon run. The major and most consistent spawning runs return to the mainstem Columbia River (from just upstream of the estuary at RM 25 to immediately downstream of Bonneville Dam) and in the Cowlitz River. Eulachon typically spend 3-5 years in saltwater before returning to freshwater to spawn from late winter through early summer. Spawning occurs in January, February, and March in the Columbia River. Spawning occurs at temperatures from about 39° to 50°F (4° to 10°C) in the Columbia River and tributaries over sand, coarse gravel, or detrital substrates. Shortly after hatching, the larvae are carried downstream and dispersed by estuarine and ocean currents. After leaving estuarine rearing areas, juveniles move from shallow nearshore areas to deeper areas over the continental shelf. Larvae and young juveniles become widely distributed in coastal waters and are found mostly at depths up to about 49 feet.

Bull Trout

Bull trout are endemic to western North America and were more widely distributed historically. The Columbia River may have provided important historical rearing and overwintering habitat for bull trout. Currently, the occurrence of bull trout downstream of Bonneville Dam appears to be incidental, and their occurrence upstream of Bonneville Dam appears to be limited. However, there are resident populations in rivers and creeks both in and east of the Cascades. Historic records have documented bull trout passing the fish ladder at Bonneville Dam in 1941, 1947, 1982, 1986, and 1994, as well as in the lower Columbia River near Jones Beach. High quality bull trout habitat is characterized by cold water temperatures; abundant cover in the form of large wood, undercut banks, boulders, etc; clean substrate for spawning; interstitial spaces large enough to conceal juvenile bull trout; and stable channels. The Columbia River downstream of Bonneville Dam does not typically achieve water temperatures suitable for bull trout.

5.1.2.2. Effects of the Proposed Action

Possible effects of the proposed action on anadromous and resident fish species include:

- Temporary and permanent interruption/alteration of adult and juvenile migration pathways.
- Temporary and permanent loss of shallow water habitat.
- Juvenile predator attraction to the jetty substrate and habitat type.
- Temporary disruption and displacement from piling installation and barge offloading traffic.
- Temporary loss of benthic organisms.
- Temporary displacement from dredging and rock placement activities.

- Temporary water quality impacts from construction activities and potential spills.
- Temporary increase in turbidity.
- Temporary and permanent insignificant changes to salinity, velocity, and bed morphology.

Rock Placement. Rock placement is not expected to cause mortality to adult or juvenile anadromous and resident fish. Fish could be displaced during rock placement by disturbance from rocks entering the water. Some benthic habitat will be permanently lost due to rock placement. Adjacent benthic areas will suffer relatively insignificant and temporary effects due to settling of suspended sediments. Because much of the rock will be placed above MLLW on existing relic rock, most benthic habitat should not be adversely affected. Because the jetties are in a high energy environment and are relatively unproductive near the structures, this habitat loss is not considered significant.

Jetties and Causeways. Juvenile salmonids, especially sub-yearling Chinook salmon, out-migrate in close proximity to the North Jetty, and may out-migrate in close proximity to the South Jetty as well. The length of the North Jetty forces fish that are bound for waters near the surf zone along Benson Beach farther offshore. They swim a farther distance and are potentially exposed to increased risks from predation before reaching preferred shallow-water nearshore habitat. With scheduled repairs of the North Jetty, it is expected that Benson Beach will halt its recession and resume accretion, which over time will lessen the distance that sub-yearling juvenile Chinook salmon must swim to reach preferred nearshore waters. It is possible that juvenile salmonid outmigration occurs in close proximity to the South Jetty as it does at the North Jetty. Offloading facilities and turn-outs on the channel side with elevations at or above MLLW are expected to be capable of altering outmigration routes by forcing juvenile salmonids away from the shallower waters along the jetty proper and into deeper waters as they swim around the barge offloading facilities.

Barge Offloading Facilities and Dredging. Barge offloading facilities are a potential method of delivery for stone and other construction materials. If barge offloading facilities are used, this would create the largest impacts to 404 waters of the US. Therefore, these represent the worst-case scenario for spatial effects. Pilings will be constructed out of untreated wood or steel. After installation, the presence of the barge facilities would not likely cause disturbance to salmonids in the vicinity, except for the coming and going of barges that could induce movement in fish. The construction and eventual removal of these facilities, including dredging and pile driving, would temporarily disturb fish and temporarily and permanently convert aquatic habitat (changes to depth and substrate). Because of the soft substrates, it is expected that vibratory drivers can be used effectively to install piles. The impacts from pile driving would be intermittent and would not be expected to adversely affect fish.

Material to be dredged for barge offloading facilities is primarily sand with little or no fines. Disposal of dredged material is expected to occur at approved in-water disposal sites. A clamshell dredge will be used for most dredging. Fish would likely be forced into moving to other nearby suitable habitat during dredging. There also would be a loss of benthic invertebrates in areas dredged, but only negligible losses to food resources for juvenile salmonids and aquatic species would be expected to result.

Potential Spills. Operation of heavy equipment requires use of fuel and lubricants that would kill or injure aquatic organisms if spilled into the water. The Contractor will provide a spill prevention plan to include measures to minimize the potential for spills and to respond quickly should spills occur. Due to preventative and response measures required, it is unlikely that spills would adversely affect aquatic resources because of their low chance of occurrence.

According to the Lower Columbia River Geographic Response Plan (GRP) (WADOE 2003), routes for major shipping traffic keep super tankers 50-60 Nautical Miles (NM) offshore, minimizing potential coastal effects from a catastrophic spill. Up until 2003, the GRP also quantified the volume of potential spilled material as follows. Refined product in barges and small tankers transported closer to the shoreline and up the Columbia River averaging 160 tank barge movements as well as 50-60 bunkering operations by barge to a variety of vessels per month. The majority of these bunker barges had a capacity of 15,000 barrels. Annually, self propelled tankers made approximately 100 port calls to the Portland area. The majority of the tank vessels were approximately 39,000 deadweight tonnage, having had capacity of approximately 275,000 barrels, although the largest had a capacity of 400,000 barrels. Supertankers in ballast also transited the river enroute the Portland Ship yard for routine inspections and maintenance. Approximately 2,000 general cargo, bulk, and container vessels entered the river annually, carrying bunker fuels of approximately 15,000 barrels capacity (WADOE 2003).

According to information in the Oregon Department of Environmental Quality's spill tracking database, between 1998 and March 2011, 63 spills were reported in Clatsop County in the vicinity of the Columbia River from Astoria downriver (DEQ 2011). Of these 63 spills, 43 were less than 50 gallons and were mostly the result of equipment malfunctions and minor spills and vessel leakage. Five spills were between 50 and 100 gal; 6 between 100 and 200 gallons; 2 between 200 and 800 gallons; then up to 6 at 1000 gallons; and one over 10,000 gallons (DEQ 2011). The incidents with the highest level of spill discharge generally involved storm sewage overflows or sewage release, followed by the sinking, grounding, or capsizing of fishing vessels, then land to surface water releases from other facility malfunctions (DEQ 2011). Washington Department of Ecology's Environmental Reports Tracking System (ERTS) shows about 145 incidences between January 200 and December 2010, with the majority of the sources indicated from various size vessels (WADOE 2011). Of these, most were petroleum products in the following quantities: 63 incidences were under 5 gallons; 11 were between 6-30 gallons; 9 were between 50-100 gallons; 3 were 101-300 gallons; and the largest quantified was 1 at 1500 gallons; 57 incidences did not have any associated quantities (WADOE 2011). The GRP also further describes several of the most prominent spills on the Columbia prior to 2003, including: the1984 T/V Mobiloil spill of 200,000 gallons; the 1991 discharge of 11,000 gallons of Intermediate Fuel Oil (IFO) 380 from the M/V Tai Chung at the Columbia Aluminum Facility; two similar bunkering mishaps within six months of each other at Longview Anchorage; the 1993 M/V Central spill of approximately 3,000 gallons of IFO 180; and the 1994 M/V An Ping 6 spill of a similar amount of product at the same location as M/V Central (WADOE 2003). It is notable that none of the identified spills occurred in the vicinity of the MCR, but rather further inland and upriver.

This limited spill history further indicates that spill releases from the project are very unlikely, and a spill that reaches catastrophic levels is even less likely. The required spill prevention and response plan along with additional BMPs will help avoid any significant impacts from spills.

Turbidity. Placement of rock and dredging/pile driving for barge offloading facilities will be conducted and are not likely to require measures to minimize turbidity. Placement of clean fill and pile installation in sandy substrate is not anticipated to create significant turbidity plumes. Increased turbidity from construction activities will be intermittent over the projected 8-year construction timeframe, but individual, localized increases should be of limited extent. These turbidity increases would likely not result in a reduction in feeding rates and growth, physiological stress, and increased mortality of juvenile and adult salmonids and other fish because of rapid dissipation of turbidity in the high-energy MCR environment and the mobility of fish. Movement from turbid areas and behavioral avoidance of turbid areas by fish would likely result. Sediment suspension is not thought to be an issue with respect to aquatic resource impacts because the sediments that would be suspended are mostly sand.

<u>System Effects - Permanent Changes to Velocity, Salinity, Bed Morphology</u>. Modeling results show that no appreciable permanent changes to velocity, salinity, and bed morphology at the MCR would be expected from implementation of the proposed action. Any changes to water velocities resulting from the proposed action would not likely adversely alter aquatic habitat or affect the organisms that use the MCR area.

<u>Salmonid Critical Habitat</u>. Increases in suspended sediment and resultant turbidity from driving piles and/or placement of jetty stones may impact aquatic habitat. The increases in suspended sediment and turbidity will generally be limited to the construction areas along the jetty bases and will be intermittent over the projected 6-year construction timeframe. No contaminated material would be suspended because sediment is nearly pure sand. The course-grained characteristic of the sand will cause it to settle relatively quickly.

Rock placement will occur for jetty repair and for construction of barge offloading facilities. Alteration of bottom habitat would occur from dredging, which will create temporary disturbance and greater depths that could affect the composition of benthic communities. These effects are not anticipated to be measurable, as the character of the area is naturally dynamic and prone to extreme energy conditions, and benthic organisms are adapted for such conditions and usually rapidly re-colonize. Alteration of bottom habitat by pile driving or placing additional rock to expand the bases of the jetties should not adversely affect aquatic habitat. The MCR is an active migration corridor and it is unlikely that salmon are feeding to any extent in the area. Consequently, effects on salmon feeding habitats are not anticipated.

The permanent removal or conversion of some shallow water, nearshore sandy habitat likely used by juvenile salmonids for migrating, foraging, or rearing habitat would result from previously described rock placement for turnouts, set-up pads, causeways and stone docks for offloading facilities. In addition, some shallow water, nearshore sandy habitat likely used as migrating, foraging, or rearing habitat by juvenile salmonids would be unavailable for the projected 6-year construction timeframe. Some causeway structures would be removed upon project completion and others will remain.

In-water aquatic habitats, both shallow intertidal and deeper subtidal areas will also be affected by the project. Habitat conversions and temporal disturbance will occur from maintenance dredging and placement of jetty cross-sections, turnouts, crane set-up pads, barge offloading facilities, and causeways. There will also be permanent fill lasting more than a year at the South Jetty. The biological consultation has been completed between the Corps and NMFS and the U.S. Fish and Wildlife Service (USFWS). The consultation evaluated effects from a larger project footprint than the currently selected plan. The current plan selection has further minimized impacts and the following quantities represent the worst-case scenario from effects of barge offloading facilities after minimization measures have been implemented to the maximum extent practicable.

- North Jetty – 4.36 acres, 404 waters
- South Jetty – 13.84 acres, 404 waters
- Jetty A – 6.62 acres, 404 waters

For further detail, please see both Biological Opinions (NMFS, USFWS) in Appendix D.

Shallow-water habitat is especially important to several species in the estuary; therefore, specific initial estimates were also calculated regarding shallow-water habitat (shallow here defined as -20-ft or -23-ft below MLLW). About 21 acres of area at these depths will be affected by, maintenance dredging, and construction of the causeways and barge offloading facilities. However, this shallow-water footprint estimate does NOT including any expansion of the jetty's existing footprint. For this analysis, there was no distinction drawn between periodically exposed intertidal habitat and shallow-water sandflat habitat. As with wetland estimates, these approximations will be updated and may be reduced as project designs are refined and as additional analyses and surveys are completed to quantify changes in jetty and dune cross sections.

Consequently, these conversions and disturbances could result in disturbance of benthic invertebrates and a possible conversion of biological communities. Within an estimated 3-mile proximity of the MCR jetties, about 19,575 acres of shallow water habitat (anything -20 ft or shallower) exists, of which 33 acres represents a difference of much less than 1%. Therefore, these effects of habitat conversion are expected to be minimal, and unlikely to appreciably impact food resources or foraging behavior of juvenile or adult salmonids. Spawning does not occur in the areas of habitat conversion, so effects from the proposed action will not impact spawning substrate or behavior.

<u>Green Sturgeon</u>. The federally listed green sturgeon (southern DPS) occurs in the Columbia River estuary. Its distribution and habitat use in the estuary is not well known, though the area was recently listed as critical habitat (74 FR 52300). Green sturgeon would be expected to occur in the more tranquil estuary proper to a greater extent than in the vicinity of the MCR jetties. Though sandlance provide one food source for the green sturgeon, the proposed project is not expected to have any considerable impact on this supply. Given the existing relic rock substrate resulting from the current jetty structures, it is unlikely that the area in the vicinity of the jetty repairs provides much suitable habitat for sandlance. Therefore placements of the jetty stone on top of or near the existing footprint will not likely result in any measurable impact to the green sturgeon's food availability. There is a slightly higher likelihood of affecting sandlance habitat in the vicinity of the proposed barge off-loading sites, but these impacts are also anticipated to be negligible relative to the habitat available, and new ephemeral shallow-water habitat will likely be created as sand is accreted behind the repaired jetty structures. During construction, rock placement and dredging (turbidity) could disturb green sturgeon in the area. Some sand habitat in close proximity to the jetties that green sturgeon could potentially use would be permanently removed by placement of rock for off-loading facilities, jetty and stabilization stone.

The Corps and USGS have recently been working on a green sturgeon study in the Coos and Columbia River estuaries. Though results are preliminary and sample sizes are relatively small, acoustic receivers detected green sturgeon presence several times off the tip of Jetty A, near the North Jetty, and in the area of Social Security beach off the Clatsop Spit (USGS Preliminary 2009-2010 data). Information about specific use in the action area is still under development, but activities at Jetty A and North Jetty could cause some avoidance behavior by green sturgeon present during construction.

<u>Eulachon</u>. Impacts to federally listed eulachon are anticipated to be temporary and minimal. Eulachon occur in nearshore ocean waters and to 1,000 feet in depth, except for the brief spawning runs into their natal (birth) streams. After leaving estuarine rearing areas, juvenile eulachon move from shallow nearshore areas to deeper areas over the continental shelf. Larvae and young juveniles become widely distributed in coastal waters and are found mostly at depths up to about 49 feet. Though substrate likely to be impacted by dredge and fill activities may be similar to eulachon spawning habitat, the likely timing for work in late summer/early fall are outside of the typical

eulachon spawning season. Further, eulachon are planktonic feeders, so minimal losses of benthic invertebrates would not affect their foraging behaviors. Finally, the Biological Review Team further identified dredging activities as low to moderate threats for eulachon (NOAA 2009).

Bull Trout. Federally listed bull trout are known to have occurred in the Columbia River historically but now appear to occur only incidentally in the lower river. Water temperature and lack of spawning substrate likely limits their use at the MCR to migratory passage. Only sporadic records of bull trout in the Columbia River downstream of Bonneville Dam or passing through the dam have been documented dating to 1941. The proposed action will occur in the area designated as bull trout critical habitat, mostly serving as a migratory corridor. For these reasons, the proposed action is not likely to adversely affect bull trout.

Pacific Lamprey. Pacific lampreys are likely present in the vicinity of the MCR as juveniles out-migrate from February to June, adults return to freshwater from July to October. During the likely construction period between April and October, either end of the age distribution may be present during project activities. However, the project is not anticipated to impact their food sources or habitat, as the jetty system is not expected to discernibly alter the current distribution of predator or prey species, and the rocky substrate may provide some resting habitat on which lampreys could attach.

Resident Fish Species. The proposed action will directly affect species such as English sole, sand sole and starry flounder from the permanent loss of sandy bottom habitat preferred by these species from jetty and spur groin construction. Impacts to groundfish habitat are likely to be insignificant because the jetties do not provide highly productive rocky habitat due to low benthic productivity, unstable bottoms, and high current/wave action in the jetty areas. There may be a long term, intermittent impact from disturbance to some groundfish species that use the jetty habitat over the projected 6-year construction timeframe. Effects on groundfish migratory habitat are likely to be insignificant since disturbed areas will be small relative to the amount of available migratory habitat at the MCR. It is unlikely that disturbing this small amount of migratory habitat would impact the population levels of groundfish. On the other hand, construction of the spur groins would create a substantial amount of additional rocky habitat that would provide a permanent, long-term benefit to many groundfish species. Groundfish species should quickly recolonize the jetty areas once construction for a particular jetty is completed.

Essential Fish Habitat (EFH). The Columbia River estuary and the Pacific Ocean are designated as EFH for various groundfish and coastal pelagic and salmon species. The proposed action will directly affect EFH for Chinook salmon, coho salmon, English sole, sand sole and starry flounder from the permanent loss of sandy bottom habitat from jetty and spur groin construction. Short-term disturbances to EFH would result for lingcod, English sole, sand sole, starry flounder, black rockfish, brown rockfish, China rockfish, copper rockfish, and quillback rockfish. However, the addition of rock would increase EFH for lingcod, black rockfish, brown rockfish, China rockfish, copper rockfish, and quillback rockfish.

5.1.4. **Macrophytes and Invertebrates**

The mobile sand community at the MCR provides habitat for invertebrate species such as polychaetes, clams, amphipods, and crabs. This is a high-energy zone and generally less productive than other areas of the estuary. The jetties provide rocky intertidal and subtidal habitat. Dominant macrophytes include brown and green seaweeds and sea lettuce that are attached to the jetty rocks. Invertebrate species include sponges, hydroids, sea anemones, crabs, tubeworms, limpets, and mussels that live on the rocks or in crevices. There would be some loss of invertebrates with construction; however, those species occupying rocky habitats would colonize newly placed rock. No permanent, adverse effects to macrophyte and invertebrate populations are expected.

5.1.5. Dungeness Crab

Crabbing occurs in river between the jetties. Extensive use by crabs occurs on sandy bottom areas on the south side of the North Jetty and to a lesser extent on the north side of the South Jetty. Crabs move out of the estuary in large numbers (as 1+ aged crabs) along the northern part of the channel (south side of the North Jetty) in the fall and move into the estuary as megalops in the spring. Megalops enter the estuary passively by current mainly along the north side of the entrance (on the south side of the North Jetty) where current is strongest and salinity highest. No adverse impacts to adult and juvenile Dungeness crabs would be expected from the proposed action because modeling shows no appreciable permanent changes to velocity, salinity, and bed morphology at the MCR. The insignificant changes to water velocities from adding spur groins would not likely adversely alter the migration paths of young crabs moving in or out of the estuary.

5.1.6. Marine Mammals and Sea Turtles

Federally listed marine mammals and sea turtles that could occur in the vicinity of the vicinity of the MCR project are shown in Table 5-2.

Table 5-2. Federally Listed Marine Mammals and Sea Turtles

Listing status: 'T' means listed as threatened under the ESA; 'E' means listed as endangered. FR = Federal Register

Species	Listing Status	Critical Habitat	Protective Regulations
Marine Mammals			
Steller sea lion (*Eumetopias jubatus*)			
Eastern	T 5/5/1997; 63 FR 24345	8/ 27/93; 58 FR 45269	11/26/90; 55 FR 49204 10/1/09; 50 CFR 223.202
Blue whale (*Balaenoptera musculus*)	E 12/02/70; 35 FR 18319	Not applicable	ESA section 9 applies
Fin whale (*Balaenoptera physalus*)	E 12/02/70; 35 FR 18319	Not applicable	ESA section 9 applies
Humpback whale (*Megaptera novaeangliae*)	E 12/02/70; 35 FR 18319	Not applicable	ESA section 9 applies
Killer whale (*Orcinus orca*)			
Southern Resident	E 11/18/05; 70 FR 69903	11/26/06; 71 FR 69054	ESA section 9 applies
Sei whale (*Balaenoptera borealis*)	E 12/02/70; 35 FR 18319	Not applicable	ESA section 9 applies
Sperm whale (*Physeter macrocephalus*)	E 12/02/70; 35 FR 18319	Not applicable	ESA section 9 applies
Marine Turtles			
Green turtle (*Chelonia mydas*)			
Excludes Pacific Coast of Mexico & FL	ET 7/28/78; 43 FR 32800	9/02/98; 63 FR 46693	ESA section 9 applies
Leatherback turtle (*Dermochelys coriacea*)	E 6/02/70 ; 39 FR 19320	1/5/10; 75FR319	ESA section 9 applies
Loggerhead turtle (*Caretta caretta*)	T 7/28/78; 43 FR 32800	Not applicable	7/28/78; 43 FR 32800
Olive ridley turtle (*Lepidochelys olivacea*)	ET 7/28/78; 43 FR 32800	Not applicable	ESA section 9 applies

Steller sea lions breed along the West Coast from California's Channel Islands to the Kurile Islands and the Okhotsk Sea in the western North Pacific Ocean. They are year-long residents along the Oregon Coast. Steller sea lions are not known to use the North Jetty or Jetty A. A major haul-out area for Steller sea lions occurs at the head of South Jetty, where the monthly averages between 1995 and 2004 ranged from about 168 to 1106 animals at the South Jetty. They primarily use the concrete block structure that has become an island with the erosion of the rubble mound structure landward.

This concrete block structure is the farthest ocean-ward, above-water portion of the South Jetty. Their use of the South Jetty is concentrated more in the winter months and is least during the May-July breeding season when adults disperse to rookeries. Placing jetty rock near or at the head will disturb Stellar sea lions by forcing them to move off haul out areas; however, they will be able to haul out elsewhere in the vicinity. Prey resources for sea lions are not expected to be affected. The proposed action is not likely to adversely affect Steller sea lions.

The whale species listed in Table 5-2 are all federally endangered and occur as migrants off the Oregon Coast in waters typically much farther from shore than the nearshore MCR area. Blue whales occur off the coast in May and June, as well as in August through October. Blue whales typically occur offshore as individuals or in small groups and winter well south of Oregon. Fin whales also winter far south of Oregon and range off the coast during summer. Sei whales winter south of Oregon and probably occur in southward migration off the Oregon Coast in late summer and early fall. Sperm whales occur as migrants and some may summer off the coast; they forage in waters much deeper than those in the nearshore area. Humpback whales primarily occur off the Oregon Coast from April to October with peak numbers from June through August. Humpback whales are particularly concentrated in Oregon along the southern edge of Heceta Bank and are found primarily on the continental shelf and slope. North Pacific right whales may occur off the coast during winter and summer in cool waters north of 50 degrees north latitude. During winter, killer whales have moved into Pacific coastal waters and are known to travel as far south as central California. Sightings of killer whales off the coast of Washington, Oregon, and California indicate that they are utilizing resources in the California current ecosystem. These whale species are migratory in the vicinity of the MCR, generally are not found close to shore, and are highly mobile. Moreover, MCR is likely not the preferred habitat for these species, they are unlikely to feed in the vicinity of the jetties, and jetty rehabilitation work would have inconsequential impacts on their prey base. The proposed action is not expected to adversely affect these whale species.

The sea turtle species listed in Table 5-2 are migratory in the vicinity of the MCR, are generally are not found close to shore, and are highly mobile. The loggerhead sea turtle, green sea turtle, leatherback sea turtle, and olive Ridley sea turtle have been recorded from strandings along the Oregon and Washington coasts. The occurrence of sea turtles off the Oregon Coast is associated with the appearance of albacore. Albacore occurrence is strongly associated with the warm waters of the Japanese current. Because these warm waters generally occur 30 to 60+ miles offshore from the Oregon Coast, these sea turtle species do not typically occur in the nearshore MCR area. In 2010, the NMFS proposed a revised critical habitat designation for leatherback turtles that includes the vicinity of the MCR project (*Federal Register* 75:319). However, the project area is not likely preferred habitat for the species, they are unlikely to feed in the vicinity of the jetties, and rehabilitation work will have inconsequential impacts on their prey base. The proposed action is not expected to adversely affect these sea turtle species.

5.1.7. **Terrestrial Wildlife and Seabirds**

Federally listed wildlife and seabird species that could occur in the vicinity of the MCR project are shown in

Table 5-3. A description of these species is provided below.

Table 5-3. Federally Listed Terrestrial Wildlife and Seabirds

Listing status: 'T' means listed as threatened; 'E' means listed as endangered. FR = Federal Register

Species	Listing Status	Critical Habitat
Marbled Murrelet *(Brachyramphus marmoratus)*	T 10/01/92; 57 FR 45328; 2/11/09 74 FR 6852	5/24/96; 61 FR 26255; 2/11/09; 74 FR 6852
Western Snowy Plover *(Charadrius alexandrinus nivosus)*	T 3/05/93; 58 FR 12864	9/29/05; 70 FR 56969
Short-tailed Albatross *(Phoebastria albatrus)*	E 7/31/00; 65 FR 46643	Not applicable
Northern Spotted Owl *(Strix occidentalis caurina)*	T 6/26/90; 55 FR 26114	1/15/92; 57 FR 1796; 8/13/08 73 FR 47325
Columbian White-tailed Deer *(Odocoileus virginianus leucurus)*	E 3/11/67; 68 FR 43647	Not applicable
Oregon Silverspot Butterfly *(Speyeria zerene hippolyta)*	T 07/02/80; 45 FR 44935	7/02/80; 45 FR 44935

Marbled Murrelet

The marbled murrelet is a near-shore marine bird that is most frequently observed within 1.5 miles of shore. Marbled murrelets forage just beyond the breaker-line and along the sides of river mouths where greater upwelling and less turbulence occurs. Marbled murrelets nest in old growth/mature coniferous forests. The low incidence of marbled murrelets at coastal locations is probably related to the loss of old growth coniferous forest from harvest and/or fire (*Federal Register* 56:28362). Marbled murrelets are expected to occur in the general vicinity of the MCR, specifically on the Columbia River bar and nearshore waters. Their numbers are anticipated to be low throughout the general project area. Cape Disappointment State Park is located about 1.6 miles northeast of the North Jetty at Benson Beach and contains suitable habitat for marbled murrelet nesting. While nesting has not been documented in this area, birds have been noted in flight during the nesting season. Periodic minor disturbance may occur to marbled murrelets due to noise generated from trucks on haul roads through Washington State Parks property adjacent to possible nesting habitat, although all truck traffic would occur only during daylight hours. The following measures would be employed during the marbled murrelet nesting season (April 1 to September 15) to reduce impacts from noise to nesting murrelets:

- Trucks will only be allowed to use roads through Cape Disappointment during daylight hours.
- Trucks will not unnecessarily stop along the roads through Cape Disappointment.
- Trucks will be prohibited from using compression brakes (jake brakes) on roads through Cape Disappointment.

No adverse impacts on feeding by marbled murrelets would be expected from the proposed action because modeling shows no appreciable permanent changes to velocity, salinity, and bed morphology at the MCR. Because the proposed action is located approximately 1.6 miles from potential nesting areas, periodic disturbance may occur to marbled murrelets in project vicinity because of noise generated from construction and from trucks on the haul roads through Washington State Parks property. Conservation measures will further avoid and minimize disturbance to marbled murrelets.

Western Snowy Plover

Western snowy plovers historically occurred in the vicinity of Clatsop Spit although no breeding or wintering plovers have been reported from these beaches in recent years. This evidence was supported by a survey completed by the USFWS and Corps representatives in May 2010 when no plovers were observed. However, two birds were sighted in recent surveys (Blackstone 2012). Benson Beach and Clatsop Spit are not designated as critical habitat, although a Habitat Conservation Plan (HCP) has been developed for Clatsop Spit by Oregon Parks and Recreation Department (OPRD). Most of the land-based construction activities will occur above the MHHW levels in the near and immediate vicinity of the jetties. Thus, this limits the geographical extent of the disturbance effects from construction clearing, and reduces the likelihood that actions would occur in foraging areas preferred by snowy plover. According to USFWS, European beachgrass reduces the amount of open, sandy habitat and contributes to steepened beaches, and increases habitat for predators. These conditions are problematic at the Spit, and may actually be improved by the proposed foredune augmentation, clearing for stockpiling and construction staging, and eventual replanting of native dune plants.

A draft Habitat Conservation Plan (HCP) for western snowy plovers was prepared (Jones and Stokes 2007 and 2009) and included restoration activities at various locations along the Oregon Coast including Clatsop Spit. The Snowy Plover Management Area identified on Clatsop Spit included 0.62 mile of beach along the Columbia River within the park and is located north of the South Jetty. This area is owned by the Corps and leased by the OPRD. The OPRD manages the natural resources, facilities, and visitors within the leased area. Activities that OPRD are interested in include predator management, symbolic fencing, public outreach and education, habitat restoration and maintenance (which could include grading of vegetated areas), and monitoring. On December 17, 2010, the Corps joined the USFWS, other federal agencies, and the State of Oregon in signing a statewide HCP for snowy plovers. The area proposed for construction, storage, and staging is mostly outside of the area on Clatsop Spit identified in the HCP. Thus, the proposed action is not likely to adversely affect snowy plovers. The Corps is implementing best management practices (BMPs) that are in alignment with our efforts under the HCP.

The Corps is investigating opportunities to create western snowy plover nesting habitat on Clatsop Spit within Fort Stevens State Park. As staged areas could be attractive to plovers, the Corps will consider creation of habitat after use of the Spit for rock storage is completed to avoid potential limitations to rock storage and transport on the Spit if plovers begin to nest in staging areas. The Corps will also consider options to create plover habitat concurrently with rock storage if it is certain that plover use of the created habitats and beaches would not interfere with the Corps' ability to use Clatsop Spit throughout the life of the project. This habitat area would be implemented with the intention to create more preferable nesting areas such that plover are lured away from the potential attractive nuisance of the cleared staging areas. In other words, the Corps is creating bare sand areas that would attract birds away from construction site impacts. Habitat maintenance each year after creation would be required to preserve functional habitat. The Corps would maintain these sites during construction, but maintenance would not be Corps responsibility after completion. The Corps has had initial discussions with the USFWS and OPRD regarding snowy plover habitat creation.

Short-tailed Albatross

There have been three confirmed sightings of short-tailed albatross off the Oregon Coast. The closest sighting to the project was 20 miles southwest of the MCR (Marshall et al., 2003). This species would not be expected to occur in the vicinity of the MCR.

Northern Spotted Owl

Northern spotted owls are nocturnal predators that generally prey primarily on small forest mammals and nest from February to June, with parental care of the juveniles lasting into September. Spotted owls live in forests characterized by dense canopy closure of mature and old-growth trees, abundant logs, standing snags, and live trees with broken tops; they prefer older forest stands with variety multi-layered canopies of several tree species of varying size and age, both standing and fallen dead trees, and open space among the lower branches to allow flight under the canopy. Benson Beach and Clatsop Spit have large areas of land that have accreted since the construction of the MCR jetty system and are not old enough to have evolved these forest characteristics. These habitat conditions do not exist in the immediate vicinity where the majority of the construction activities will occur. Benson Beach and Clatsop Spit are not designated as critical habitat.

Columbian White-tailed Deer

Columbian white-tailed deer occur on the Oregon and Washington mainland and instream islands primarily from Skamokawa, Washington upstream to Port Westward, Oregon. Their closest location to the MCR jetties project vicinity is 34 miles upstream at the Julia Butler Hansen National Wildlife Refuge near Cathlamet, Washington. This species does not occur in the vicinity of the MCR.

Oregon Silverspot Butterfly

The Oregon silverspot butterfly occupies coastal headlands or Coast Range peaks that provide specific habitat features, primarily because of the presence of its host plant, the early blue violet (*Viola adunca*). The closest populations of this butterfly to the project area occur at Camp Riles in Clatsop County, Oregon to the south and at Long Beach, Washington to the north. No Oregon silverspot butterfly populations are known to occur in the project area, and suitable viola habitat was not observed during the plant community surveys on Clatsop Spit. The proposed project would not be expected to have any effect on this species.

Waterfowl

Common loon, Clark's grebe, western grebe, horned grebe, red-necked grebe, Brandt's cormorant, bufflehead, rhinoceros auklet, Cassin's auklet, tufted puffin, black oystercatcher, harlequin duck, fork-tailed storm petrel, and peregrine falcon are species of concern in the states of Oregon and/or Washington and could occur in the vicinity of the MCR. The proposed action is not expected to significantly affect these species because they could readily avoid the construction areas.

Pelagic and Brandt's cormorants nest on the cliffs of Cape Disappointment. Three species of terns occur in the Columbia River or over nearshore waters. Caspian terns are present from April to September and have established a large colony on East Sand Island within the estuary. Common and arctic terns occur off the Oregon and Washington coasts from April to September principally during migration. Shorebirds found on coastal beaches at the MCR and estuarine flats include sanderlings and various species of sandpipers, dunlins, and plovers. Various species of gulls are common in the vicinity of the MCR. Shearwaters, auklets, murres, fulmars, phalaropes, and kittiwakes are occasionally noted in the vicinity of the MCR but more commonly offshore. Again, the proposed action is not expected to significantly affect these species because they could readily avoid the construction areas, and impacts to shallow intertidal habitat is minimal relative to the availability of adjacent foraging habitat, and the short temporal loss is likely to be replaced with accreted habitat that is captured and formed behind the new and repaired structures. Furthermore, wave and current action at the jetty features likely limits shorebird use of these areas.

It is unlikely that bald eagles would be impacted by the proposed action because they can readily avoid the construction areas while foraging. The Cape Disappointment bald eagle pair nests in close proximity to roads through the park, but use of haul roads is less of a concern for nesting bald eagles because they appear to be acclimated to traffic and noise.

Overall, the proposed action is not expected to significantly affect terrestrial wildlife and seabird species. These species could readily avoid the construction areas, any impacts to shallow intertidal habitat would be small relative to the availability of adjacent foraging habitat, and the short temporal loss is likely to be replaced with some accreted habitat that is formed behind the repaired jetty structures. This habitat will likely be ephemeral and will not provide a long-lasting benefit. At the jetty structures, wave and current action likely limits seabird and shorebird use of these areas.

5.1.8. Vegetation

Federally Listed Plant Species

Nelson's Checker-mallow (*Sidalcea nelsoniana*), a federally threatened species (*Federal Register* 58:8235), is a perennial herb with tall, lavender to deep pink flowers. Critical habitat has not been designated. Flowering occurs as early as mid-May and extends into September. This plant most frequently occurs in Oregon ash swales and meadows with wet depressions, or along streams. It also grows in wetlands in remnant prairie grasslands or along roadsides at stream crossings where non-native plants, such as reed canarygrass, blackberry, and Queen Anne's lace, also are present. Most sites where the species occurs are in the Willamette Valley in Oregon; the plant is also found at several sites in the Coast Range of Oregon and at two sites in the Puget Trough of southwestern Washington. The proposed action would not occur in or significantly affect habitat for this species.

5.1.9. Wetland and Waters of the U.S. Mitigation

The process used to determine mitigation was to first maximize avoidance of the impacts. However, some impacts to wetlands and waters remain unavoidable. Mitigation for unavoidable impacts was then based on the extent and quality of the habitat affected.

Impacts associated with wetlands have a known and quantified footprint and are the same under all the construction alternatives. Specific wetland mitigation sites and methods have been identified and developed. A cost effective incremental cost analysis was done on this mitigation.

The exact extent of impacts to 404 waters of the US is unknown because they are contingent upon the delivery method of the rock which will be determined during contract bidding. Impacts associated with method of delivery are unknown, therefore the extent of mitigation is uncertain and variable based on the mode of stone delivery and placement. Impacts will be greater if the contractor chooses to use offloading facilities; hence, the maximum potential effects were evaluated in the EA. Because of this, maximum mitigation requirements were also assumed for 404 waters, and the cost associated with mitigating these impacts was estimated based on this scenario. The costs were estimated using a similar representative mitigation project. Mitigation requirements will be further coordinated with the adaptive management team (AMT) which is described below. A cost effective incremental cost analysis will be completed on the refined mitigation requirements during design development.

Wetland mitigation options for Jetty A and the South Jetty are very limited. No land is available near Jetty A; therefore, it's most cost effective to use lands near the North Jetty because construction mobilization costs are much lower there. Also, it is environmentally preferable to use lands near the North Jetty.

The selected plan design and construction methods for repair and rehabilitation of the MCR jetties have been developed and refined to take advantage of opportunities to avoid and minimize to the maximum extent practicable the project's ecological impacts to wetland, aquatic habitats, and species per requirements under the Clean Water Act and Executive Order (EO) No. 11990. Efforts were made to reduce the project footprint and to locate staging areas away from wetland and waters areas. However, there will be unavoidable effects to wetlands and waters as aquatic habitat will be filled and converted as a result of the project.

Staging and rock stockpile areas are required to work with the large stone and to construct the repairs. A balance was struck to provide and locate such staging areas that allowed project completion in an efficient and timely manner while minimizing both the areal and temporal extent of project impacts to wetlands and waters. This also includes siting offloading facilities in areas that minimize the extent of dredging and impacts to critical shallow water habitat. To avoid and reduce shallow-water impacts, the Corps determined that offloading facilities would avoid locations within Baker Bay as well as in the small bay area along the north shore of Clatsop Spit. Further, by potentially utilizing barging operations to supply and place the large-sized and large volume of stone, this both reduces the impacts of traffic and somewhat avoids and reduces safety issues with large trucks entering and exiting the Coast Guard and State Park facilities, respectively.

It is assumed all wetlands will be impacted for more than one year. Impacts to 404 waters of the US will also occur for more than one year with maintenance dredging and continuous use. Facilities may be removed or left in as permanent fixtures depending on hydraulic conditions at the offloading sites and along the adjacent jetties themselves, as well as costs associated with both removal and mitigation. For these reasons, impacts are considered permanent under assumptions for the worst-case scenario. Mitigation will be commensurate with the project footprint, which may be reduced further depending on whether or not the final implementation requires barge offloading facilities.

Official wetland delineations have now been completed for all three jetties. Prior to this at release of the Draft EA, preliminary available information allowed the Project Delivery Team (PDT) to initially locate construction activities and features to reduce anticipated impacts to wetlands. This information was also used to calculate initial estimates regarding potential wetland impacts. The original estimates, pre-delineation, approximated wetland acreages potentially impacted to be: North Jetty ~4.78 acres, South Jetty up to ~22 acres, and Jetty A up to ~11 acres, for an estimated total of ~38.28 acres of potential wetlands impacts. Post wetland delineations and after further minor refinement of locations for staging areas since the release of the draft EA, these impact numbers have been revised and dramatically reduced.

Ultimately, the project seeks to achieve no net loss in wetland habitat, to protect, improve and restore overall ecosystem functions, and to provide mitigation actions that are anticipated to restore affected benefits to aquatic species in the vicinity of the project. Towards that end, specific project footprints and activities described above have been identified, categorized, and quantified with conservative estimates where appropriate. Per initial consultation with regulating resource agencies and as a result of the wetland types, functional values and aquatic habitat proposed to be impacted, a preliminary ratio of 2:1 was suggested for wetland mitigation, and a ratio of 1.5:1 for waters other than wetlands to offset impacts that would occur to aquatic resources. As required, the Corps will mitigate for impacts which could not be otherwise avoided or minimized. Mitigation plans currently address three general categories: actions that create wetlands, offsetting actions for 404 impacts in-water, and actions that re-stabilize and replant construction-disturbed upland habitats. Onsite or adjacent mitigation to address impacts is preferred.

The Corps coordinated with the regulating agencies to determine appropriate mitigation ratios based on functions and typical compliance requirements. Proposed wetland mitigation is at a 2:1 ratio and mitigation for waters other than wetlands is at a 1.5:1 ratio. Though WQCs have not yet been obtained, the Corps has been working closely with the Certifying agencies to ensure it is meeting its legal responsibilities. The effects evaluated in the BA and the BiOp assumed a larger suite of actions, the effects of which have been reduced in the current plan selection. It is anticipated that through meetings and discussions with the AMT (the role of which is described in the coordination section of this chapter), the total for proposed mitigation will reflect the reduced project footprint. All agencies will be kept abreast of the project development to ensure construction and mitigation commitments are appropriate and realized.

Wetlands near South Jetty (on Clatsop Spit)

In order to acquire the 44 acres needed for staging and rock stockpiles, 2.65 acres of unavoidable wetland impacts will occur at the South Jetty. However, by slightly revising locations, maintaining hydrologic connections at wetland and lagoon crossings, and by maintaining a 50-ft wetland, shoreline, and riparian buffer for preserved areas whenever possible, these impacts have been greatly reduced and minimized relative to initial conservative impact estimates. This includes limiting the roads required to cross wetlands to a 20-ft width and requiring culverts to maintain hydrologic connectivity at crossings. In addition to wetlands, about 3.5 of the existing 5.2 acres of other waters of the US will be impacted in the form of fill in a lagoon area adjacent to and along the jetty. There will be a road and crossing over these waters, which will be culverted in order to maintain flows into and out of the marsh wetland complex; and the 40-ft wide causeway/jetty access roadway will be constructed immediately adjacent to the jetty in order to minimize interference with and impacts to the inlet of the marsh complex.

According to the Cowardin Classification system (1979), of the wetlands impacted, approximately: 0.77 acres are classified as Estuarine-Intertidal-Emergent-Persistent; 0.66 acres are classified as Palustrine-Forested-Needled-leaved-Evergreen; 0.75 are classified as Palustrine-Emergent-Non-persistent; and, 0.47 acres are classified as Palustrine-Forested-Broad-leaved-Deciduous.

As described in the South Jetty section under Landforms 2.1.3., wetlands were scored for grouped service functions as define by Oregon Rapid Wetland Assessment Protocol, 2010 (ORWAP), and the categories depressional and estuarine were identified.

It is notable that Cowardin and Hydrogeomorphic (HGM) classifications are not necessarily the same thing. For ORWAP scoring purposes, the HGM class for Estuarine appears broader than the Cowardin class. Because a portion of the wetlands preserved and impacted may be small, fringe parts of a larger wetland complex or feature (with possibly a tenuous connection to those other wetlands), therefore the dominant hydrological influence of the greater wetland area was considered. In some cases though the wetland was classified under Cowardin as Palustrine (considering landscape position and degree of connectivity of the delineated area to the greater wetland area), the greater dominating hydrologic regime was tidal (therefore the Estuarine classification in ORWAP).

Following this method in determining the types of wetland impacts, this brings the totals under the ORWAP categories to 1.15 acres of impacts to depressional wetlands at the South Jetty, which were ranked relatively as follows: low for hydrologic function and fish support group; and high for water quality, carbon sequestration, aquatic support, and terrestrial support. Alternatively, the relative scores for the grouped service values were: low for hydrologic function, terrestrial support, and public use and recognition; equal for provisioning services, and high for water quality, fish support, and aquatic support. The wetlands also ranked relatively high for ecological condition and sensitivity, and low for stressors.

In comparison to State wetland scores for grouped service functions as define by ORWAP (2010), 1.49 acres of impacts would affect estuarine wetlands at the South Jetty which are ranked relatively as follows: low for hydrologic function, aquatic support, and terrestrial support; and high for water quality, carbon sequestration, and fish support group. Alternatively, the relative scores for the grouped service values were: low for hydrologic function, aquatic support, terrestrial support, and public use and recognition; equal for provisioning services, and high for water quality and fish support. The wetlands also ranked relatively high for ecological condition, and low for stressors and sensitivity.

These wetlands will be mitigated near the impact site in an area identified in Trestle Bay near the channel entrance to Swash Lake. At a 2:1 mitigation ratio, this equals about 5.3 acres of wetland mitigation. Anecdotally, it is thought that the uplands in this area are the result of previous historic fill from the dredging the adjacent channel, so that excavation of uplands would result in restoration of wetland that are likely to be intertidal. There is also a former ODOT mitigation site that the Corps will likely abut. This is an appropriate mitigation site because it is within the same subwatershed (HUC 7), and per the ORWAP scoring and Cowardin classification, the adjacent areas have wetland types similar to those being impacted. The likelihood of successful wetland plant establishment is also higher because of proximity to already functioning native wetland communities and exisiting hydrology.

In comparison to State wetland scores for grouped service functions as define by ORWAP (2010), depressional wetlands at the South Jetty mitigation area are ranked relatively as follows: low for hydrologic function, carbon sequestration, fish support group, and aquatic support; and high for terrestrial support; and equal for water quality. Alternatively, the relative scores for the grouped service values were: low for hydrologic function, aquatic support, terrestrial support, and public use and recognition; equal for provisioning services, and high for water quality and fish support. The wetlands also ranked relatively high for ecological condition and sensitivity, and low for stressors.

In comparison to State wetland scores for grouped service functions as define by ORWAP (2010), estuarine wetlands at the South Jetty mitigation area are ranked relatively as follows: low for hydrologic function and water quality; and high for carbon sequestration, fish support group, aquatic support, and terrestrial support. Alternatively, the relative scores for the grouped service values were: low for hydrologic function, aquatic support, terrestrial support, and public use and recognition; equal for provisioning services, and high for water quality and fish support. The wetlands also ranked relatively high for ecological condition and stressors, and low for sensitivity.

Proximity of the uplands proposed for wetland conversion to the existing wetlands from both classes that had similar ORWAP scores at the mitigation site, in addition to tidal and precipitation hydrology should serve as reasonable indicators for potential success of the mitigation site. For all proposed mitigation, detailed designs, plans, and specifications will be further determined in the next stages of project development and will be constructed concurrent with wetland impacts.

Actions adjacent to or onsite of the South Jetty that were identified to mitigate wetland impacts include excavation of low and high saltwater marsh wetlands and new interdunal wetlands adjacent to existing wetlands; establishment of native wetland plant communities and removal of invasive species around a buffer zone for wetlands; restoration or provision of hydrology to newly excavated wetlands via appropriate elevation design; and/or restoration of wetland connectivity between existing fragmented wetlands. Offsite opportunities for wetland mitigation in the estuary that warranted further investigation were associated with: levee breaches, inlet improvements, or tide gate retrofits, as appropriate. However, these were not the preferred mitigation alternative as they were further away from the impacted areas and were not of similar wetland or habitat type impacted. Purchasing mitigation bank credits was considered as a possibility, though this is currently constrained by limitations of service area and availability of appropriate wetland types. Hydrology and vegetative communities are heavily influenced by elevation; therefore, providing improved hydrology combined with strategic excavation and appropriate plantings should result in a simple and self-sustaining design and outcome.

Wetlands near Jetty A

Rock storage and staging activities require a minimum of about 23 acres to meet the project need for implementation at Jetty A. This encompasses most of the area adjacent to the jetty root at the Coast Guard Station. A total of about 0.91 acres of wetland at Jetty A will also be filled due to rock storage and construction staging activities. Unfortunately, these wetlands cannot be avoided, but impacts to adjacent water of the U.S. will be minimized by implementing a 100-ft buffer beyond the Highest High Tide elevation, which is consistent with the setbacks required for lands designated as “Conservancy” by Pacific County. Of the wetlands impacted, 0.74 acres rated as a Category III Interdunal, Depressional wetlands with scores under 26. 0.17 acres rated as Category 1 Estuarine, Freshwater Tidal Fringe wetlands.

Because of onsite space constraints and site conditions, these wetlands at Jetty A will be mitigated at the North Jetty, north of the North Jetty Access Road. At a 2:1 mitigation ratio, this equals about 1.82 acres of wetland mitigation, plus the required buffer. These requirements were determined and align with joint Corps and Washington Department of Ecology, 2006 (WADOE) guidance. Reduced disturbance coupled with improved potential hydrology and adjacent functioning wetlands at North Jetty compared to at Jetty A make the success of wetland creations more likely at the location at the North Jetty compared to any creation at Jetty A. Therefore the mitigation for Jetty A is 1.82 acres. Jetty A mitigation ratios and acreages are likely close to the final amounts, they may change following further coordination with WA Department of Ecology and receipt of conditions in the Washington State Clean Water Act 401 Water Quality Certification and the determination of Coastal Zone Management Act Consistency.

Figure 5-1. Clatsop Spit Vegetative Communities

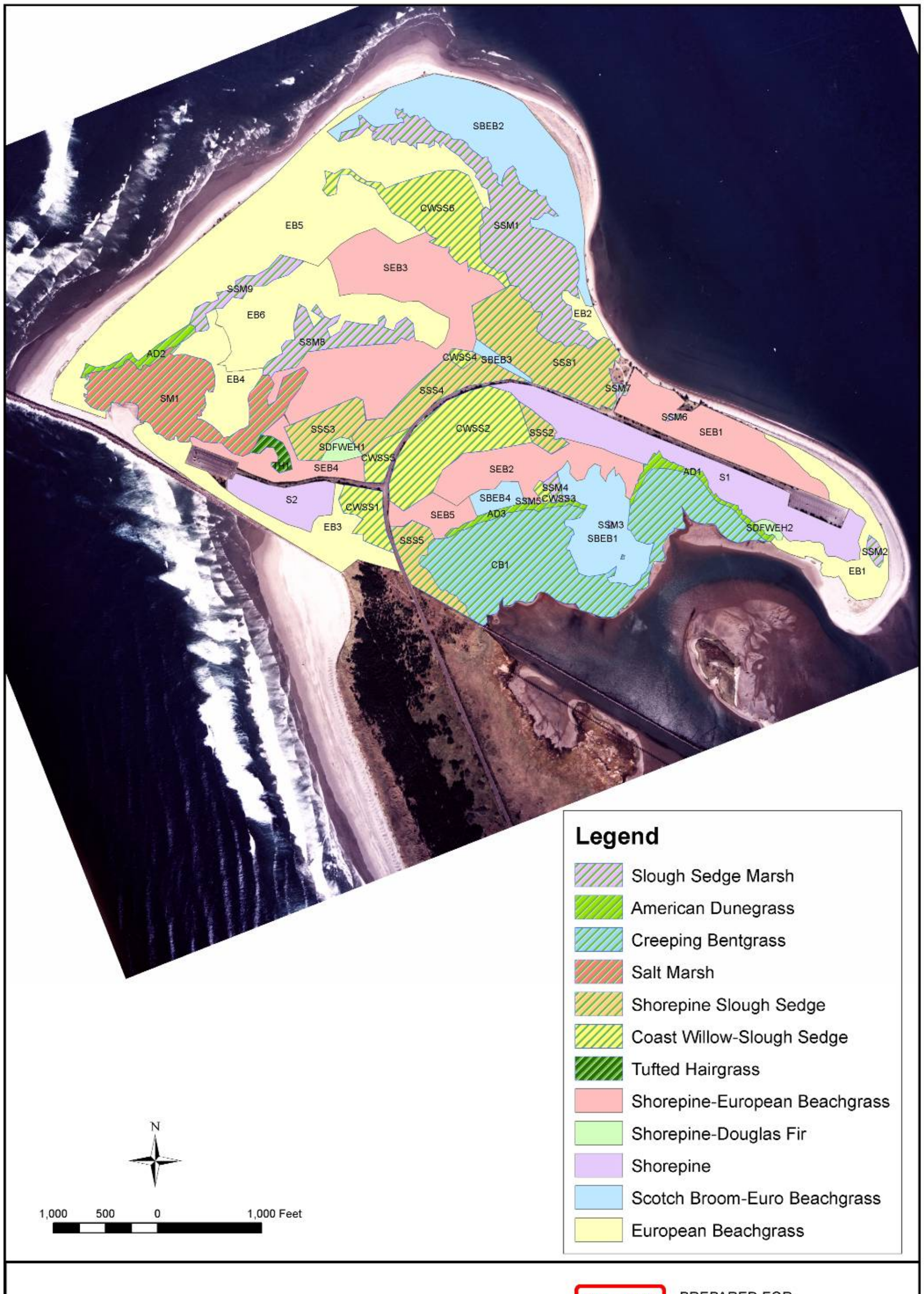


Figure 11. Clatsop Spit Vegetation Communities

Figure 5-2. North Jetty Potential Offloading, Staging, Storage and Causeway Facilities

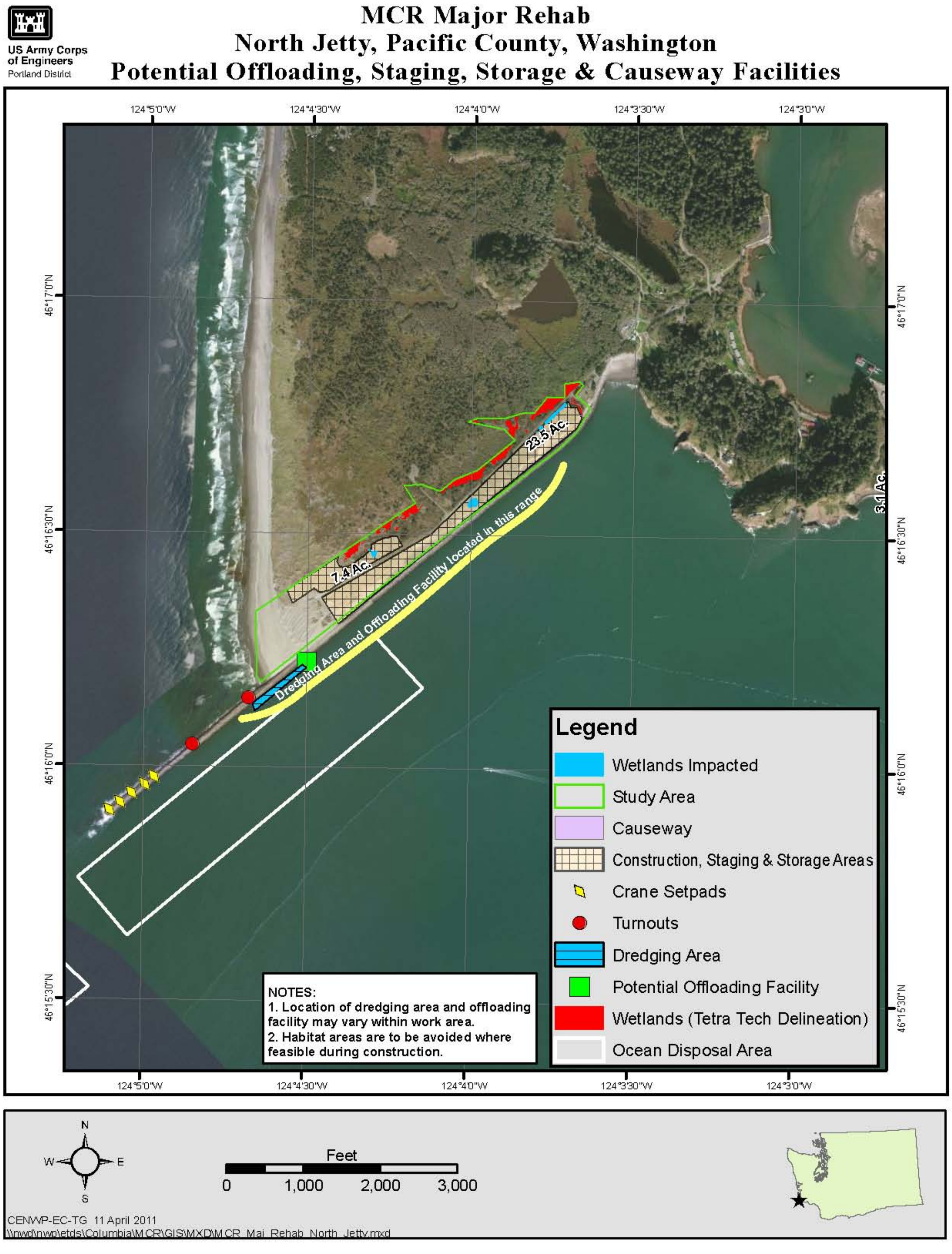


Figure 5-3. South Jetty Potential Offloading, Staging, Storage and Causeway Facilities

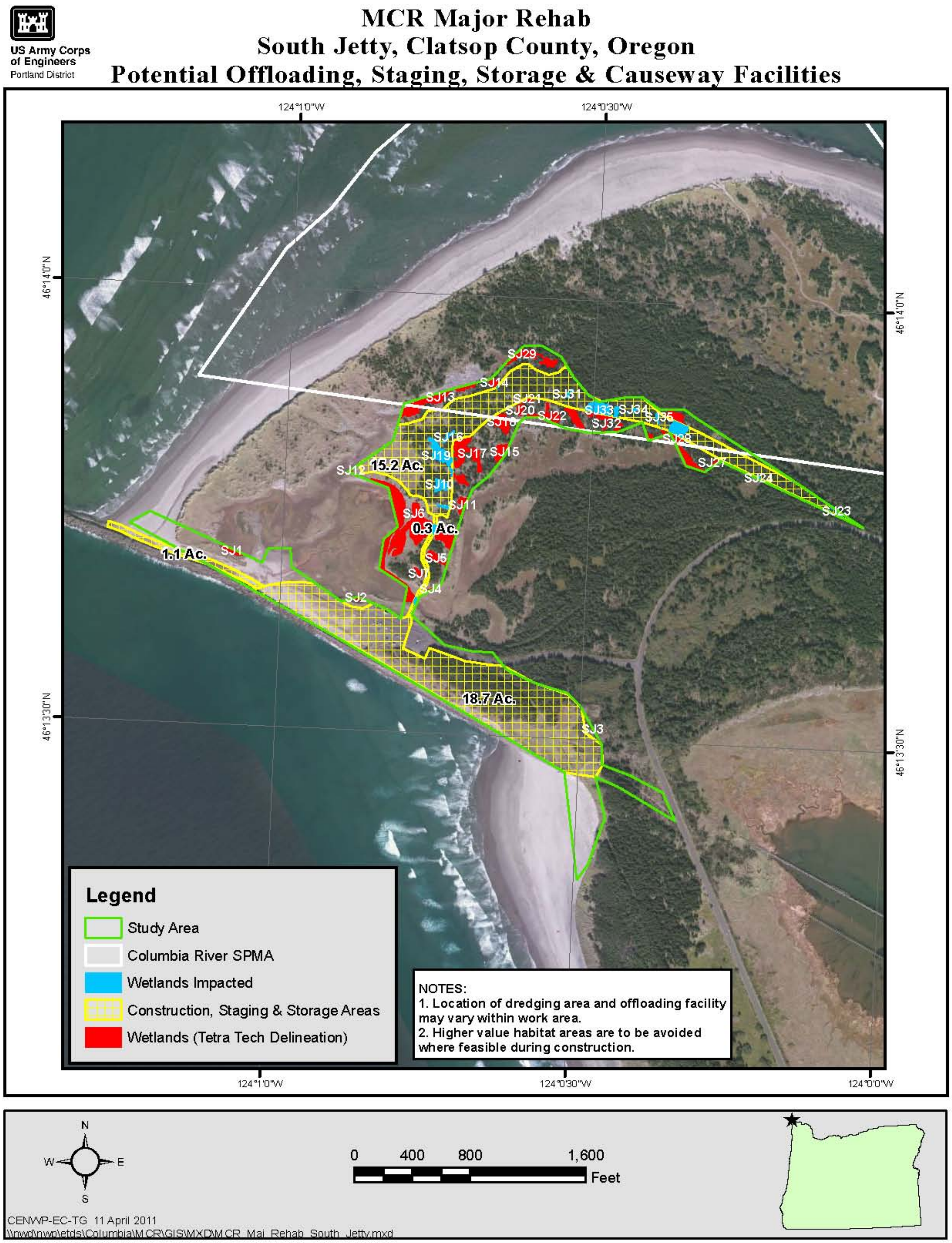


Figure 5-4. South Jetty Potential Offloading, Staging, Storage and Causeway Facilities

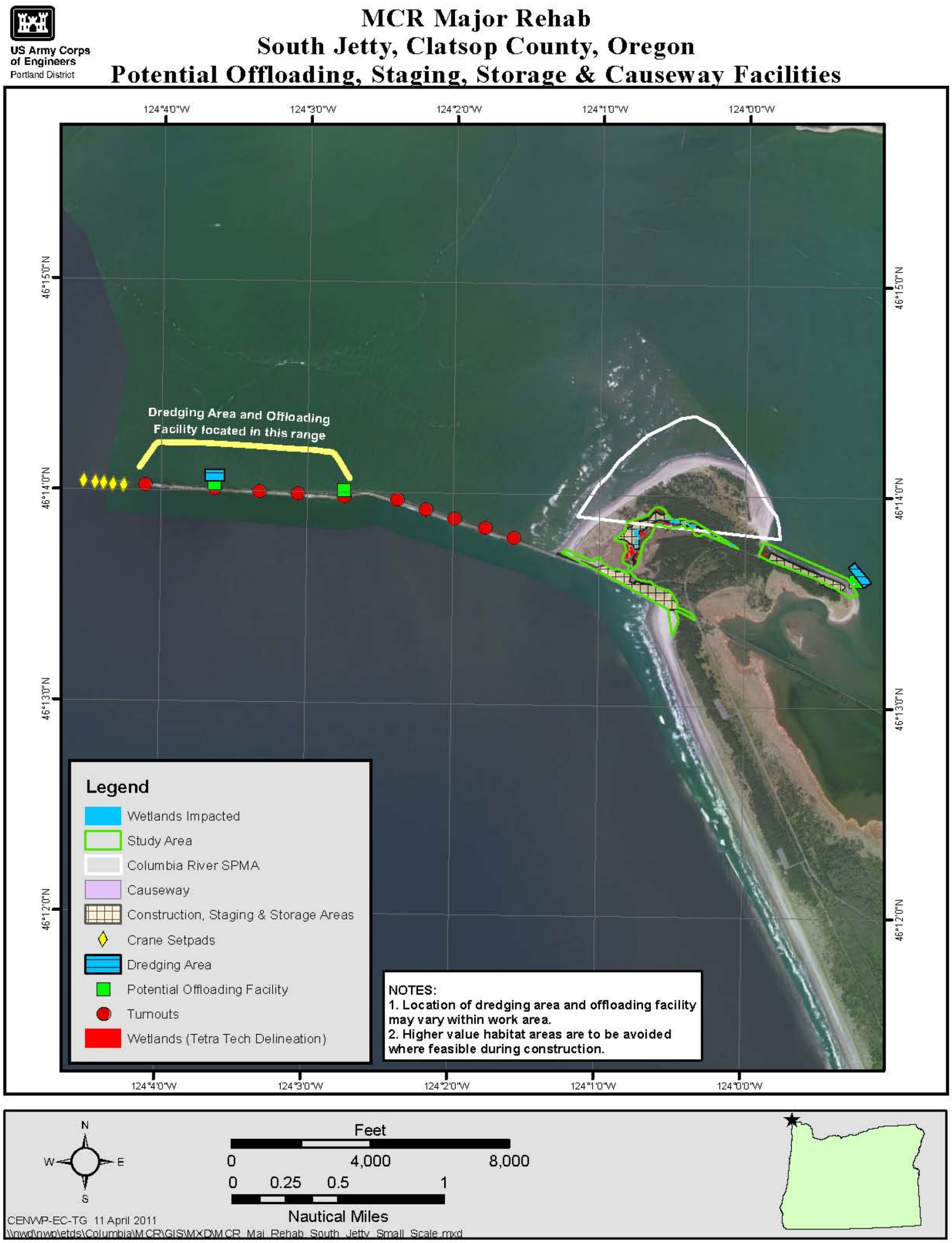
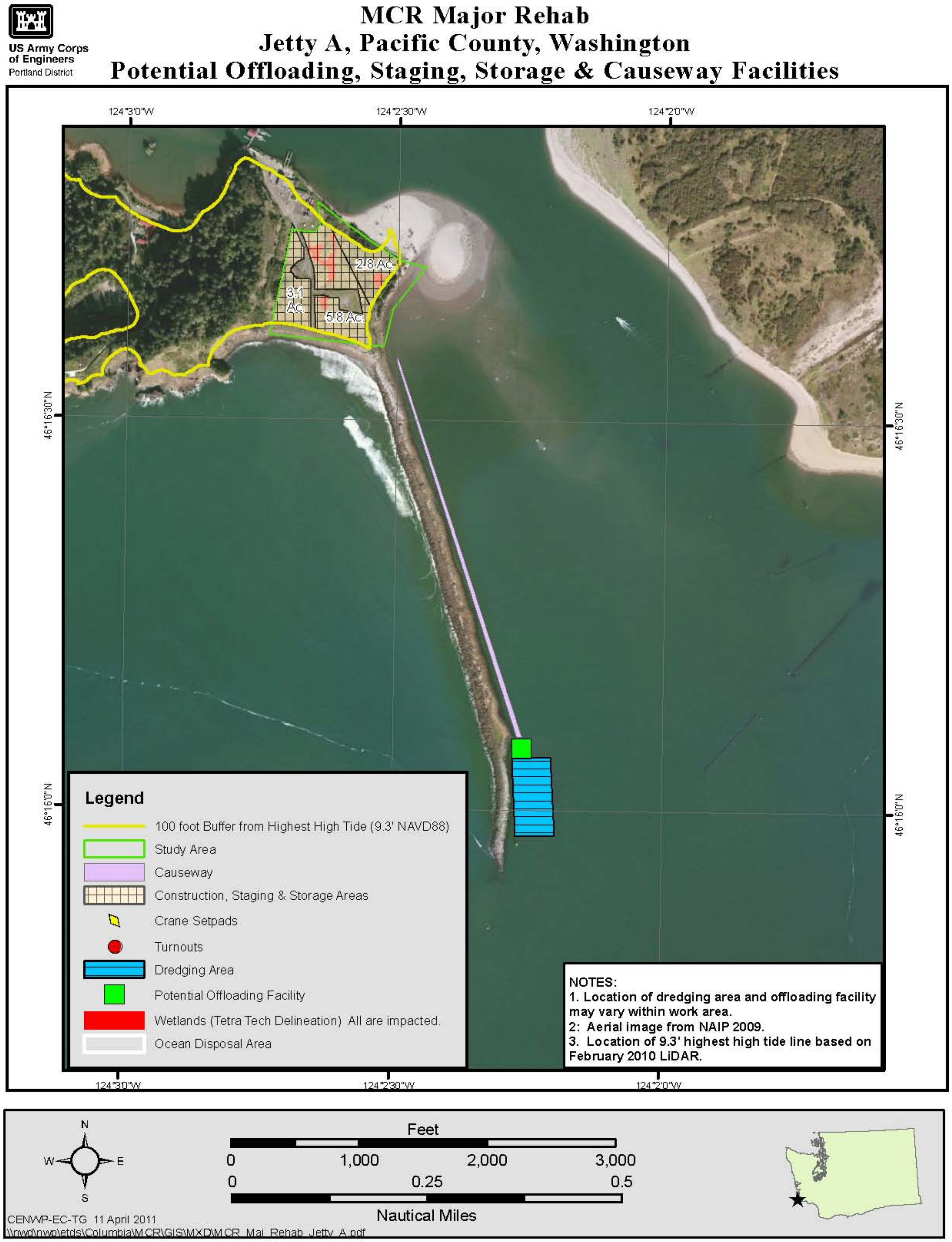


Figure 5-5. Jetty A Potential Offloading, Staging, Storage and Causeway Facilities



Fill in Other Waters of the U.S.

In-water habitats (below MHHW), both shallow intertidal and deeper subtidal areas will also be affected by the project. These waters are also considered "waters of the US" as defined by the Clean Water Act. Habitat conversions and impact to 404 waters will occur from lagoon fill, maintenance dredging, jetty cross-sections, turnouts, barge offloading facilities, and causeways. Effects to waters and the aquatic resources residing there will occur on a temporal and spatial scale. Though dredged areas may refill over time and some facilities and fill may be removed, there will still be repeated and chronic site disturbance in these waters over the duration of the project. There will also be permanent lagoon fill at the North Jetty root and temporary, partial lagoon fill at the South Jetty for construction access. This fill will be in place for several years.

The calculated extents of impacts were strictly based on the area of habitat that was converted by fill or removal. They did not include value or functional assignments regarding the significance of the conversion, whether it was a beneficial, neutral, or detrimental effect to specific species, nor if conversions created unforeseen, indirect far-field effects. For example, acreage of conversion for shallow sandy sub-tidal habitat to rocky sub-tidal habitat was calculated in the same manner as conversion from shallow intertidal habitat to shallow sub-tidal habitat. Multiple aquatic species utilize these waters, including macro-invertebrates like crabs, benthic organisms, marine mammals, and various other fish and wildlife species. It is also notable that impacts to 404 waters of the US will occur in an area that is listed as Essential Fish Habitat (EFH) for various species as well as in Critical Habitat for several listed ESA species. This impact was described in the 404(b)(1) analysis.

In WA at MCR, the designated CWA beneficial use designations for fresh waters by Water Resource Inventory Area (WRIA) include the following general and specific uses: Aquatic Life Uses - Spawning/Rearing; Recreation Uses; Water Supply Uses; Misc. Uses - Wildlife Habitat, Harvesting, Commerce/Navigation, Boating, and Aesthetics. In OR, the following list of beneficial uses were identified: Anadromous Fish Passage; Drinking Water; Resident Fish and Aquatic Life; Estuarine Water; Shellfish Growing; Human Health; and Water Contact Recreation. These designated beneficial uses also include specific water quality criteria to protect the most sensitive uses, which includes use by salmonids for rearing and migration. For this reason, mitigation under the CWA also complements protections and conservation measures under the ESA for salmon and steelhead.

Because of these impacts, the Corps has proposed mitigation actions at a ratio of 1.5 :1 to offset temporal and spatial impacts to 404 waters and associated aquatic resources. This ratio was determined with input from the regulating resource agencies considering several factors including: beneficial use listings that involve species with EFH and critical habitat designations in the impacted areas, the duration of the construction period, the number of different beneficial uses in the area impacted by the project, and the temporal and spatial extent of the actions. These actions are not proposed to directly mitigate or compensate for any project-related impacts to ESA-listed species but will mitigate for effects to CWA 404 waters of the US. However, the 404 mitigation actions will also complement but are not driven by Conservation Recommendations in the NMFS BiOp for recovery of ESA-listed salmonid habitats and ecosystem functions and processes.

Mitigation features will be commensurate with impacts and will be designed to create or improve aquatic habitat. In-kind mitigation opportunities for impacts to 404 waters were investigated, specifically tidal marsh, swamp, and shallow water and flats habitat. Though a specific site or action has yet to be determined for mitigation of impacts to waters other than wetlands, if possible fish access to these mitigation features will be an important consideration.

Table 5-4 Possible Mitigation Features for Impacts to 404 Waters of the US

Feature/Site	Area Affected	Type and Function
Trestle Bay	5 to 8 acres with potential for additional acres	Estuarine Saltwater Marsh Wetland and Intertidal Mudflat Creation and Restoration • Create and expand estuarine intertidal brackish saltwater marsh wetland habitat • Expand and restore Lyngby sedge plant community • Expand/increase intertidal shallow water habitat, including dendritic mud flats and off-channel habitat • Remove and control invasive species and improve/restore diversity and density of native plant assemblages • Increase habitat complexity for fisheries benefit • Potentially expand floodplain terrace and improve riparian function • (Re)introduce natural tidal disturbance regime to area currently upland dunes
Wetland Creation at Cape Disappointment	Up to ~10 acres	Creation and Expansion of Interdunal Wetland Complex • Excavation of new interdunal wetlands adjacent to existing wetlands • Establishment of native wetland plant communities and removal of invasive species around a buffer zone • Restoration or provision of hydrology to newly excavated wetlands via appropriate elevation design • Restoration of wetland connectivity between existing fragmented wetlands via culvert retrofits, if feasible
Tide Gate Retrofits for Salmonid Passage	Variable	Select Tributaries from ODFW Priority Culver Repair List – Tributary Reconnection • Restore and improve existing fish passage and provide access throughout greater range of flows to off-channel juvenile rearing • Restore and increase habitat complexity for fisheries benefit • Restore and improve adult salmonid access to headwaters and potential spawning habitat
Pile Dike Removal	Variable	Remove Existing Pile Dike Fields • Restore and improve existing aquatic habitat • Restore and increase habitat complexity for fisheries benefit
Beneficial Use of Dredge Material	Variable	Beneficial Placement of Dredge Material • Restore and improve existing aquatic habitat • Restore and increase habitat complexity for fisheries benefit

From the list of possible mitigation features shown in Table 5-4, one or a combination of actions will be selected for further development and implementation in order to offset actions affecting 404 waters. Selection will occur by the Corps with input from the AMT regarding legal requirements and completion of supplementary compliance documentation, and work is anticipated to be completed concurrent with jetty repair actions. Please refer to the CE/ICA discussions in chapter 2 where estimates were based on the worst-case analysis for impacts to 404 waters. These will be refined during DDR.

General Wetland Mitigation Design and Monitoring

Materials removed from impacted wetlands will be reused in the created wetlands as appropriate to take advantage of the existing wetland seed bank and hydrologic soils constituents. Plantings, revegetation, and invasive species removal will also be implemented, including the required buffer around the new wetland area. It is anticipated that upland material removed during wetland creation will be placed as part of the lagoon fill on the South Jetty. With ample precipitation, functioning adjacent reference sites, and appropriate plantings, the likelihood of successful wetland establishment is reasonably high.

At the South Jetty, wetland mitigation will take place adjacent to an existing mitigation site further southwest of the impact area at the bottom of Trestle Bay such that there are reference elevations and hydrophytic species to facilitate design planning and vegetation establishment, respectively. The mitigation location near Swash Lake is not as close to the area of impacts as the site at the North Jetty, but the proposed location is further away from areas experiencing heavy recreation and all-terrain vehicle (ATV) use such as is occurring in the existing wetlands on Clatsop Spit itself. Therefore, the likelihood of successful wetland establishment is greater in the proposed location.

The process for creating the wetlands at the South Jetty site will be similar to that at the North Jetty, but an additional dendritic channel may also be included as appropriate such that newly created wetlands experience an estuarine connection like those that are being impacted by the project. This will also involve excavation to create hydrologic conditions based on tidal and reference site elevations

Monitoring of all mitigation sites is expected to occur prior to, during, and for three years after mitigation implementation. For wetlands, sample reference plots will be established along with a photo point, and success criteria will be based on achievement similar or better functions and values scores relative to those indicated by the delineations for those impacted by the project. Monitoring components will likely include the following elements, which may be modified as further mitigation development details are available: percent survival; percent cover; percent of native vs. non-native species; and achievement of appropriate hydrology. Hydrologic indicators will include establishment of topography and contouring/geomorphology that is similar to adjacent representative sites, and in the case of South Jetty, achievement of regular tidal inundation. Appropriate monitoring criteria will also be developed for the mitigation to waters other than wetlands.

Refinement and implementation of this overall mitigation plan will help protect species and habitats while restoring wetland, in-water, and upland functions affected by the proposed action. Monitoring and maintenance of mitigation will be required to ensure successful establishment of mitigation goals and satisfactory return on investment. These mitigation actions and monitoring results will also be recorded on the Corps mitigation website at:

https://sam-db01mob.sam.ds.usace.army.mil:4443/pls/apex/f?p=107:1:1390572094248259.

Regular coordination with the AMT will further facilitate implementation of appropriate mitigation for impacts to wetlands and waters that appropriately offset affected habitat and are complementary to the framework for successful protection and preservation of aquatic resources, ESA listed species, and high-value habitat. The mitigation action(s) for 404 waters of the US ultimately selected will be evaluated in a subsequent NEPA document(s) when further details are available.

General Aquatic Habitat Mitigation Design and Mitigation Monitoring

Specific opportunities were investigated in the Columbia River estuary and Youngs Bay and several are under consideration to mitigate for impacted aquatic functions in 404 waters of the US. Depending on further development and determination of appropriate mitigation siting for final impacts to 404 waters, a specific project or combination of projects will be designed and constructed concurrently as the proposed repair and rehabilitation options are completed over time. Proposed projects are subject to further analysis, and unforeseen circumstances may preclude further development of any specific project. In all cases, final selection, design, and completion of specific mitigation features is contingent on evolving factors and further analyses including: potential reduction in estimated impact acreage due to alterations in project implementation, hydraulic and hydrologic conditions, cultural resource issues, etc. For this reason a suite of potential proposals has been identified and subsequent selection of one or some combination of these or other projects and designs will occur during continued discussion with resource agencies participating on the AMT. The Corps will make a decision regarding the specific mitigation proposal for waters other than wetlands and then will vet the final designs through the AMT in order to obtain necessary legal clearances.

Actions considered and investigated to provide mitigation for in-water habitat impacts include levee breaches, inlet improvements, or tide gate retrofits. However, mitigation efforts must consider in-kind mitigation and are constrained by the project's O&M authority, which precludes acquisition of private property and does not authorize breaches of federal levees. Additional associated actions that were investigated and may be implemented with the wetland mitigation include: excavation in sand dunes and uplands to specified design elevations in order to create additional intertidal shallow-water habitat with dendritic channels and mud flats, and excavation for potential expansion of the floodplain terraces. Though conceptually considered, other specific opportunities for mitigation projects such as the following were not identified but warrant further investigation if none of the projects in the list is determined to be feasible: removal of overwater structures and fill in the estuary; removal of relic pile-dike fields; removal of fill from Trestle Bay or elsewhere; removal of shoreline erosion control structures and replacement with bioengineering features; beneficial use of dredge material to create shallow water habitat features; and restoration of eelgrass beds. Certain pile fields and engineering features may be providing current habitat benefits that could be lost with removal, and such actions would require appropriate hydraulic analysis coordination with engineers and resource agencies.

For potential mitigation projects located in Trestle Bay, there is additional monitoring and assessment opportunity. A separate hydraulic/engineering study under a different project authority could investigate whether or not an expansion of low-energy, intertidal habitat near Swash Lake could effectively provide additional storage capacity and affect circulation in the bay such that erosive pressure at neck of Clatsop Spit could be reduced.

Table 5-5 Summary of Estimated Acreages for 404 Wetland and Waters Mitigation

Area Affected	Impacted Acreage	Mitigation Acreage	Comment
North Jetty			
Wetland	1.14	2.28	Base Condition: MMR
404 Waters Lagoon	8.02	12.03	Base Condition: MMR
Other 404 Waters	4.36	6.54	CE/ICA during DDR phase
South Jetty			
Wetlands	2.65	5.30	CE conducted
404 Waters	13.84	20.76	CE/ICA during DDR phase
Jetty A			
Wetlands	0.91	1.82	CE conducted
404 Waters	6.6	9.9	CE/ICA during DDR phase

5.1.10. Uplands Disturbance and Re-stabilization

Rock storage and staging areas will impact uplands as well as wetlands. Best management practices (BMPs) to reduce the environmental footprint and to avoid and minimize impacts have been incorporated and will be implemented, including appropriately locating staging sites, implementing stormwater management plans, and stabilizing the site during and after construction. Post-construction upland re-stabilization would include re-establishing native grasses, shrubs, and trees where appropriate; controlling and removing invasive species like scotch broom and European beach grass in the project vicinity; and re-grading/tilling the area to restore pre-project natural contours. The Oregon Parks and Recreation Department (OPRD) has requested that the Corps utilize the State Forester as one resource for determining optimal revegetation plans.

As mentioned in the snowy plover discussions, on Clatsop Spit there is a unique opportunity to partner with USFWS and OPRD regarding creation and management of snowy plover habitat under the 2010 HCP. There may be locations in the vicinity and away from projected construction and staging areas to convert upland habitat to snowy plover habitat via invasive species removal, tilling, and application of shell hash. Newly cleared habitat would be created with the intention of luring plover to a more preferable nesting location away from the potential attractive nuisance of the disturbed staging areas. Operation and maintenance during the project via regular tilling and shell hash distribution could be coordinated between the agencies through a Memorandum of Agreement (MOA) or similar avenue. The Corps currently has a signed MOA indicating it will cooperate with OPRD in the implementation of the snowy plover management plan under development.

5.1.11. Cultural and Historic Resources

The proposed action is being conducted in an area that is highly erosive and has previously been disturbed by jetty construction. Jetty site evaluations concluded that shipwrecks or remnants of shipwrecks do not occur at the jetty locations. Although the MCR jetties are currently not listed on the National Register of Historic Places, nomination of the structures is planned. Documentation of the structures will be coordinated with the State Historic Preservation Offices. Section 106 documentation of the current condition of the jetty trestle remnants was conducted in 2006 for the repair work. Both the North and South jetties are eligible for the National Register of Historic Places because they are important historically. However, they do not retain original materials of workmanship as they have been repaired many times, but they do retain their original alignments.

Interim repair work done in 2005 and 2006 on the Washington side was coordinated with the State Historic Preservation Office; a no adverse effect determination was supported for this interim repair after remnants of the original trestle were documented by a historic architecture study in an area adjacent to the jetty rock structure in a planned staging area where trestle remnants would be impacted. Much of the area around each jetty is composed of accreted material from littoral drift with little or no potential for historic properties. The undertaking has been determined to have no effect on historic properties since the action will not affect the criteria that make the jetties eligible for the Register and the Washington and Oregon SHPOs have concurred.

5.1.12. **Socioeconomic Resources**

Construction vehicles and trucks hauling jetty rock would have an intermittent but long-term affect on local traffic patterns in the Long Beach/Ilwaco area (North Jetty/Jetty A) and in Warrenton/Hammond area (South Jetty), depending on whether barge or truck transport is used for jetty rock. The approximate number of trucks or barges to be used for rock transport is shown below (additional information is provided in Section 6.4):

Construction of the proposed action would have minor adverse impacts to recreationists at Cape Disappointment State Park and Fort Stevens State Park, both those participating in water-sports and beach activities near the jetties, and those using the jetty structures for fishing and crabbing. Heavy equipment using park roads and parking lots will delay or inconvenience park visitors and water sport and beach recreationists. Park visitors and recreationists are likely to be disturbed by construction noise. A number of restrictions would be in place near the construction zones at each jetty to protect park visitors, water sport and beach recreationists, and the public. For public safety reasons, the Corps discourages use of the jetty structures themselves, and this policy would remain in force throughout the construction period. Along the South Jetty where surfing occurs, there may be some exclusion areas near the jetty structure and during dune augmentation and portions of jetty repair. However, the bulk of vessel traffic will occur on the channel side of the jetty and repairs will be in the immediate vicinity of the structure, so the minimal and short-term effects on surfing are likely to be negligible. Some park roads and parking lots would likely be closed at times during construction. Razor clam beds in the vicinity of the jetties may be temporarily closed during construction activities, but are not expected to be negatively impacted. Access to the jetties and nearby beaches would also be closed periodically at different times during construction of the individual jetties, which would also impact water sport and beach recreationists and anglers using the immediate vicinity. However, large portions of the parks and beaches will remain open and accessible to the public, and the bulk of the construction activities are likely to be seasonally concentrated. The long-term reduction in the levels of recreational activity could also affect the local economy of the Long Beach peninsula and the Warrenton/Hammond area, which are highly dependent on tourism. However, navigation traffic transiting the MCR, including recreational vessels and cruise ships that dock at Astoria, Oregon, would not be affected during construction. Overall, the recreation and local economy impacts during construction of the proposed action are expected to be minor. Therefore, the Corps is not proposing mitigation for recreational impacts, nor is the Corps proposing to construct additional beach access points. The potential environmental impacts of creating additional beach access points outweigh the inconvenience and reduced access caused by seasonal construction activities.

After construction there would have a long-term, positive effect on navigation vessel safety, including recreation vessels and cruise ships. Maintenance of the shoreline at Clatsop Spit and Benson Beach is expected, which preserves these areas for recreational opportunities mentioned above. The proposed action would have no effect on utilities and public services in the area. The MCR is the gateway to the Columbia-Snake River system, accommodating commercial navigation traffic with an approximate annual value of $20 billion dollars a year. The proposed action would have a long-term, positive effect on maintaining this vital transportation link and associated economy for the states of Oregon, Washington, Idaho and Montana, as well as for the Nation as a whole.

5.2. COORDINATION AND CORRESPONDENCE

An agency coordination meeting was held on May 25, 2006 for the purpose of introducing the project to several agencies that will be involved with review of environmental documents. Staff from the USACE Portland District presented the current state of environmental review and engineering modeling to the National Marine Fisheries Service (NMFS), U.S. Fish and Wildlife Service (USFWS), Washington Department of Ecology, Oregon Department of Environmental Quality, and Oregon Department of Land Conservation and Development.

On April 13, 2007 the USACE met with the U.S. Geological Survey (USGS) and Portland State University regarding numerical modeling in support of the MCR rehabilitation project. Also in 2007, four resource agency meetings and presentations were held regarding the MCR project on April 27, May 30, July 11, and September 5. A public information meeting was held in Astoria, Oregon on July 31, 2006. After a presentation about the MCR jetty rehabilitation project, the public was invited to ask questions and talk to USACE staff about the project. In addition, the USACE Portland District established a web site to keep the public informed about the repair/rehabilitation of the MCR jetties, located at https://www.nwp.usace.army.mil/issues/jetty/home.asp.

An initial draft Environmental Assessment (EA) was distributed for a 30-day public review in June 2006. Six comment letters were received based on the June 2006 EA. Since the current range of alternatives and project description changed, comments received on the June 2006 EA may no longer be relevant to the current proposed alternatives. A summary of these comments is provided below.

- Interested in how rehabilitation would impact siltation in side channels and in Baker Bay and effects to coastal erosion.
- Need to analyze/mitigate losses to crab nursery habitat.
- Loss of sand from coastlines (primarily Benson Beach) needs to be analyzed/mitigated. Interested in sand placement on Benson Beach.
- Focus on Environmental Impact Statement (EIS) and evaluate all projects in the MCR vicinity cumulatively in a comprehensive context (dredging, dam regulation, disposal, etc).
- Purpose should be to get goods to market not rehabilitate the jetties. Alternative should consider other options besides shipping.
- Jetty A’s purpose should be discussed; noted that channel has moved north.
- Evaluate how existing spur groins have performed.
- Affected environment should extend to Grays Harbor.
- Role of near-jetty disposal should be evaluated in greater detail.
- The degree to which waves have changed should be evaluated with respect to jetty design.
- Discuss project impacts to Clatsop Spit and Peacock Spit and sediment budget to littoral cell.
- Sand placement alternatives should be considered to address jetty foundation shoal erosion.
- The draft EA (2006) was put out for public review too early and has deprived the public its opportunity to comment.
- Should report current rates of erosion at Peacock Spit.

- Supports rehabilitation of the MCR jetties citing navigation safety and economic benefits.
- Interested in how rehabilitation of Jetty A would affect base of North Jetty and channel entrance to Port of Ilwaco with respect to sand accumulation.
- Supports studying/planning and rehabilitating the MCR jetties citing the international/economic importance of shipping.
- Recommend that rehabilitation be accomplished from land-based work sites to minimize amount of dredging.
- Recommend that dredged material resulting from project be used to create snowy plover habitat at base of South Jetty by covering beach grass. Interested in reviewing any planting plan.
- Interested in type of wetlands to be impacted at North Jetty and location of disposal site.
- The wetlands behind the North Jetty should be categorized using the Washington State wetland rating system for Western Washington to assist in determining appropriate mitigation.
- Interested in potential impacts/mitigation to wetland north of the North Jetty access road from filling behind the North Jetty (the area is considered Conservancy Shorelands under Pacific County Shoreline Management Plan).
- Best management practices should be in place to prevent adverse impacts to wetlands from construction traffic.
- Interested in alternative routes to beach, and viewing area during construction.
- Assess impacts of barge offloading facility creation and haul routes when known.
- Interested in interactions with other planned activities about the MCR including Benson Beach project.
- Modeling should consider impacts from sediment transport/deposition at Benson Beach and whether build-out would affect ability to do the Benson Beach project.

Due to changes in the project description, a revised draft EA was prepared. A revised draft 2010 EA was informed by and revised to reflect and address the above comments, as appropriate. The revised draft EA was issued for a 30-day public review period in January 2010. The revised draft EA was provided to federal and state agencies, organizations and groups, and various property owners and interested publics. In addition, a public information meeting was held in Astoria, Oregon on February 3, 2010. After a presentation by the Corps about the MCR jetty rehabilitation project, the public was invited to ask questions and talk to USACE staff about the project. Another public information meeting to describe likely construction techniques was also held on June, 4, 2010, at Fort Vancouver, WA to solicit input from potential construction contractors and to provide additional information regarding the feasibility of the Major Rehabilitation and Repair approach.

A summary of the comments received on the January 2010 revised draft EA is provided below, followed by the Corps' response and subsequent changes to the 2011 EA and the 2012 revision, as appropriate.

1. Confederated Tribes of the Grand Ronde, email dated January 21, 2010.
    a. Requested any reviews related to the National Historic Preservation Act.
        i. No change to EA text. This will be done as part of the actions described in the Compliance section.
2. Clatsop County Transportation and Development Services, letter dated January 21, 2010.
    a. Project will affect the safety and operations of Ridge Road to be used to access the South Jetty project area; request meeting to discuss requirements for road's use.

        i. No change to EA text. This will occur later during development of the Detailed Design Report and Plans and Specifications prior to construction.

3. Oregon State Historic Preservation Office, letter (no date).
    a. Project will have no effect on any known cultural resources; no further archaeological research is needed unless cultural material is discovered during construction.
        i. No change to EA text. This will help inform part of the National Historic Preservation Act actions described in the Compliance section.
4. Columbia River Crab Fisherman's Association, letter dated February 1, 2010.
    a. Agree with findings of report/no action is unacceptable; EA and Finding of No Significant Impact (FONSI) is appropriate.
        i. No change to EA text.
    b. Just adding stone to jetties will not solve entire foundation problem, direct sand supplementation of the sand foundation is needed to stabilize jetties over coming decades.
        i. No change to EA text. Engineering staff has evaluated and designed the project as described in the EA to address the perceived problems and causes, including consideration of spur groins to accrete sand and protect the jetties' foundations.
    c. Lengthen Jetty A to full length will help stabilize natural northern migration of shipping channel and help somewhat with increasing erosion on Sand Island.
        i. No change to EA text. Engineering staff has evaluated and designed the project to address the perceived problems and causes as described in the EA, including capping or stabilization of the head of Jetty A at its current length to avoid further head loss.
    d. Routine direct placement of sand near root of jetties and north along Benson Beach will be required and must be part of the long-range stabilization plan. Consider a permanent pipe with frequent outlets for length of jetties to distribute sediment on both sides of jetties to supplement sand foundation. Consider permanent pipeline to supplement Benson Beach.
        i. No change to EA text. Engineering staff has evaluated and designed the project to address the perceived problems and causes as described in the EA, including lagoon fill and consideration of spur groins to address protection of the jetty foundation. Benson Beach littoral drift replenishment is being conducted under a separate project.
    e. In general, the Columbia River Crab Fisherman's Association supports the project.
        i. No change to EA text.
5. Public Commenter, email dated February 12, 2010.
    a. Previous jetties repairs have required a great deal of truck traffic in SW Washington; transport rock this time via barge. State is in a budget crisis cannot afford to repair roads; barges are more energy efficient and would keep roads from being compromised.
        i. As described in Section 5.5.3, the feasibility of several transportation options have been considered, and a combination of approaches may be implemented.
6. Public Commenter, letter dated January 15, 2010.
    a. During design, consider how construction will affect the surf break.
        i. No change to EA text. Wave climate and currents were modeled and considered for their impacts to the function and integrity of the jetty structures for maintaining navigation. Understanding wave formation for recreational uses was not one of the project purposes evaluated.

b. Locations of spur groins not clearly shown in the EA.
    i. Locations of spurs were clearly shown on the proposed action figure for each jetty. They are no longer proposed in this 2012 preferred alternative.
c. The EA does not adequately address impact to socio-economics of Warrenton; revise text (Sections 2.4.3 and 6.8) to acknowledge other activities like water sports (surfing, kayaking, kite boarding), clam digging, and beach activities such as walking, running, dog exercise, etc.
    i. Text of EA was revised as suggested.
d. There needs to be public access to beach immediately south of South Jetty; prohibiting access by not allowing climbing over jetty rocks is not a solution. Public beach access should be maintained during construction. Letter provides two ways to address this: (1) contractor can retain some parking at Lot C and provide safe pedestrian access through construction zone; or (2) contractor can build new or temporary parking lot/path to the beach south of jetty.
    i. As described in the Socio-economic sections of the EA, for safety reasons, the Corps prohibits climbing on jetty rocks, and to maintain safety will also have certain portions of the park closed where there is construction, equipment, or staging activities. Though there may be intermittent closures in certain areas, there are likely to be portions of the beach that remain open and unaffected. The Corps will be coordinating with the Park and construction staff to maintain the safety of park visitors.
e. Post-construction establish a permanent, safe public access from the parking area to the beach.
    i. No change to EA text. The purpose of this project is to maintain the jetties and does not include construction of additional beach access points.
f. The EA should address construction safety for surfers and other water sport enthusiasts; contractor to delineate safety zones when working in or around the water using buoys or other types of notification; provide signs or displays warning surfers when in-water work is underway.
    i. No change to the EA text. This is mentioned in Section 6.15

7. Chadbourne + Doss Architects, email dated February 4, 2010.
    a. Spends time at South Jetty and sees opportunity for interpretive center or thoughtful installation to help communicate purpose of the jetty and efforts of Corps.
        i. No change in the EA text. This does not fit with the purpose and need of the project.
8. Public Commenter, letter dated January 17, 2010.
    a. Provides information and photos of Japanese approach to sea walls and breaker barriers.
        i. No change in the EA text. Concrete armor units similar to those shared by the commenter are already under consideration for use at the jetty heads.
9. JP&M Mining, email dated January 20, 2010.
    a. Attending meeting in Astoria on February 3, wants any existing surveys on North and South jetties and information on previous quarries used.
        i. Request was forwarded to the geotechnical engineer, and a quarry list has been provided in the EA.
    b. Putting together a business plan that may include revamping a coastal port.
        i. No change in the EA text.

   c. Jetty rehab excellent way to use local workers and improve infrastructure in coastal communities.
      i. No change in the EA text.

10. Public Commenter, letter dated February 2, 2010.
    a. Provided two historical references to be added to history of MCR jetties section.
       i. These were added to reference section.
    b. Draft EA overemphasizes use of quarried armor stones; other approaches like reinforced concrete armor units and structural solutions using reinforced concrete elements should also be given emphasis in decision-making process.
11. More information was added to EA about physical model (Section 4.1.2.3). Concrete armor units are under consideration for use at the jetty heads.PND Engineers, letter dated February 12, 2010.
    a. Provided information on OPEN CELL jetty structures.
       i. No change in the EA text. Information was forwarded to the coastal engineers.
12. Northwest Environmental Advocates, letter dated February 12, 2010.
    a. USACE must prepare an EIS that complies with the purpose of NEPA.
       i. No change to the EA text. With the release of the Draft EA for solicitation of public comments, through its evaluation of impacts and alternative, and through meeting its other compliance obligations, the Corps has also been complying with its NEPA obligations. At the conclusion of the Final EA, the Corps will make its determination as to whether or not an EIS or a FONSI will be completed.
    b. Information required for public disclosure has been omitted from draft EA (disposal of dredged materials, costs and benefit-to-cost ratio for the project, meaningful discussion of impacts, etc).
       i. EA text has been revised for dredged material disposal, alternative selection, and impact discussions.
    c. Draft EA segregates connected actions; the jetties, maintenance of the MCR and Columbia River navigation channel, and dredged material disposal sites are connected actions.
       i. No change to text in the EA. The purpose and need described in the proposed action is limited to repair and rehabilitation of the existing jetty system.
    d. Biological Assessments for the Services not completed prior to public review of draft EA.
       i. The EA text has been edited to reflect updated evaluations and information, including in the ESA Compliance section. Biological Assessments have been completed, and a Biological Opinion and Letter of Concurrence have been obtained from the Services prior to completion of the final EA.
    e. Inadequate information on future conditions that will degrade the jetties, e.g., wave height changes, climate change.
       i. Text was added to the EA in section 6.11 describing hydrologic and hydraulic processes and modeling that was conducted during evaluation and design of the jetty alternatives.
    f. Draft EA does not address the impacts of filling the Trestle Bay area with cobble.
       i. As described in the alternatives discussion for the South Jetty, this alternative component has been removed as part of the selected or preferred plan. Text was added to Section 6 to discuss impacts from fill at the foredune augmentation.

g. Draft EA does not adequately analyze alternatives.
    i. Changes to the text were made for describing the selection of alternatives.
h. Draft EA does not contain a detailed mitigation plan.
    i. The wetland impacts and mitigation sections have been revised to reflect mitigation plans.
i. Draft EA fails to identify/analyze cumulative impacts of past, current and future actions; as with previous EIS or EAs for MCR and Channel Deepening projects, including deepwater site, there is no evaluation of baseline conditions and cumulative changes to issues such as salinity, ocean plume, risk of oil spills, changes in shipping, habitat loss, impacts on salmonids, and sedimentation processes.
    i. The Cumulative Effects section has been revised. The No Action and Baseline conditions, impacts, and hydrology and hydraulics have also been described.
j. Draft EA does not discuss how littoral cell and other Corps actions, such as hydrosystem operation and dredging and disposal of dredged materials, have affected sedimentation in the littoral cell and how continued maintenance of existing jetty length will continue to affect sedimentation processes.
    i. Text was added to the EA in section 6.11 describing hydrologic and hydraulic processes and modeling that was conducted during evaluation and design of the jetty alternatives.
k. Draft EA does not address possible effects of filling the dunes at South Jetty root/Trestle Bay.
    i. As described in the alternatives discussion for the South Jetty, the Trestle Bay fill alternative component has been removed as part of the selected or preferred plan. Text was added to Section 6 to discuss impacts from fill at the foredune augmentation.
l. Action area should encompass the entirety of the littoral cell.
    i. The affected environment and possible environmental consequences were both described, as were effects to hydraulics and hydrology in the project vicinity.
m. Project timing and schedule not clear – draft EA does not state how long repairs should last; timing of project is described as lasting 50 years but project actions take place in 2045 and 2069.
    i. More information has been added to EA under Construction Scheduling, and also in the description of alternatives and proposed actions. The construction schedule has also been revised here and subsequent the draft and final EA. Even with repairs and rehabilitation earlier in the project life, the model predicts that future repairs could be required given storm and wave climate at the jetties. This has been described in the No Action section.
n. A supplemental EIS for the MCR is required to address impacts of jetty rehabilitation project.
    i. No changes were made to the EA text. The Corps disagrees and has determined a separate EA for jetty repairs and rehabilitation is an appropriate path for complying with NEPA requirements.
o. Independent peer review is required by the Water Resources Development Act of 2007.
    i. No change to EA text. The 90% Major Rehabilitation Report, of which the draft EA was a part, has completed independent external peer review (IEPR).

13. United States Fish and Wildlife Service, letter received February 23, 2010.

a. Requests disposal of dredged material be used to cover European beach grass.
    i. These actions will be evaluated during construction implementation by the Corps and will also be vetted through the AMT.
b. Requests heavy equipment to remove European beach grass and to restore and enhance snowy plover nesting habitat in concert with the draft Habitat Conservation Plan and Oregon Parks and Recreation Department (OPRD).
    i. These actions will be evaluated while establishing staging areas in order to reduce the potential attractive nuisance created by these disturbance areas.
c. Requests habitat improvement in coordination with OPRD for rock storage via creation of habitat areas for snowy plover that do not interfere with use of the Spit.
    i. Habitat preferred by snowy plover will be created adjacent to the staging areas in order to reduce the potentially attractive nuisance created by the cleared staging area.

5.2.1. The Adaptive Management Team

Due to the dynamic conditions at MCR and the long duration of the MCR Jetty construction sequence, the Corps proposes formation of a modified Adaptive Management Team (AMT). The Corps suggests annual meetings, and more as needed, to discuss relevant design and construction challenges and modifications, technical data, new species listings or critical habitat designations, evolving environmental conditions, and adaptive management practices as needed. The primary purpose of the proposed AMT and its implementation is to ensure construction, operation, and maintenance actions have no greater impacts than those described in the Biological Assessments and Environmental Assessment, and that Corps obligations and terms and conditions are being met. This will also allow confirmation that any necessary construction or design refinements remain within the range and scope of effects described during Consultations and that compliance obligations are being met and efforts are being made to adjust mitigation once final impacts are fully understood. These adjustments could result in a reduction in mitigation based on actual impacts occurring. This forum will provide an opportunity for periodic evaluation as to whether or not the proposed actions, ESA listings, or environmental conditions result in any re-initiation triggers. It will also facilitate continued coordination and updating and allow the Corps to inform agency partners when unforeseen changes arise. Results regarding marine mammal and fish monitoring, mitigation monitoring, as well as water quality monitoring will also be made available to the AMT in order to fulfill reporting requirements and to address any unexpected field observations. Results of jetty monitoring surveys will also inform the AMT of the repair schedule and design refinements that may become necessary as the system evolves over time. This venue will provide greater transparency and allow opportunities for additional agency input. Final selection and design of the mitigation proposal will be determined by the Corps and will be vetted through this forum to facilitate obtaining final environmental clearance documents for this component of the MCR proposed action. Potential principal partners include federal (National Marine Fisheries Service, U.S. Fish and Wildlife Service) and State (Washington and Oregon) resource management agencies.

5.3. COMPLIANCE WITH LAWS & REGULATIONS

5.3.1. Clean Air Act

This Act established a comprehensive program for improving and maintaining air quality throughout the United States. Its goals are achieved through permitting of stationary sources, restricting the emission of toxic substances from stationary and mobile sources, and establishing National Ambient Air Quality Standards. Title IV of the Act includes provisions for complying with noise pollution standards. Section 118 (42 U.S.C. 7418) of the Clean Air Act specifies that each department, agency, and instrumentality of the executive, legislative, and judicial branches of the Federal Government (1) having jurisdiction over any property or facility or (2) engaged in any activity resulting, or which may result, in the discharge of air pollutants, shall be subject to, and comply with, all Federal, State, interstate, and local requirements respecting the control and abatement of air pollution in the same manner, and to the same extent as any non-governmental entity. Corps activities resulting in the discharge of air pollutants must conform to National Ambient Air Quality Standards (NAAQS) and State Implementation Plans (SIP), unless the activity is explicitly exempted by EPA regulations10.

Repair and rehabilitation of the MCR jetty system is anticipated to remain in compliance with the Clean Air Act and the State Implementation Plan. This is not a transportation project, it will not qualify as a major stationary source of emissions of criteria pollutants, and the project does not appear to be located in a non-attainment area for limited air quality.

There would be an intermittent but long-term reduction in air quality during construction of the proposed action due to emissions from construction equipment. Any emissions that do occur during and after construction from motor vehicles or facility functions are expected to be de minimus and will be from activities of a similar scope and operation to those of the original facility. There also would be an intermittent but long-term increase in noise levels from construction equipment. Efforts to avoid and minimize these effects have been considered when comparing and evaluating construction methods. Use of vibratory hammers will minimize some of the noise impacts during piling placement. It is also possible barging rocks verses overland trucking would result in reduced truck traffic and lower project emissions. These effects will be evaluated while taking into consideration other environmental factors during final selection of construction methods.

5.3.2. **Marine Protection, Research and Sanctuaries Act**

Prior to dredging and disposal activities, the Corps will request authorization to use one of the designated Section 102 sites for disposal of dredged materials. This will include a request for concurrence that the Corps' proposed Annual Use Plan is in compliance with the Site Monitoring and Management Plan. The proposed transportation of dredged material for placement or disposal in ocean waters will be further evaluated to determine that the proposed disposal will not unreasonably degrade or endanger human health, welfare, or amenities or the marine environment, ecological systems, or economic potentialities. In making this determination, the criteria established by the Administrator, EPA pursuant to section 102(a) of the Ocean Disposal Act will be applied. In addition, based upon an evaluation of the potential effect which the failure to utilize this ocean disposal site will have on navigation, economic and industrial development, and foreign and domestic commerce of the United States, an independent determination will be made regarding the need to dispose of the dredged material in ocean waters, other possible methods of disposal, and other appropriate locations.

5.3.3. **Clean Water Act**

Effects to water quality and effects from discharges and disposal into navigable waters, including 404 wetlands and waters including mitigation have been described in the pertinent sections of this EA. This Act also requires 401 Water Quality Certification from state or interstate water control agencies which certify that a proposed water resources project is in compliance with established federal and state effluent limitations and water quality standards. The proposed action is expected to be in compliance with the Act. A Section 404(b) (1) Evaluation has been prepared for the proposed action. The Section 404(b) (1) Evaluation and any additional necessary information will be submitted to the ODEQ and the WDOE. These agencies will be responsible for project review and issuance of the 401 Water Quality Certificates which will likely include terms and conditions to ameliorate impacts from the proposed action, including BMPs and turbidity monitoring requirements. The Corp will obtain these State 401 Water Quality Certifications prior to any inwater work or wetland fill. In addition, a National Pollutant Discharge Elimination System permit will be required from the USEPA and obtained prior to disturbance and work performed on federal lands in Washington, and the Corps intends to use the construction general permit after development of an appropriate Stormwater Protection Plan. The Corps has a general 1200-CA permit (#14926) through the ODEQ that, though expired, has been administratively extended indefinitely by ODEQ and remains in effect. The Corps intends to maintain compliance with its terms and conditions, including development of an Erosion and Sediment Control Plan prior to disturbance and work performed on federal, state, and local lands in the Oregon State.

5.3.4. **Coastal Zone Management Act**

This Act requires federal agencies to comply with the federal consistency requirement of the Coastal Zone Management Act. This activity will be coordinated with the Oregon Department of Land Conservation and Development and the WDOE. A consistency determination will be prepared and concurrence received from both States prior to construction.

5.3.5. **Endangered Species Act**

In accordance with Section 7(a) (2) of this Act, federally funded, constructed, permitted, or licensed projects must take into consideration impacts to federally listed or proposed threatened or endangered species. Information on federally listed species and designated critical habitat is presented in this EA. Biological Assessments (BAs) were prepared for the proposed action to address federally listed species under the jurisdiction of the NMFS and USFWS. The BAs were provided to the respective agencies for review and consultation.

On March 18, 2011, The Corps received a Biological Opinion from NMFS indicating that the Corps' proposed actions were not likely to adversely affect any listed species, with the exception of eulachon, humpback whales, and Stellar sea lions (2010/06104). For these species, NMFS determined that Corps' actions were not likely to jeopardize the existence of the species. NMFS also concluded that Corps actions were not likely to adversely modify any of the current or proposed critical habitats. There was a Conservation Recommendation to carry out actions to reverse threats to species survival identified in the Columbia River Estuary ESA Recovery Plan Module for Salmon and Steelhead. The Corps also provided a conference report for critical habitat that NMFS proposed for leatherback turtles, eulachon, and Lower Columbia River coho salmon. The Corps will request NMFS adopts its conference report when this habitat becomes designated. Prior to construction, the Corps will also request an Incidental Harassment Authorization of Stellar sea lions, humpback whales, California sea lions, and harbor seals.

On February 23, 2011 the Corps received a Letter of Concurrence from USFW regarding potential effects to species under their jurisdiction (13420-2011-I-0082). The Corps' determined its actions would have no effect on listed species, with the exception of bull trout, marbled murrelets, and snowy plover. The Corps concluded that its actions were not likely to adversely affect these species or their critical habitat. The USFW concurred with the Corps' determination. USFW also included four Conservation Recommendations to protect and improve snowy plover habitat and manage attractant waste derived from construction actions.

Mitigation components have been included in the proposed action by the Corps. These actions complement the Corps' affirmative commitment to fulfill responsibility to assist with conservation and recovery of ESA-listed salmonids.

5.3.6. Fish and Wildlife Coordination Act

This Act states that federal agencies involved in water resource development are to consult with the USFWS concerning proposed actions or plans. The proposed action has been coordinated with the USFWS in accordance with the Act. The Corps has also been in regular coordination with ODFW and WDFW regarding plan selection and development of wetland and waters mitigation projects.

5.3.7. Magnuson-Stevens Fishery Conservation and Management Act

The Sustainable Fisheries Act of 1996 amended the Magnuson-Stevens Act establishing requirements for essential fish habitat (EFH) for commercially important fish. Pursuant to the Magnuson-Stevens Act, an EFH consultation is necessary for the proposed action at the MCR jetties. Essential fish habitat is defined by the Act as "those waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity." The estuary and the Pacific Ocean off the MCR are designated as EFH for various groundfish and coastal pelagic and salmon species. The proposed action will directly affect EFH for Chinook salmon, coho salmon, English sole, sand sole, and starry flounder from the permanent loss of sandy bottom habitat from jetty construction. Short-term disturbances to EFH would result for lingcod, English sole, sand sole, starry flounder, black rockfish, brown rockfish, China rockfish, copper rockfish, and quillback rockfish. However, the addition of rock would increase EFH for lingcod, black rockfish, brown rockfish, China rockfish, copper rockfish, and quillback rockfish. An EFH assessment under the Magnuson-Stevens Act was provided as part of the Biological Assessment submitted to the NMFS for the proposed action. In the subsequent Biological Opinion, no additional Conservation Measures were proposed.

5.3.8. Marine Mammal Protection Act

This Act prohibits the take or harassment of marine mammals. It is possible that the proposed action could result in harassment of the federally listed Steller sea lion with construction at the existing above-water portion of the head of the South Jetty. They can be present at any time of the year. Impacts to this species were evaluated and are described in this EA. Impacts were further evaluated as part of the Biological Assessment submitted to the NMFS for the proposed action. The Biological Opinion from NMFS indicated Corps actions would NOT jeopardize the survival of the species.

Prior to construction activities, an incidental harassment authorization (IHA) for marine mammals at the South Jetty will be obtained from the NMFS. The Corps anticipates that the new IHA permit will entail requirements similar to those in the previous permit for repair of the South Jetty. The Corps also proposed Conservation Measures as previously described.

5.3.9. Migratory Bird Treaty Act and Migratory Bird Conservation Act

These acts require that migratory birds not be harmed or harassed. Under the Migratory Bird Treaty Act, "migratory birds" essentially include all birds native to the U.S. and the Act pertains to any time of the year, not just during migration. The Migratory Bird Conservation Act aims to protect game birds. Impacts of construction at the jetties and the hauling of rock to the jetties could displace birds by causing flushing, altering flight patterns, or causing other behavioral changes, but it is not expected that effects would rise to the level of harm or harassment.

5.3.10. National Historic Preservation Act

Section 106 of this Act requires that federally assisted or federally permitted projects account for the potential effects on sites, districts, buildings, structures, or objects that are included in or eligible for inclusion in the National Register of Historic Places. This project is being conducted in an area that is highly erosive and has previously been disturbed by jetty construction and prior dredging. There are no known historic properties recorded within the immediate project footprint other than the jetties and associated trestle remains. The proposed action has been coordinated with the Washington and Oregon State Historic Preservation Offices (SHPO) in order to obtain their comments on this Section 106 action in accordance with the Act. The Oregon and Washinton SHPOs have concurred that the undertaking will have no effect on historic properties as the action will not affect the criteria that make the structures eligible, essentially, importance in historic events and alignment. Original workmanship and materials have all changed over a century of repairs and the alignment and configuration remain essentially the same.

5.3.11. Native American Graves Protection and Repatriation Act

This Act provides for the protection of Native American (and Native Hawaiian) cultural items, established ownership and control of Native American cultural items, human remains, and associated funerary objects to Native Americans. It also establishes requirements for the treatment of Native American human remains and sacred or cultural objects found on federal land. This Act also provides for the protection, inventory, and repatriation of Native American cultural items, human remains, and associated funerary objects. There are no recorded historic properties within the immediate project area and the probability of locating human remains in this area is low. However, if human remains are discovered during construction, the Corps and/or the Contractor will be responsible for following all requirements of the Act.

5.3.12. Environmental Justice

Executive Order 12898 requires federal agencies to consider and minimize potential impacts on subsistence, low-income, or minority communities. The goal is to ensure that no person or group of people should shoulder a disproportionate share of the negative environmental impacts resulting from the execution of domestic and foreign policy programs. The proposed action is not expected to disproportionately affect low income and/or minority populations and is in compliance with Executive Order 12898.

5.3.13. Executive Order 11988, Floodplain Management

The proposed action would not further encourage development in, or negatively alter any floodplain areas. Executive Order 11988 regarding Floodplain Management was signed May, 24, 1977. The order requires that Federal agencies recognize the value of floodplains and consider the public benefits from their restoration and preservation. The objective is to avoid long and short-term adverse impacts to the base floodplain (100-year flood interval), and to avoid direct and indirect support of development in the base floodplain when there is a practicable alternative. Though the jetties are located in the floodplain on accreted land at the Clatsop Spit and Benson Beach, the floodplain in which they are located is relatively recently created and is at the mouth of the Columbia River. Therefore, these areas do not provide much floodplain storage or peak attenuation capacity. Furthermore, there are no other practicable alternative locations to conduct repairs or their associated construction activities, as the jetties are in a fixed location which is water and location dependent to maintain navigation. Additionally, the construction activities and fill will not be affecting floodplain areas that that have any private property, and there are few structures within the vicinity of the State Park lands and action area. The location of the State Park also precludes additional development in the vicinity of the jetties. Finally, the Corps does not expect any loss of beneficial values in the floodplain, and will be conducting some mitigation and restoration actions that will improve wetland function and dune stabilization. In order to inform the public of the proposed action, a draft EA was widely distributed and public comments were solicited. None of the commentators remarked on concerns for floodplain issues.

5.3.14. Executive Order 11990, Protection of Wetlands

Wetlands near the North and South Jetties and Jetty A will be filled for the proposed action. Plans for filling wetlands and the associated subsequent mitigation has been documented here and has been documented through the Section 404 (b) (1) evaluation that has also been prepared for the proposed action.

5.3.15. Prime and Unique Farmlands

No prime or unique farmlands will be affected by the proposed actions.

5.3.16. Comprehensive Environmental Response, Compensation, and Liability Act and Resource Conservation and Recovery Act

There is no indication that any hazardous, toxic, and radioactive wastes are in the vicinity of the MCR jetties. Any presence of these types of wastes would be responded to within the requirements of the law and Corps' regulations and guidelines.

5.3.17. National Environmental Policy Act

A Revised Final Environmental Assessment (EA) evaluates the environmental effects for major rehabilitation and repairs of the North and South Jetties and Jetty A, including all associated actions covered in the Major Maintenance Report and the South Jetty dune augmentation. For a complete chronology and explanation of all NEPA conducted for this project, please see Appendix D. The final EA and FONSI will be posted on the Corps' district website for public notice.

5.4. REPORTS AND STUDIES

The following studies were conducted to obtain environmental information and data to evaluate the effects of the proposed rehabilitation of the MCR jetty system.

Pacific Northwest National Laboratory. February 2006. Use of Acoustic Telemetry to Assess Habitat Use of Juvenile Chinook Salmon and Steelhead at the Mouth of the Columbia River. PNNL-15575. Prepared for U.S. Army Corps of Engineers, Portland District, Portland OR.

Tetra Tech, Inc. April 2007. Clatsop Spit Plant Communities Investigation and Mapping, South Jetty, Mouth of the Columbia River, Clatsop County, Oregon. Final Report. Prepared for U.S. Army Corps of Engineers, Portland District, Portland OR.

Tetra Tech, Inc. April 2007. Wetland and Waters of the U.S. Delineation, North Jetty, Mouth of the Columbia River, Pacific County, Washington. Revised Final Report. Prepared for U.S. Army Corps of Engineers, Portland District, Portland OR.

U.S. Army Corps of Engineers. August 2006. Section 106 Documentation of Current Conditions: Historic Jetty Trestle Remnants. Portland District, Portland OR.

U.S. Army Corps of Engineers. September 2009. Mouth of the Columbia River North Jetty, South Jetty and Jetty A, Barge Offloading Facilities, Level I Sediment Evaluation. Prepared by Wendy Briner and Tim Sherman. Portland District, Portland OR.

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6. CONSTRUCTION AND COST ESTIMATE

6.1. GENERAL PROJECT DESCRIPTION

This chapter provides an overview of the construction methods (both land-based and water-based) and estimated production rates and schedule for the recommended plan. The associated cost estimates are provided.

The government estimate covers repair and rehabilitation of the MCR North and South jetties and Jetty A. The project consists of scheduled repairs to the jetties by rebuilding selected sections of the jetties. The repairs will be made by placing jetty stone that ranges from 6 to 33 tons. Stone placement from ocean-based equipment, such as jack-up barges, was considered. Because of harsh weather and strong wave action, only minimal use of ocean-based placement is likely.

In a land-based operation, jetty stone would be transported to the site either by barge, truck or a combination of the two. This estimate assumed barging would be the main delivery method for stone. Once on-site, the stone would be hauled to a stockpiling area. Existing roads may be used or new haul roads may have to be built. A haul road would be constructed on the jetty crest so equipment and material can reach the repair sites and where required, the jetty would be restricted using relic stone. At the jetty repair site, stone would be delivered to the site using off-road trucks. Depending on the size of the stone, the depth and distance from the equipment, either a crane or excavator would be used.

6.2. EXPECTED CONSTRUCTION SEQUENCE FOR RECOMMENDED PLAN

Due to both the magnitude of the construction effort and the projected sequencing of the work based on vulnerability, rehabilitation of the MCR jetties is expected to start in 2015 and would extend until 2020. Work would be performed every year during this time frame. In addition, the scheduled repair alternative for the North and South jetties are predicted repair activities and scheduling will vary with actual jetty degradation over time. Jetty A is a schedule repair alternative that is scheduled to occur during the first year of construction. Due to the large quantity of rock required to complete the work, the rock supply and storage activities can be expected to be continuous throughout the time frame.

Quarrying of the rock may be limited to the months of April through October depending on the regulations pertinent to each quarry. Rock delivery, however, can be conducted throughout the entire year by truck and during the months of April through October by barge. Approximate transport quantities by method are 30 tons per truck and 6,500 tons per barge. The majority of the jetty rehabilitation work is expected to be conducted from the root of the jetty seaward using an excavator or a crane.

Work elements fall into three general categories: (1) site preparation, (2) rock quarrying and delivery, and (3) jetty rehabilitation work. Site preparation would consist of the preparation of the rock stockpile and staging areas, as well as the construction of any barge-offloading facilities that may be required. Barge offloading facilities would be constructed with the first construction contract and be removed with the last contract. Ocean-going barges require 20-22 feet of draft when fully loaded. Under-keel clearance shall be no less than 2 feet. The elevation at barge offloading sites shall be no higher than -25 feet MLLW and shall provide for a maneuvering footprint of 400 feet by

400 feet with access to navigable water. The depth along the barge unloading sites would be maintained during the active period when barges will be unloaded.

6.3. CONSTRUCTION CONSIDERATIONS

6.3.1. Rock Placement

Placement of armor stone and rock on the MCR jetties would be accomplished by land- or water-based equipment. For water-based delivery of rock, a tow boat and barge would deliver the rock to either side of the jetties where water depth, waves, and current conditions permit. During rock offloading, the barge may be secured to approximately 4 to 8 temporary dolphins/H-piles, sheet pile, dock or utilize anchor arrays for tie-up or positioning. The dolphins/H-piles/sheet pile would be composed of either untreated timber or steel piles driven to a depth of approximately 15 to 25 feet below grade by a vibratory pile driver. If dolphins/H-piles/sheet piles are used, they will be located at a single designated location for each jetty and be removed at the completion of jetty construction. Rock would be off-loaded from the barge by a crane, land or water based, or with an adjustable ramp for land based equipment. The rock is then placed either within the jetty work area or stock piled for subsequent placement.

For land-based delivery of rock, jetty access for rock hauling trucks would be via an existing paved road to the Benson Beach parking lot at Cape Disappointment State Park (North Jetty) and via an existing paved road to the parking lot at the South Jetty. Work areas for delivery of rock, maneuvering of equipment, and stockpiling of rock near the jetties are already in place to facilitate recent and future repair work on the jetties. For water-based rock placement, a crane or a large track-hoe excavator could be fixed to a moored or jack up barge. The moored barge would use a series of anchors or the barge would be lashed to 4 to 8 temporary dolphins/H-piles paralleling the jetty work area (same concept as marine-based rock delivery). The crane or excavator would pick rocks either directly from the rock barge or from rock stock-piled on the jetty crest. The crane or excavator would advance along the jetty as work is completed.

For land-based rock placement, a crane or a large track-hoe excavator could be situated on top of the jetty. The placement operation would require construction of a haul road along the jetty crest within the proposed work area limits. The crane or excavator would use the haul road to move along the top of the jetty. Rock would be supplied to the land-based placement operation by land and/or marine-based rock delivery. For marine-based rock, the land-based crane or excavator would pick up rock directly from the barge or from a site on the jetty where rock was previously offloaded and stockpiled, and then place the rock within the work area. For land-based rock, the crane or excavator would supply rock via a truck that transports rock from the stockpile area. The crane or excavator would advance along the top of the jetty via the haul road as the work is completed.

The availability of adequate sources of rock has been a problem in several of the previous repairs jobs. This problem is further compounded by the fact that once the contract is awarded, rock quality and quantity both drive the resulting end product. The geometry of the rock is another area of great concern. In order to achieve a tight, minimum void, well distributed mass, with maximum interlock, the geometry of stones must be prismatic. The longest dimension of the stone must not be greater than three times the shortest dimension. This requirement eliminates slab-like pieces of rock that will not perform well in a rubble mound structure. Selective placement can only occur if adequate time to acquire and sort materials is allowed.

6.3.2. **Production Rates**

Due to the armor material size and weight requirements, crane size, supplemental counterweights, special rigging, and effective radius considerations, slower production rates may limit production rates previously experienced. The length of time between placements for the boom swing increases with a greater horizontal boom angle. Crane placement rates for the jetty stone may be as low as 80 to 100 tons per hour for outlying stations away from the root area. Effectiveness on daily production rates has been shown to increase dramatically with supplemental placement equipment such as a large hydraulic excavator, although the limited reach capabilities restricts land-based placement to within 15 feet down slope from the jetty crest and within the core and cap areas. As a contrast between equipment placement rates, during interim repairs to MCR South Jetty in FY 2006, crane placement rates of up to 173 tons per hour were observed over sections where large pocket holes were prevalent within a jetty segment. Hydraulic excavator placement rates up to 220 tons per hour were observed within the same set areas. However, due to effective radius limitations the hydraulic excavator is limited to placing material within the upper side slope and crest area. These rates came near the end period of the contract after several months of placement operations well beyond the initial learning curve.

6.3.3. **Barge Offloading Facilities**

Multiple barge offloading facilities may be used, as described below (see Figure 5-2 through Figure 5-5). Jetty offloading facilities would be removed upon project completion.

- Commercial Site in Ilwaco. For the North Jetty, barges would pull up to a dock at Ilwaco where rock would be transferred by crane onto trucks that would proceed by public road to Cape Disappointment State Park (formerly Fort Canby State Park). Trucks would then pass through the park grounds to the staging area adjacent to the jetty. For Jetty A, trucks would proceed through the Coast Guard facility to the staging area near the root of the jetty.

- Commercial Site in Warrenton. Nygaard Logging has a deep-water offloading site at their facility that could be used to offload rock. For the North Jetty, rock would be transferred to trucks that would likely use Highway 101 into Astoria, cross the Astoria-Megler Bridge, and head west through Ilwaco to Cape Disappointment State Park. Trucks would then pass through the park grounds to the staging area adjacent to the jetty. For the South Jetty, rock would be transferred to trucks which would then proceed West through Hammond to Fort Stevens State Park and use the existing park road to the staging area adjacent to the jetty. This site needs no improvement to accommodate deep-draft vessels.

- Contract-provided Site near South Jetty. Barges would dock at a site near Parking Area D within Fort Stevens State Park. For the North Jetty, rock would be unloaded by crane and hauled on the state park road to Highway 101, into Astoria, cross the Astoria-Megler Bridge, and then head west through Ilwaco to Cape Disappointment State Park and the Coast Guard facility. Trucks would then pass through the park grounds to the staging area adjacent to the jetty. For the South Jetty, rock would be unloaded by crane and hauled to the jetty via off-road trucks to the staging area.

- Contract-provided Site on North Jetty. Barges would dock at a contractor constructed offloading site on the channel side of the jetty. For the South Jetty, rock would be unloaded by crane and hauled on the state park road to Highway 101, cross the Astoria-Megler Bridge, into Astoria, and then head west through Fort Stevens State Park to the designated storage areas on Fort Clatsop Spit. For the North Jetty, rock would be unloaded by crane and hauled to the jetty via off-road trucks to the staging area.

- Contract-provided Site near Jetty A. Barges would dock at a contractor constructed offloading site on the tip of the jetty. Rock would be unloaded by crane or excavator and hauled along a causeway via off-road trucks to the staging area at the root of the jetty.

6.3.4. Dredging for Barge Offloading Facilities

Transport of rock would most likely be done by ocean-going barges requiring deeper draft (20-22 feet) when fully loaded than river-going barges. The elevation of barge maneuvering footprints at each barge-offloading facility would require no less than -25 feet MLLW with access to navigable waters. A barge offloading facility will be required in close proximity to each jetty. Dredging will be required to develop barge offloading facilities adjacent to the North Jetty and Jetty A, and for the South Jetty adjacent to Parking Area D at the east end of Clatsop Spit in Fort Stevens State Park. Appropriate depth to -25 feet MLLW is required for each facility. A clamshell dredge will be used for all dredging. The material to be dredged is medium to fine-grained sand, typical of MCR marine sands. Disposal of material will occur in-water and/or upland. The volume of material to be dredged is shown in
Table 6-1; these estimates are based on current bed morphology and may change. Also, maintenance dredging to a depth of -25 feet MLLW will be needed before offloading during each year of construction. Dredging is likely to occur on a nearly annual basis for the duration of the project construction period (approximately 6 years), but this will be intermittent per jetty depending upon which jetty is scheduled for construction in a particular year. The in-water work window for the Columbia River typically restricts dredging from November 1 to February 28, depending on the location.

Table 6-1. Dredging Volumes for Barge Offloading Facilities

Location*	Dredging Volume (cy)	
	Initial	Est. Maintenance**
North Jetty	30,000	30,000
Jetty A	60,000	N/A
South Jetty	20,000	20,000
South Jetty - Parking Area D	20,000	20,000

* Some of the locations will not be used on an annual basis; it depends on the construction schedule for each jetty.
**All dredging will be based on surveys that indicate depths shallower than -25 feet MLLW.

6.3.5. In-water Fill for Barge Offloading Facilities

Development of causeways from barge offloading facilities would be required to the North Jetty/Jetty A and near the South Jetty adjacent to Parking Area D at the east end of Clatsop Spit in Fort Stevens State Park (but not along the South Jetty). These structures would be removed upon project completion.

6.3.6. **Site Access**

Access to the construction areas will be via public roads, local access roads, and jetty haul roads as well as from the water for certain stages of work. Stone would be hauled from the quarries to the nearest port and loaded onto a barge. The stone would then be barged to offloading sites at the jetties. Once the stone is off-loaded at the site, the stone would be transported to a stockpile using off-road trucks. Local park roads will need to be repaired to pre-construction condition at the completion of the construction.

6.3.7. **Haul Road Considerations**

Equipment requires a flat road surface for travel as placement continues and for retreat during equipment exchanges and inclement weather. A number of contractor constructed equipment turnouts of adequate size will be needed for equipment passage along the haul road to the point of final placement. A minimum crest width of 30 feet is required for the anticipated crane size. Road width will accommodate a small gravel berm on each side of the haul road to act as a safety barrier for wheel traffic, and to support top of slope delineators for vehicle operators during haul and placement operations.

6.3.8. **Offloading Site Installation**

Offloading sites will be constructed during the first construction season and removed at the completion of each individual jetty. Offloading sites will be constructed either with mooring dolphins, with using existing spur groins with topping rock, or with a sheet pile retaining wall with backfill. Installation of about 4-8 temporary dolphins or piles will be needed for each barge offloading facility. Because sediments in the area are soft (sand), a vibratory or hydraulic pile driver will be used and is preferred over using an impact driver when fish are present. The presence of relic stone may require locating the piling further from the jetties so that use of this method is not precluded by the existing stone. It is possible that a bubble curtain or some other sound attenuation method may be employed along with a fish exclusion plan. Offloading sites would remain in place for the duration of construction at each jetty.

6.3.9. **Placing Jetty Stone**

The typical construction window on the Oregon Coast extends from approximately June through September, based on coastal wind and wave conditions. There are no in-water work restrictions for placing stones. Work activities on Jetty A may extend somewhat later in the season since this area is slightly more protected from sea conditions. The on-site placement operations will be dormant over the winter months. Early award of the contract must allow sufficient rock production and storage for placement operations during the optimal on-site placement timeframe. Continuous quarrying will allow for consistent rock production and stockpiling during the winter season as weather permits. The quarrying production process will be a critical element for optimal material selection/availability and when jetty rehabs are undertaken concurrently. Equipment capable of placing the stone individually in such a manner as to not displace the underlying material is required. The capabilities to move, turn, adjust, or relocate the stone after placement will be necessary. The selected equipment must be capable of placing the stone near its final position before release, and be capable of moving the stone, if necessary, to achieve maximum interlock with adjacent stones. Dropping armor stone from a height greater than 2 feet will be prohibited.

6.4. CONSTRUCTION SCHEDULE

The construction schedule for the MCR jetty system is based on the most recent TRACES MII version 4.1 estimate and constructability review. The estimate assumes the work will be accomplished with multi-year contracts. The schedule for the recommended plan is shown at the end of this chapter.

Rock procurement activities will be initiated for the North Jetty in 2014 concurrent with Plans and specification development. Quarries utilized are expected to be located in Oregon or Washington, although some rock may be obtained from Canadian quarries. The North jetty repair work will begin in 2015 repairing cross section damage between stations 20+00 and 45+00. The North Jetty will require installing a barge offloading facility on the channel side of the jetty at approximately station 45 in order to facilitate efficient rock delivery to the site. Dredging of 30,000 cy is anticipated to provide the minimum 25 feet of working clearance. Repair of Jetty A will occur concurrently with the first year of repair for North Jetty. Jetty A work will begin with constructing the off loading facility which requires approximately 60,000 cy of dredging to accommodate the rock delivery by barge, and constructing the jetty crest haul road from stations 40+00 to 84+00. Total new stone in 2015 will consist of approximately 170,000 tons of imported rock, equivalent to 5700 trucks or 26 barges.

In 2016, construction will continue on the North Jetty from stations 45+00 to 76+00. The haul road will need to be constructed with approximately 21,000 tons of rock fill material. Total new stone for 2016 will consist of approximately 86,000 tons of imported rock, equivalent to 2900 trucks or 13 barges. Site preparation work and stockpiling stone at the South Jetty will occur to prepare the staging and stockpile areas for 2017 construction.

In 2017, work continues on the North Jetty with placement of 29,000 tons of small and large armor near between stations 77+00 to 85+00. This ending stations corresponds with the beginning of the repair identified in the Major Maintenance report released prior to this rehabilitation report. Work at these seaward stations requires refurbishing the haul road and building vehicle turnouts. At the North Jetty the 29,000 tons of imported small and large armor stone is equivalent to 970 trucks or 5 barges.

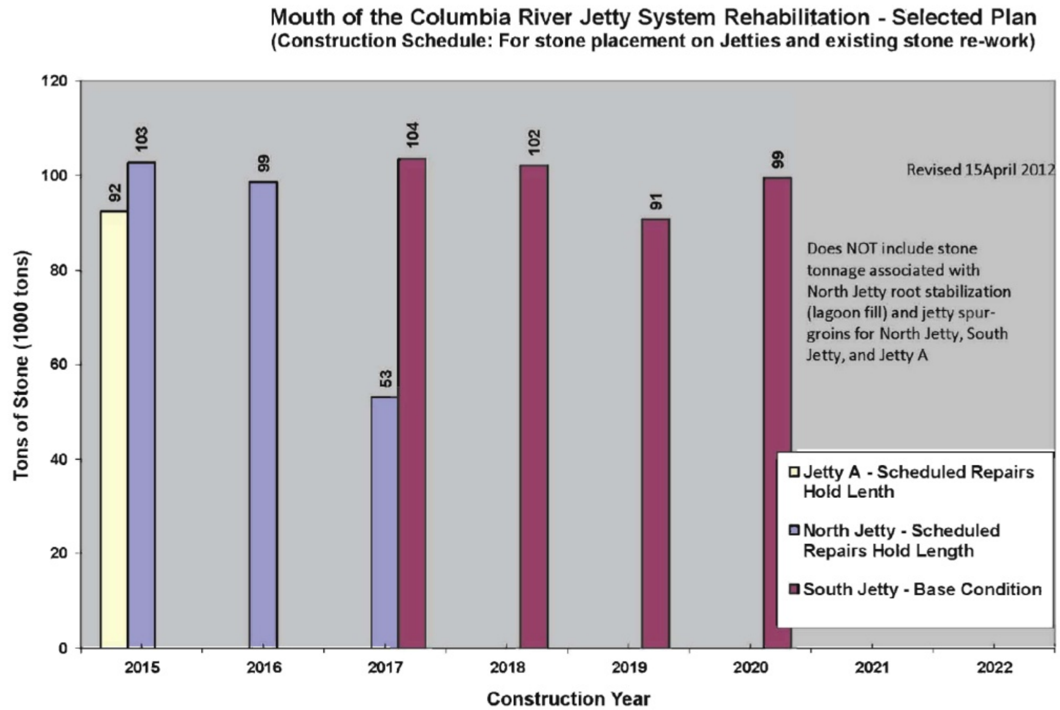
In 2017, construction on the South Jetty is projected to begin, starting with repairing damaged cross-sections between stations 167+00 and 195+00. South Jetty construction will require either a haul road be constructed on top of the jetty or constructed from a marine plant. Total work effort on the South Jetty in 2017 is projected to consist of approximately 90,000 tons of small and medium armor stone; equivalent to 3000 trucks or 14 barges.

In 2018, construction on the South Jetty continues by extending the repairs from station 197+00 to station 222+00. It is anticipated that the haul road will have to be repaired and extended to accommodate the placement of the small, medium and large armor stone. Total work effort in 2018 is projected to consist of approximately 89,000 tons of small and medium armor stone; equivalent to 2970 trucks or 14 barges.

In 2019, construction on the South Jetty continues by extending the repairs from station 223+00 to station 246+00. The haul road will again have to be repaired and extended to accommodate the placement of the armor stone which is evenly divided between medium and large armor stone for these stations. Total work effort in 2019 is projected to consist of approximately 79,000 tons of small and medium armor stone; equivalent to 2640 trucks or 12 barges.

In 2020, the initial repairs for the three jetties are completed with the conclusion of South Jetty repairs on stations 258+00 to 290+00. The haul road will again have to be repaired and extended to accommodate the placement of the armor stone which large and very large armor stone. The transportation and placement of the stone may be accomplished by marine plant and land based crane depending upon the capabilities of the selected contractor. Total work effort in 2020 is projected to consist of approximately 87,000 tons of imported large and very large armor stone; equivalent to 2980 trucks or 13 barges. The size of the very large armor stone, (16-33 tons) may dictate how they are transported and will require additional time and effort for placement.

Figure 6-1 Mouth of the Columbia River Jetty System Rehabilitation – Selected Plan



** = rework % varies from 10% - 20%, based on estimated tonnage placed per 100 ft jetty
0.15

JETTY "A" Schedule Repairs Hold Length - REVISED 12 APR 2012

Year	From Sta	To Sta	Re-Work** (5 to 15 tons) (tons)	Small Armor (3 to 15 tons) (tons)	Large Armor (4 to 18 tons) (tons)	Total New Armor + Existing Stone Re-work for Each Repair Campaign based on template neat-line tolerances (tons)
2015	48+00	60+00	4,823	32,150		36,973
	69+00	73+00	1,608		10,717	12,324
	85+00	89+00	1,608		10,717	12,324
	74+00	84+00	4,019		26,792	30,810
		TOTAL	12,056	32,150	48,225	
				TOTAL NEW REPAIR ARMOR on jetty	80,375	92,431

** = rework % varies from 10% - 20%, based on estimated tonnage placed per 100 ft jetty
0.15

NORTH JETTY Schedule Repairs Hold Length - REVISED 15 APR 2012

Year	From Sta	To Sta	Re-Work** (5 to 15 tons) (tons)	Small Armor (6 to 18 tons) (tons)	Large Armor (8 to 24 tons) (tons)	Total New Armor + Existing Stone Re-work for Each Repair Campaign based on template neat-line tolerances (tons)
2015	20+00	30+00	5,360	35,733		41,093
	30+00	45+00	8,040	53,599		61,639
2016	45+00	54+00	4,824	32,160		36,983
	55+00	63+00	2,144	14,293		16,437
	64+00	71+00	3,752	25,013		28,765
	72+00	76+00	2,144	14,293		16,437
2017	77+00	85+00	4,288	11,435	17,152	32,874
	99+00	101+00	3,000		17,200	20,200
		TOTAL	33,552	186,525	34,352	
				TOTAL NEW REPAIR ARMOR on jetty	220,877	254,429

** = rework % varies from 10% - 20%, based on estimated tonnage placed per 100 ft jetty.
0.15

SOUTH JETTY Base Condition - REVISED 12 APR 2012

Year	From Sta	To Sta	Re-Work** (5 to 15 tons) (tons)	Small Armor (6 to 15 tons) (tons)	Medium Armor (10 to 20 tons) (tons)	Large Armor (13 to 26 tons) (tons)	Super Armor (16 to 33 tons) (tons)	Total New Armor + Existing Stone Re-work for Each Repair Campaign based on template neat-line tolerances (tons)
2017	167+00	175+00	5,146	17,152	17,152			39,449
	182+00	195+00	8,361	27,872	27,872			64,105
2018	197+00	215+00	9,262	30,873	30,873			71,008
	215+00	222+00	4,052		15,008	12,006		31,066
2019	223+00	246+00	11,835		39,449	39,449		90,733
2020	258+00	290+00	12,973			36,224	50,261	99,459
		TOTAL	51,629	75,896	130,353	87,680	50,261	
					TOTAL NEW REPAIR ARMOR on jetty		344,191	395,820

7. CONCLUSIONS AND RECOMMENDATIONS

7.1. CONCLUSIONS

- The MCR Jetty System Major Rehabilitation Evaluation Report and Environmental Assessment present the findings of studies conducted for the proposed rehabilitation to the authorized Mouth of the Columbia River three jetty system in Oregon and Washington.
- The purpose of this report is to assess the most efficient means of maintaining deep-draft navigation in a least-cost manner.
- This report also includes supporting documentation for the selected plan cost estimate and construction plan.
- Planning constraints recognized that alternatives were limited to the authorized footprint for the MCR jetties and that the entrance channel to the Columbia River would not be closed to navigation.
- A range of alternatives was considered. Besides the no action alternative, they included scheduled repair, immediate rehab and scheduled rehab. These were further divided into alternatives that held the head and those that did not.
- Three public meetings were held and multiple meetings to place with state and federal resource agencies to determine effects of the alternatives. It was concluded that no significant biological impact would result from the selected plan.
- The Environmental Assessment was released to the public for review in February 2006 and January 2010; in addition a public information meeting was held in February 2011.
- This report incorporates lessons learned from Hurricanes Katrina and Rita and provides an adaptive approach to planning, design, construction and monitoring.
- This report followed the Corps of Engineers' Environmental Principles in the formulation of alternatives, and the environmental documentation provided.
- Evaluation of the alternatives revealed that the most cost-effective method of maintaining navigation through the mouth of the Columbia River is improved monitoring and maintenance of the existing system.
- The different alternatives were evaluated with a MATLAB Stochastic Risk-Based Model that estimated damage on the jetties based upon historical wave data. The development of the model and the subsequent report was subject to multiple reviews compliant with EC 1165-2-209, which included two Agency Technical Reviews, two model certifications from the DDN-PCX and two reviews at the HQUSACE level.
- These documents have undergone numerous reviews: District Quality Control, Agency Technical Review, Independent External Peer Review and NWD Review.
- The project's combined BCR of 1.1 for the system (all three jetties) doesn't capture all the benefits related to protecting the entrance the Columbia River navigation channel (105 miles, 43 feet deep; $182M channel deepening project completed in 2010) and the Columbia Snake River system. For example, $20B of cargo annually travels through the entrance protected by MCR Jetties. To date, over $900M in new infrastructure investment has been made in the Pacific Northwest since 2010.

7.2. RECOMMENDATIONS

I have given careful consideration to all significant aspects of this study in the overall public interest including engineering and economic feasibility as well as social and environmental effects. The selected plan described in this major rehab report and Environmental Assessment provides the most efficient way to maintain the mouth of the Columbia River jetty system.

I recommend that the authorized mouth of the Columbia River project be maintained as described in the selected plan.

The recommended selected plan for the MCR jetty system includes:

- **North Jetty** – Scheduled repair with head stabilization at or near STA 101, (less extensive than the previously proposed capping). These repairs will be conducted after the base condition maintenance repairs to stations 86-99 and lagoon fill to stop erosion of the jetty root. It does not include spur groin construction.

- **South Jetty** – Base condition (interim repairs) allowing head recession. It does not include spur groin construction. Dune augmentation near the jetty root will be implemented in FY 13 as a separate action and not included in the cost estimate. Although the base condition is the NED plan, the interim repair, hold head alternative is very close in AAC, differing by 0.9 percent. When conditions are appropriate (i.e., repairs of the South Jetty allow for a haul road to be established to the end of the jetty approximately FY 2019), head stabilization could be re-evaluated—using parameters such as least cost, environmental acceptability and engineering feasibility.

- **Jetty A** – scheduled repair and head stabilization at approximately STA 89. It does not include spur groin construction. The modeling performed to assess the project alternatives assumes that Jetty A is in place and fully functioning. This is because Jetty A, as originally constructed, protects the North Jetty and helps to train the Columbia River main stem. In addition, Jetty A is believed to play an important function for the Columbia River plume. The plume is an important food source for the 13 Columbia River salmonid evolutionarily significant units (ESUs) listed under the Endangered Species Act (ESA).

The project has a combined BCR of 1.1 for the system (all three jetties).

The initial construction schedule is projected to be from 2014 through 2020. Based on the 100% federally fully funded, feasibility level design in 2012 dollars, project first cost at an effective price level of 01 October 2012 is $238,547,000 and a total project cost fully funded of $257,201,000**.** Total project costs fully funded are estimated as follows per jetty: North Jetty at $79,797,000; South Jetty at $146,884,000; and Jetty A at $30,520,000.

The recommendations contained herein reflect the information available at the time concurrent with departmental policies governing formation and environmental compliance. The information shown neither reflects program and budgeting priorities inherent in the formulation of a National Civil Works construction program nor the perspective of higher review levels within the Executive Branch.

6/28/12
Date

John W. Eisenhauer
John W. Eisenhauer, P.E.
Colonel, Corps of Engineers
District Commander

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MCR Jetty System Major Rehabilitation Evaluation Report

Appendix A1

Coastal Engineering

Appendix A1 - Coastal Engineering

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Appendix A1 - Coastal Engineering

1. Scope and Purpose

At the mouth of the Columbia River (MCR), three jetties with a total authorized length of 10.2 miles were constructed on massive tidal shoals during 1885-1939 to secure consistent navigation through the coastal inlet. The morphology of the inlet has been changing ever since. The rubblemound jetties have experienced significant deterioration since construction, mainly due to extreme wave attack and foundation instability associated with the erosion of tidal shoals on which the jetties were built. The purpose of the proposed action is to perform modifications to the North and South jetties and Jetty A at the MCR that would strengthen the jetty structures, extend their functional life, and maintain deep-draft navigation.

This appendix analyzes the jetties at the MCR, for the purpose of identifying the need for major rehabilitation along each jetty. Appendix A1 will introduce the MCR navigation project, summarize the sequence of events that have led to the present condition of the MCR jetties, and describe the present structural condition of the jetties. A reliability and life cycle analysis was used to examine the performance of the jetties (past and future) and develop structural alternatives to increase the reliability of the jetty system. Appendix A2 evaluates the present condition of each jetty in terms of realized life-cycle performance, defines the coastal processes affecting jetty reliability, and summarizes the event tree and life cycle analysis. Finally, a holistic approach is used to propose a phased strategy for jetty rehabilitation.

Structural degradation of the 100+ year old MCR jetties has accelerated in recent years because of increased storm activity and loss of sand shoal material upon which the jetties are constructed. In addition, beaches on the ocean sides of the North and South jetties, which formed as a result of jetty construction, have been receding gradually over the years, exposing previously protected sections of the jetties at the beach line to storm waves. Taking no action to extend the functional life of the jetties would result in further deterioration of the jetties and the sand shoals upon which they rest, increasing the likelihood of a jetty breach. Recent interim jetty repairs (2005 to 2007) have addressed immediate critical needs. Additional modifications of the jetties are necessary to address critical near- and long-term needs and reduce the potential for emergency repairs, emergency dredging, and impacts to navigation.

Despite intermittent repair and rehabilitation efforts over their lifetimes, all of the jetties are currently in a significantly deteriorated condition. Appendix A2 discusses the details of present jetty condition, in terms of sustained damage and deferred maintenance. The last partial rehabilitation on the North Jetty was conducted in 1964 and addressed 17% of its length. The last partial rehabilitation on the South Jetty was conducted in 1982 and addressed 25% of its length. The last partial rehabilitation on Jetty A was conducted in 1961 and addressed 56% of its length. The portions of the North and South jetties which have never been repaired since original construction are 55% and 36% of original lengths, respectively. The jetties continue to recede back from their original length. The South, North, and Jetty A head positions are currently shorter than authorized lengths by 6200 ft, 2200 ft, and 900 ft, respectively. Due to the interaction of wave patterns and currents with the jetty configuration, the shorter jetty lengths can expose more shoals to erosion, influence shoreline position adjacent to the jetties, and alter the forcing climate at the project.

Progressive damages to one of the primary jetties could result in a significant breach which can trigger an emergency repair to the jetty, rapid infill into the navigation channel, and emergency dredging activities. The major rehabilitation approach for the MCR jetty system focuses on defining the larger processes affecting the jetty system and describing the jetty system reliability over time. Consequences evaluated included frequency and consequences of future jetty repairs as well as potential impacts to dredging and navigation. Potential navigation impacts were evaluated qualitatively rather than quantitatively. Each alternative adds additional elements of either process stabilization or above or below water cross section stabilization as well as varying degrees of cross section reliability improvement.

2. Project Authorization - MCR Project Features

At the mouth of the Columbia River (MCR), three rubblemound jetties with a total authorized length of 10.2 miles were constructed by the U.S. Army Corps of Engineers (USACE) to secure consistent navigation through the coastal inlet. The Rivers and Harbor Act of 5 July 1884 authorized construction of the South Jetty (first 4.5 miles) to attain a 30-foot channel across the MCR bar. The Rivers and Harbor Act of 3 March 1905 authorized the extension of the South Jetty to 6.6 miles and construction of the North Jetty (2.5-miles long) to attain a 40-foot bar channel (0.5-mile wide). The Rivers and Harbor Act of 3 September 1954 authorized a bar channel at a depth of 48 feet below mean lower low water (MLLW) and Spur Jetty B on the north shore of the inlet; however, funds for Spur Jetty B were not appropriated. Public Law 98-63, 30 July 1983, authorized deepening the northern most 2,000 feet of the MCR channel to 55 feet below MLLW. Jetty A was authorized and constructed to 1.1 miles in length in connection with rehabilitation of the North Jetty for the purpose of channel stabilization. Its purpose was to assist in controlling the location and direction of the ebb tidal flow through the navigation entrance. Figure A1- 1 and Figure A1- 2 illustrate the authorized structures as well as the surrounding shoals and inlet features.

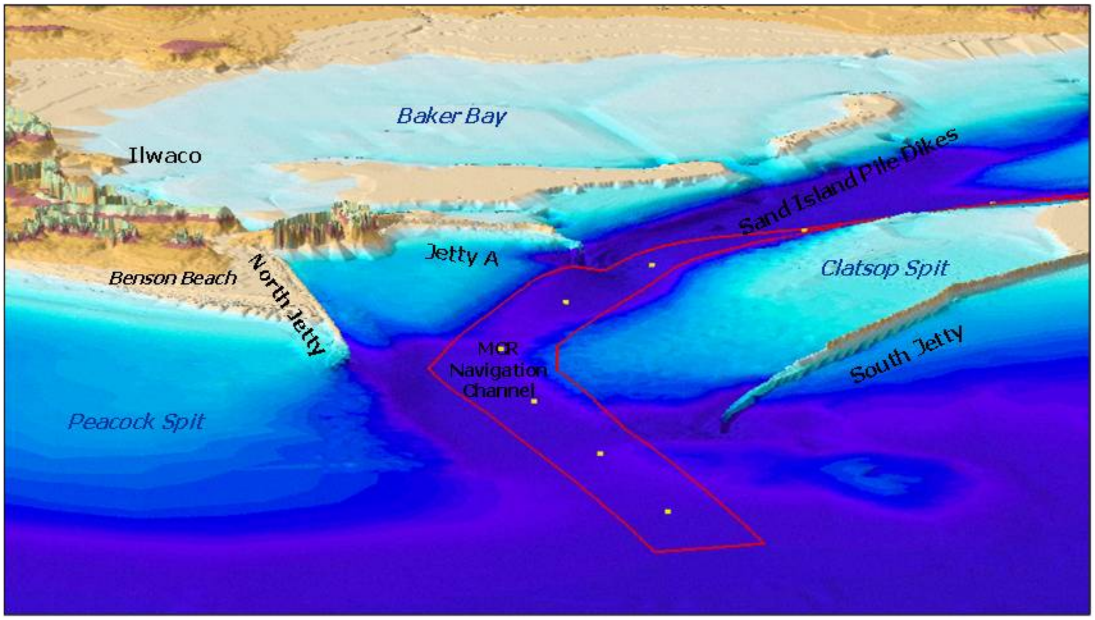


Figure A1- 1. Oblique View of MCR Project

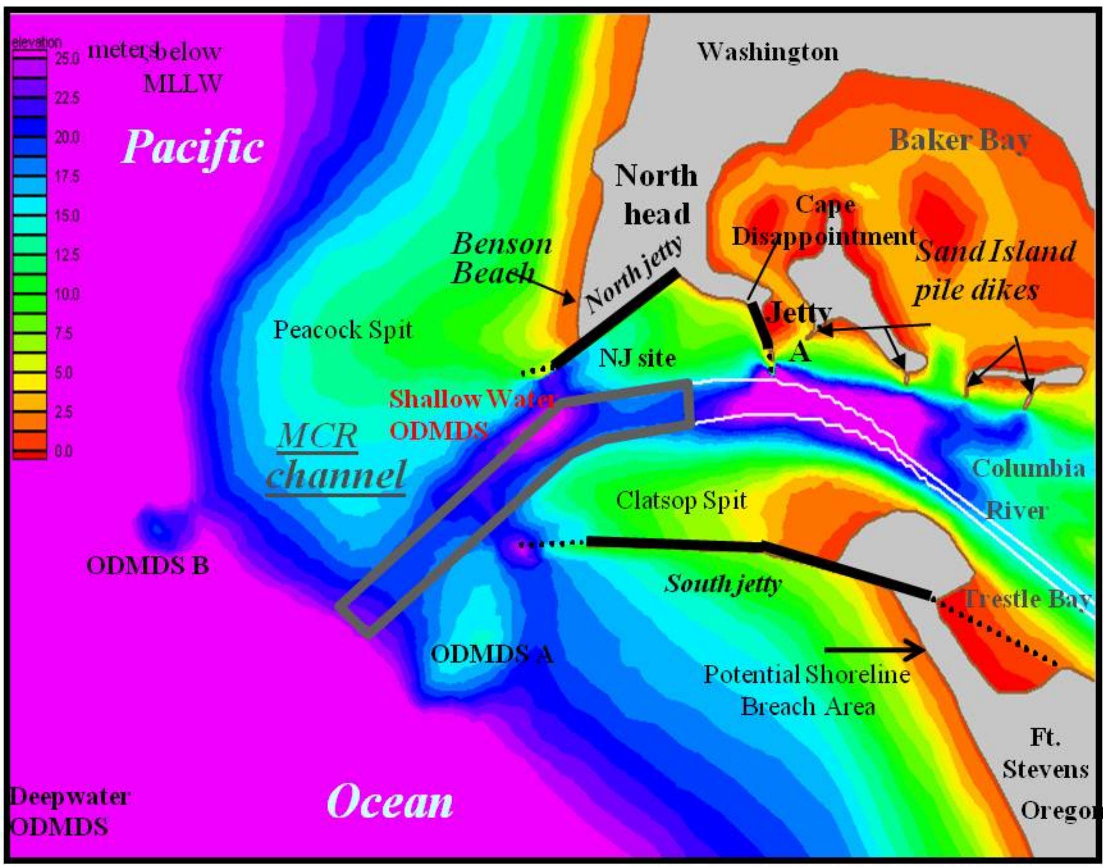


Figure A1- 2. Bathymetry & Navigation Features at the Mouth of the Columbia River, USA

The MCR is the ocean gateway for maritime navigation transiting to/from the 500-mile long Columbia – Snake River inland navigation system (Figure A1- 3). The present deep-draft navigation project at MCR consists of a dredged navigation channel 6-miles long (x 2,460 ft wide x 55 ft deep). The MCR channel passes through a jettied ocean entrance between the states of Oregon and Washington, along river mile (RM, defined from the river entrance) -3 to +3. The present condition of the MCR navigation channel is the result of continuous improvement and maintenance efforts. Figure A1- 4 illustrates the magnitude of the dredging effort at the Mouth of the Columbia River in contrast to the remainder of the Lower Columbia River system.

Figure A1- 3. Mouth of the Columbia River is an ocean gateway

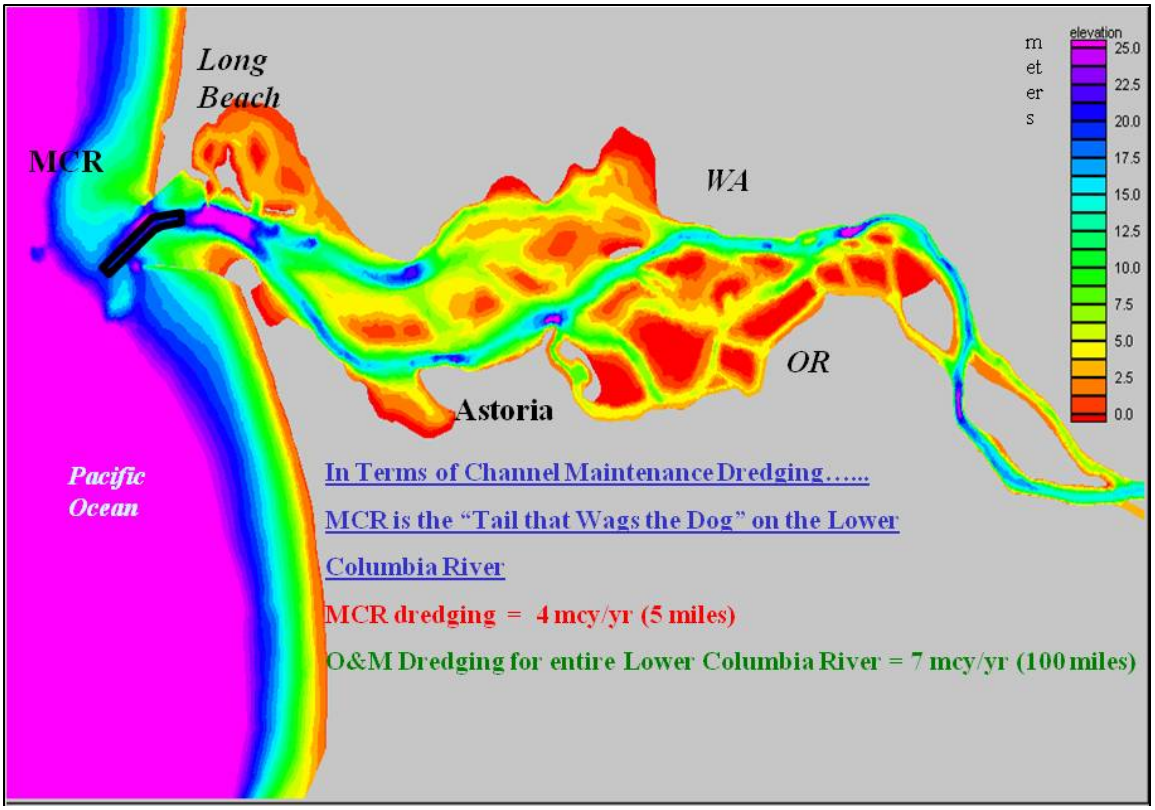


Figure A1- 4. MCR entrance vs Columbia River Dredging

Consistent navigation through the MCR is facilitated by five separate federal project features: 1) MCR navigation channel, 2) North Jetty (Figure A1- 5 and Figure A1- 6), South Jetty (Figure A1- 5 and Figure A1- 7), 4) Jetty A (Figure A1- 5 and Figure A1- 8), and 5) Sand Island pile dikes (Figure A1- 5 and Figure A1- 9). The Sand Island pile dikes are considered secondary structures and were not evaluated in this report. Each project feature was constructed to fulfill a specific hydraulic function, while minimizing the overall maintenance needed to provide safe navigation through the MCR. Figure A1- 2 shows project features, the present configuration of the subtidal shoals/morphology, and the location and orientation of the navigation channel. Figure A1- 10 illustrates the history of shipwrecks at the Mouth of the Columbia River which has had the reputation of being one of the most dangerous coastal entrances to navigate in the world.

Figure A1- 5. MCR entrance structures

Figure A1- 6. North Jetty

Figure A1- 7. South Jetty

Figure A1- 8. Jetty A

Figure A1- 9. Sand Island Pile Dikes

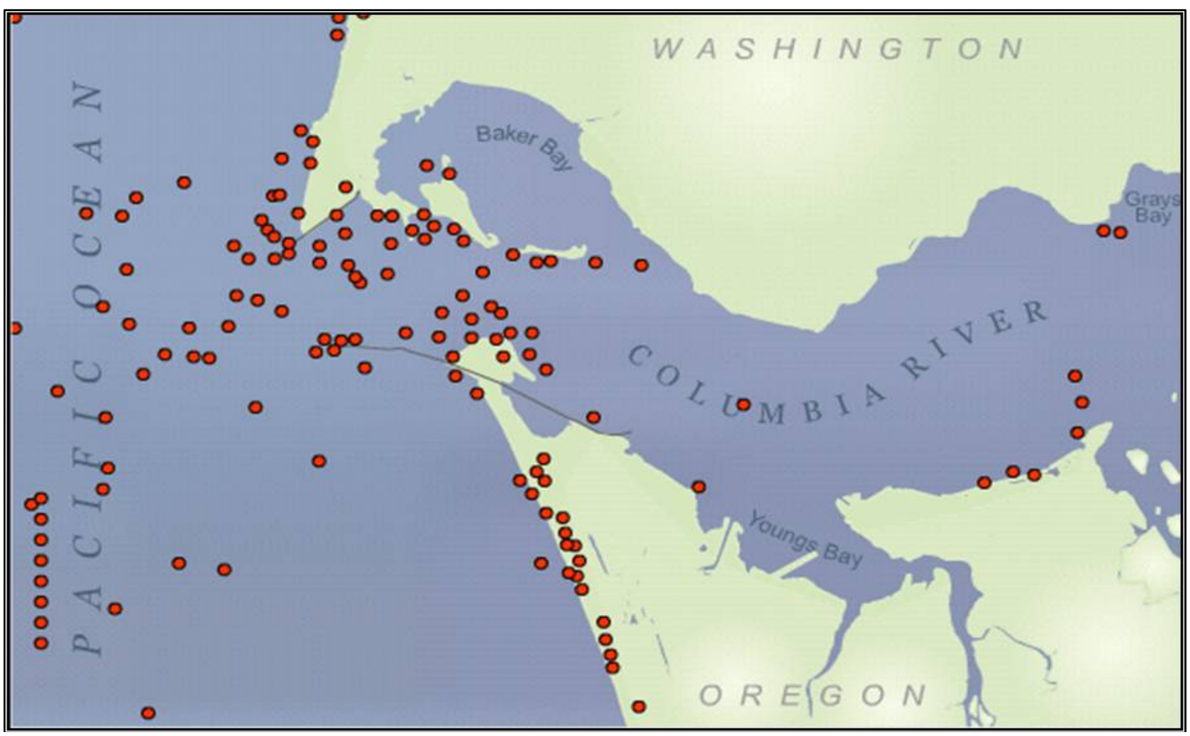


Figure A1- 10. Historical shipwreck locations at MCR (NOAA)

Through phased jetty construction (1885-1939) and the associated response of MCR morphology, all of the project features work together to maintain the function of the navigation entrance. Severe deterioration of any of these features can jeopardize the MCR navigation channel and adversely affect the other structures. Should the North Jetty experience substantial deterioration from its present condition, the MCR channel, South Jetty, Jetty A, and ultimately the Sand Island pile dikes would be negatively affected. A similar scenario would likely occur if the South Jetty experienced substantial deterioration from its present condition.

It is emphasized that the MCR jetties were constructed on tidal shoals, and that these tidal shoals have been changing since the time of jetty construction. The longevity of the jetties is tied to the stability of the shoals on which the jetties were built, and the stability of the shoals is now a function of the jetties. The jetties and shoals act as integrated units to confine tidally-driven circulation through the MCR and maintain the present channel configuration. As authorized by Congress, the basic function of the MCR jetties is to secure and stabilize the MCR deep draft navigation channel. The MCR navigation channel is inherently reliant on the presence and function of the jetties.

3. Location and Description

The 6-mile long deep-draft navigation channel at the mouth of the Columbia River (MCR) has become the ocean gateway for navigation access to and from the 500-mile long Columbia–Snake River system. The Columbia - Snake River navigation systems provides for efficient movement of commerce from the western slopes of the Rockies to the Pacific Ocean. Each year, ocean-going vessels on the Columbia River transport some $20 billion worth of U.S. products to world markets and 42 million tons of cargo passes through MCR annually. The lower Columbia River comprises the world's second largest grain export system, next to the Mississippi River. More than 40 % of the United States' wheat exports are shipped via ports on the Columbia and Willamette rivers. More than 3500 cargo vessels navigate through the MCR annually.

The present authorized deep-draft navigation project at MCR provides for a 2640-ft wide channel across the Columbia River bar. The northerly 2,000 ft of the channel is maintained at –55 ft MLLW (plus 5 ft for over dredging), and the southerly 640 ft of the channel is maintained at –48 ft MLLW (plus 5 ft for over dredging). Each year, the Portland District dredges 3 to 5 million cubic yards (MCY) of sand at MCR to maintain the 5-mile long deep-draft navigation channel. Due to the severe wave conditions of fall through spring, maintenance dredging at MCR can only be performed by hopper dredges operating during the relative calm of summer. Figure A1- 11 shows both a contract and a government dredge working at the MCR entrance. The dredged material is fine-medium sand (0.17-0.27 mm) and fine-grained material content is less than 4%. This material is disposed of in open water disposal sites (e.g. Shallow Water Site (SWS) and Deep Water Site (DWS)) as shown in Figure A1- 12.

Figure A1- 11. Contract and government dredges working at MCR

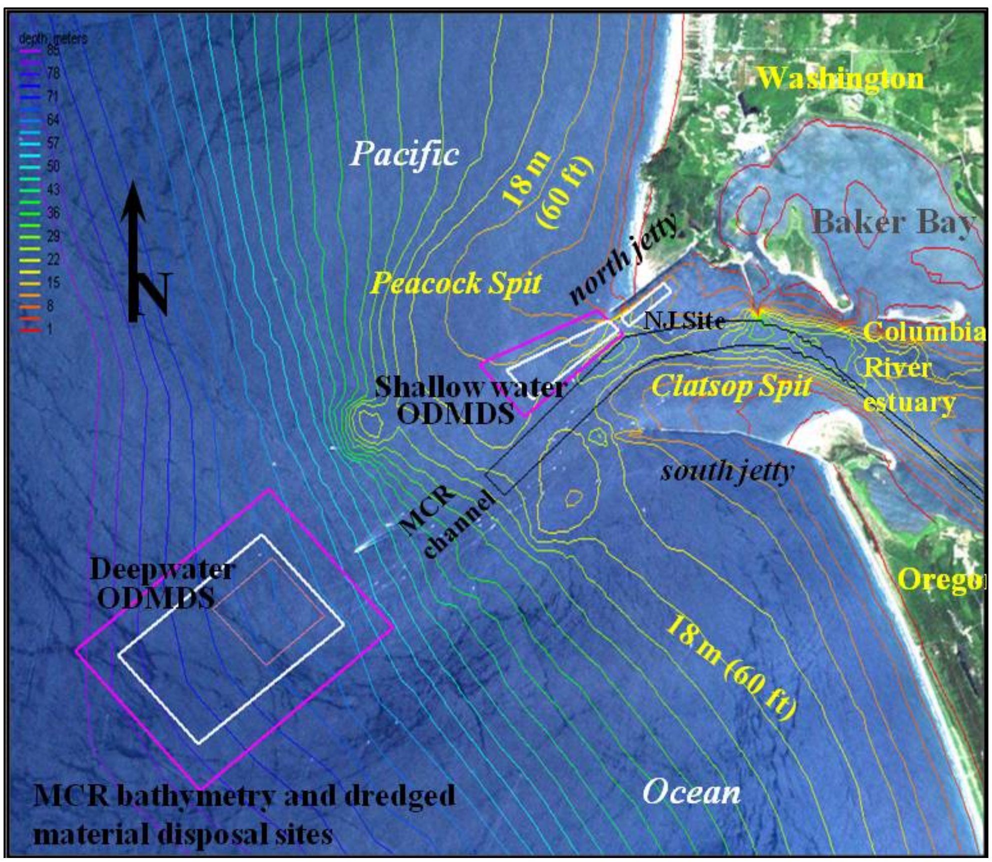


Figure A1- 12. Open water dredged material disposal sites at MCR

The central project feature at MCR is the navigation channel. The North and South jetties are the two most important features that act to maintain the stability of the navigation channel. The overall length of the rubblemound North and South jetties is 2.35 miles and 6.62 miles, respectively. Originally, each project feature was constructed as a separate entity to fulfill a specific hydraulic function, while minimizing the overall maintenance needed to provide safe navigation through the MCR. All the project features were justified based on the need to secure the MCR deep draft navigation channel.

a. MCR Upstream Physical Setting

Offshore of the MCR lays the vast expanse of the northeast Pacific Ocean. Inshore of MCR lies the Columbia River and its estuary, the coastal outlet for a 250,000 mi^2 drainage basin where the headwaters emanate from the western slope of the Rocky mountains. The course of the Columbia River is 1,210 mile long, dropping over 2,600 feet from its Canadian headwaters to the sea. The Columbia River accounts for 60% (winter) to 90% (summer) of the total freshwater discharging into the ocean from the Canadian border and San Francisco. The Columbia River estuary is the largest fluvially dominated estuary in the Pacific Northwest and its tidal prism is about 1,390 mi^2-ft [Jarrett 1976]. The upriver limit for the Columbia River estuary, defined in terms of salt water intrusion, varies between RM 28 and 38 and is a function of fluvial flow and sequencing of the tidal cycle. Current reversal due to tide can occur as far inland as RM 70. Tidal effects (fluctuation of water surface elevation) extend upriver to Bonneville dam (RM 145).

The annual discharge of the Columbia River is marked by seasonal variability, typically ranging from 100,000 to 400,000 cubic feet per second (cfs). Highest discharges occur during May through July due to snowmelt and rain runoff. Lowest flows occur during late summer and early fall [Neal 1972]. The average (regulated) river discharge is presently about 265,000 cfs. Peak river flow at the Dalles dam during the freshet of May 1997 was at about 600,000 cfs, which corresponded to a 3% chance of exceedence (35-year) regulated flow event. Physical characteristics of the Columbia River estuary differ from those of most North American estuaries - river discharge is much greater, salinities are much lower, tidal forcing is greater, and bottom sediment is less stable. Flushing time for the Columbia River's estuarine waters is 2-5 days, whereas the flushing time for many other estuaries may require weeks or months: The average flushing time for Chesapeake Bay is about 1 year.

Although the Columbia River is known for its low turbidity, swift river currents move a significant amount of bedload sediment within the lower reaches of the river and produce sand waves up to 10-ft high on the channel bottom. Within the Lower Columbia River (downstream of Bonneville Dam, RM 145), the amount of sediment contributed by the upper Columbia River is very small compared to the net water discharge and most of the sediment that is affected by bedload processes (sand-sized or larger) has originated from the Cascade arc. From 80% to 90% of the Lower Columbia River's sediment through-flow is composed of suspended sediment, yet relatively little suspended sediment is retained in the main stem of the estuary. The predominate sediment type in the main channels of the estuary (downstream of RM 30) is medium to coarse sand and small gravel which is transported as bedload, with finer silts and clays prevalent in peripheral bays and within limited areas of the main estuary

[Roy et al., 1982]. In terms of the overall estuary, average bottom sediments have been characterized as having 1% gravel, 84% sand, 13% silt, and 2% clay [Hubbell and Glenn 1973 and Roy 1982]. Fine sediment, which is normally transported in suspension, comprises only a small percentage of the sediment deposited in the main channels of the estuary. Approximately 67% of the suspended sediment (generally, silt-size and finer) discharged from the Columbia River is estimated to be transported to the continental shelf of Washington, 17% of which is estimated to be transported beyond the shelf break, down into submarine canyons [Sternberg 1986].

b. MCR Navigation Development

Prior to improvement in 1885, the tidal channels through the MCR shifted north and south between Point Adams (Fort Stevens) and Cape Disappointment, a distance of about 5.5 miles. Figure A1- 13 through Figure A1- 15 document the high degree of natural channel variability that had taken place from 1792-1885 at the MCR entrance. Note the southward migration of the natural channel from Baker Bay (1839) to the middle of the entrance and radical modification of the intervening tidal shoals (1885). The MCR was more than once divided into two or more channels, and the controlling depth of the dominant channel through the ebb tidal delta varied between 18-25 feet below MLLW. The ebb and flood tidal deltas at MCR entrance were distributed over a large area, immediately seaward and upstream of the river mouth. Ships often had trouble traversing the Columbia River bar, the area in which the flow of the estuary rushes headlong into towering ocean waves. On many occasions, outbound ships had to wait a month or more until bar conditions were favorable for crossing. To make the business of navigating through the MCR even worse, sailing ships had to approach either of the two natural channels (north channel or south channel) abeam to the wind and waves. The natural channels often shifted widely within the course of several tidal cycles. At best, crossing the bar was dangerous. At worst, it was not possible.

With the "opening of the west" that was occurring in America during 1860-1880, a consistent and reliable navigation channel was needed through the MCR to link inland areas of the Pacific Northwest with other parts of the country and world. It was assumed that a (South Jetty) stone dike would guide ebb tidal waters in the direction of the channel and away from Clatsop Spit, thereby deepening the channel. In order to improve the channel, Congress, by the River and Harbor Act of 2 August 1882, authorized a Board of Engineers to "examine in detail the mouth of the Columbia River, Oregon, and report such plan, with estimates, for its permanent improvement as they approve."

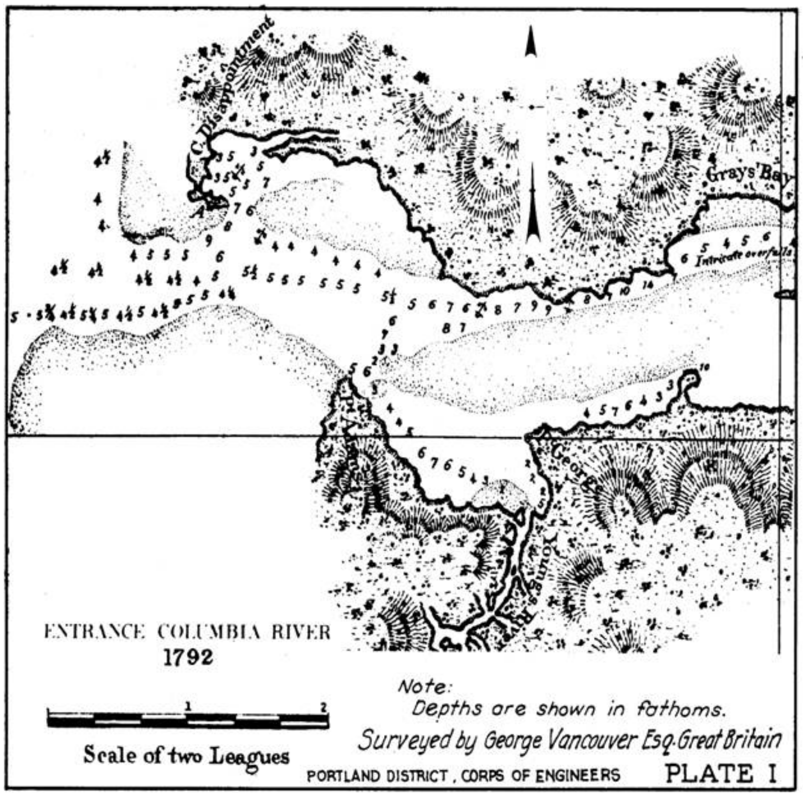


Figure A1- 13. 1792 Bathymetry at MCR

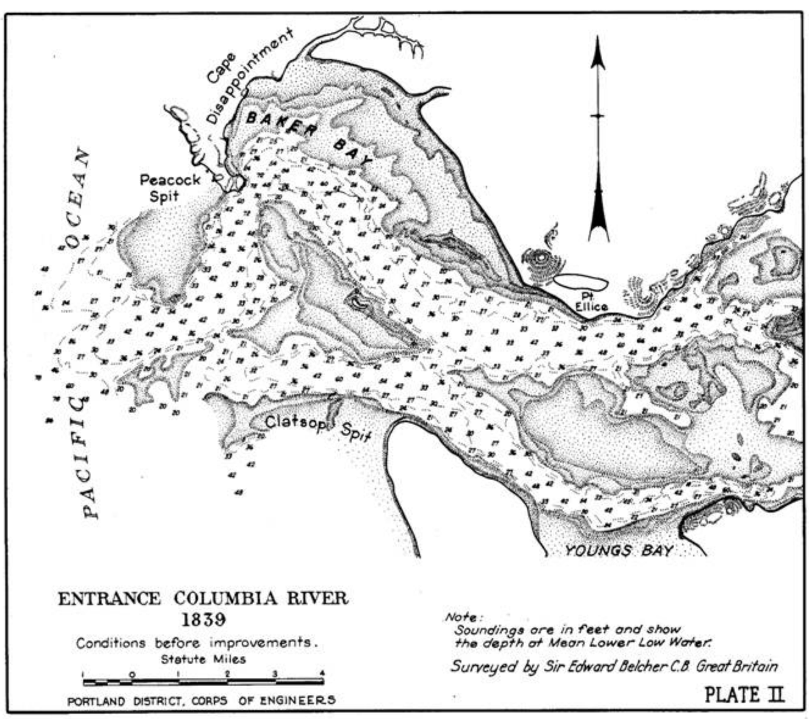


Figure A1- 14. 1839 Bathymetry at MCR

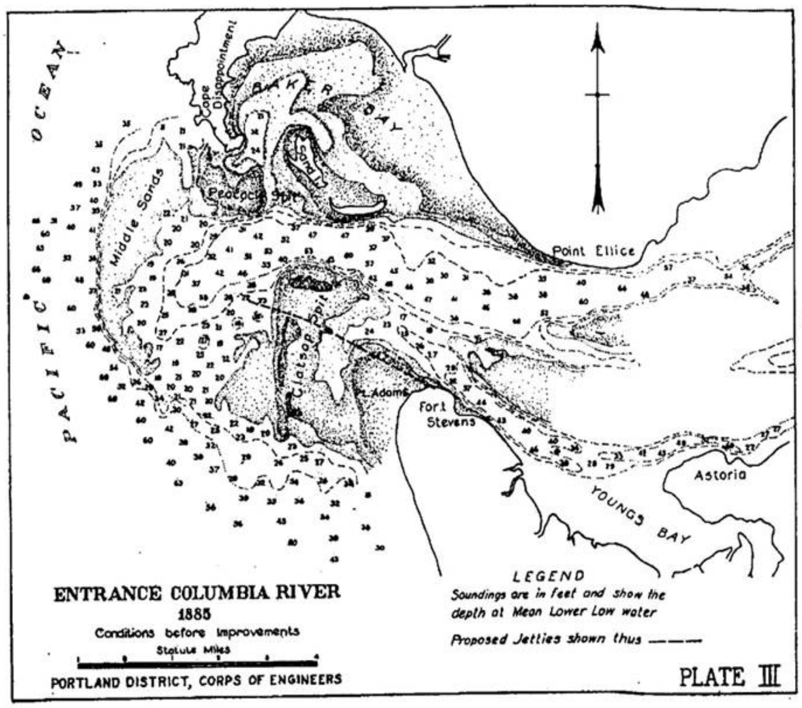


Figure A1- 15. 1885 Bathymetry at MCR

4. MCR Inlet – History and Present Condition

a. General

Navigation at many coastal inlets is typically secured using one or two rubblemound jetties. Figure A1- 16 illustrates the changes to the entrance after the first phase of the South Jetty construction. A rubblemound structure can be composed of several layers of random-shaped and random-placed stone (core), protected with a cover layer of selected armor units of either quarry stone or specifically shaped concrete units (armor layer). A jetty functions to confine tidal flow through an inlet (increase flow velocity) to promote scour and secure a navigation channel of specified depth. Figure A1- 17 and Figure A1- 18 illustrate that process in response to South Jetty and North Jetty construction at the MCR. Too little scour and shoaling degrades the navigation channel, too much scour and the inlet becomes unstable and the jetties can be undermined; regardless of how the jetty is constructed. A jetty can also stabilize an inlet by reducing the volume of open coast littoral circulation (and sand) that would otherwise enter an inlet, and lead to rapid shoaling of a navigation channel. A system of convergent jetties was used to establish and retain the deep draft navigation channel at MCR.

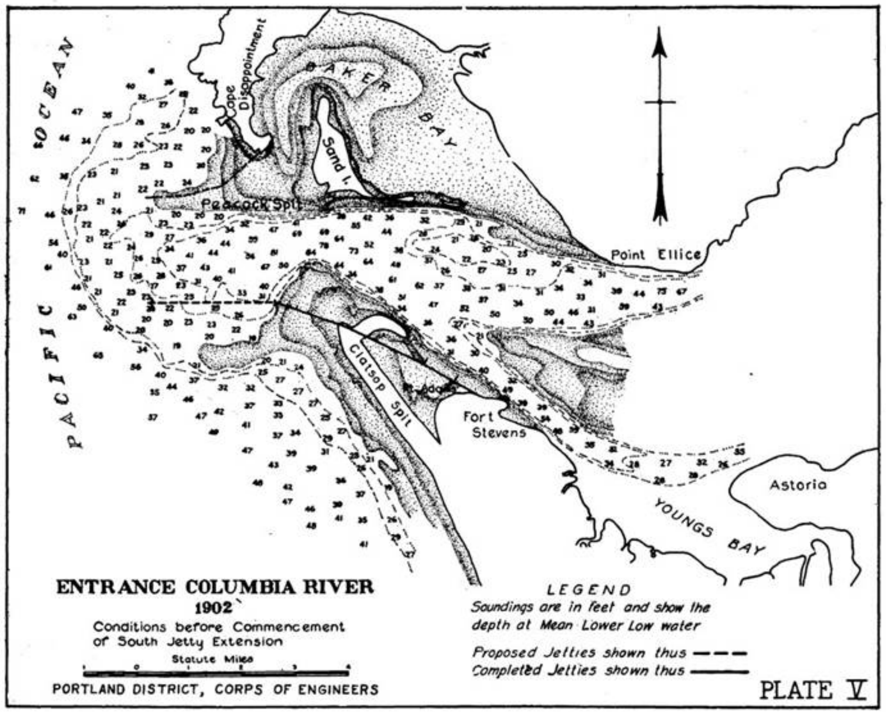


Figure A1- 16. 1902 Bathymetry at MCR

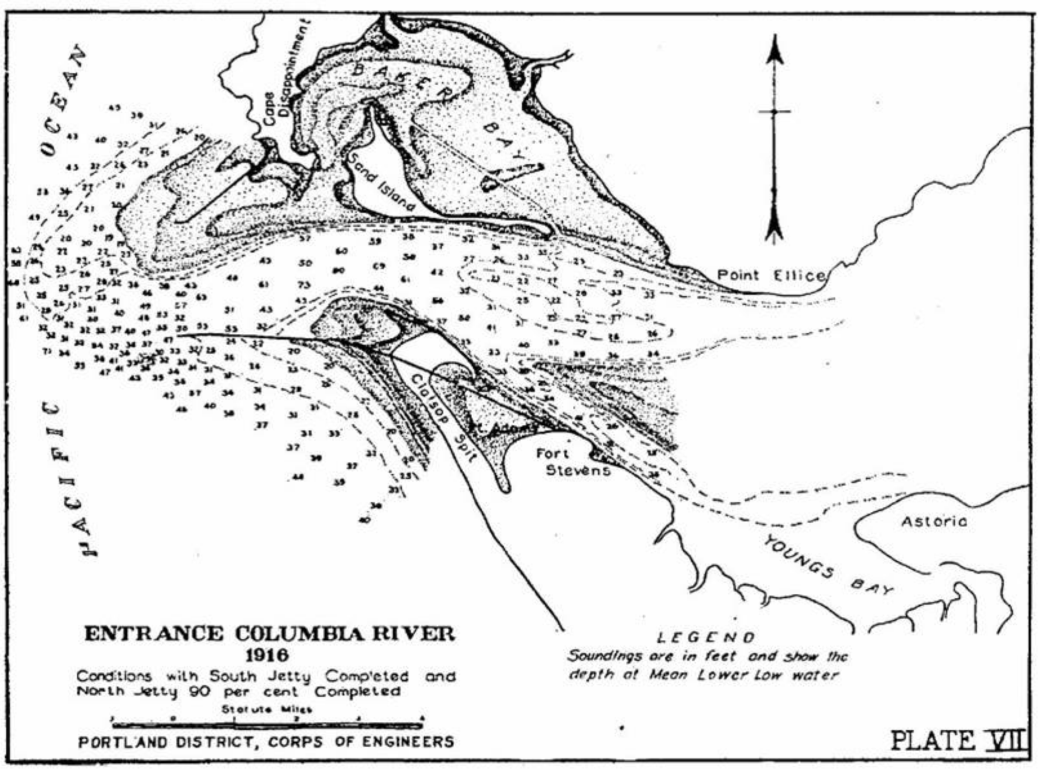


Figure A1- 17. 1916 Bathymetry at MCR

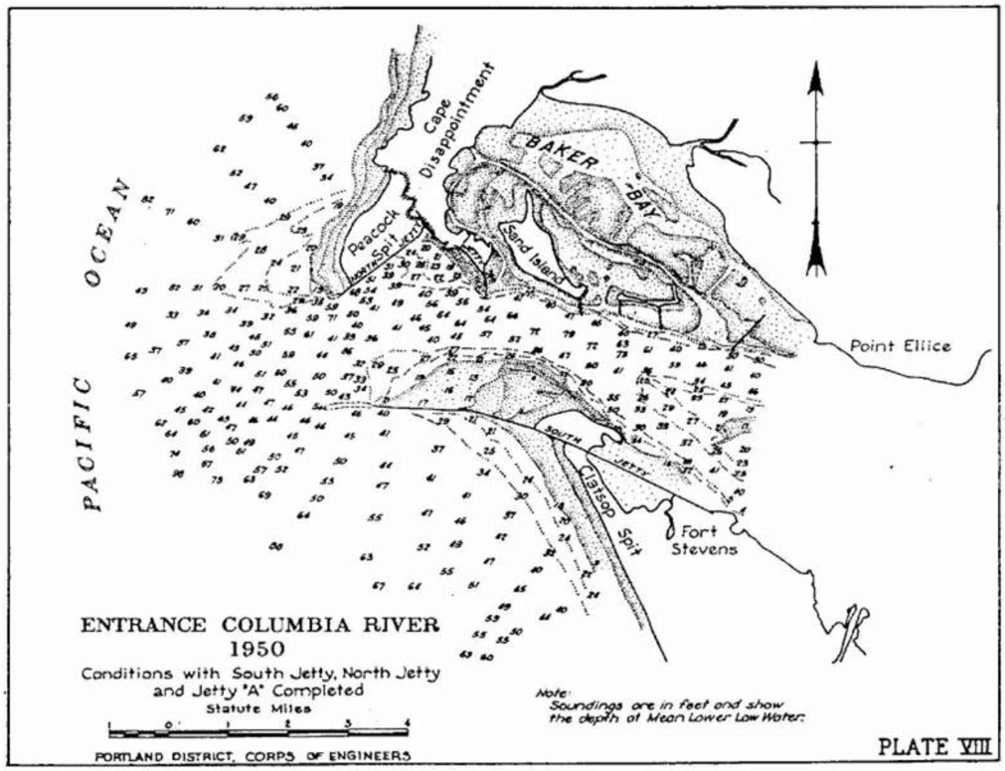


Figure A1- 18. 1950 Bathymetry at MCR

Construction of the MCR jetties reformed a broad and treacherously variable 5 mile-wide inlet into a stable 2 mile-wide inlet having a consistent thalweg suitable for navigation. Figure A1- 19 through Figure A1- 24 illustrates the reforming of the MCR inlet in response to the jetty construction. The central project feature at MCR is the navigation channel, which is secured by a system of large rubblemound jetties: 1) a 2.5 mile North Jetty constructed during 1914-1917, 2) a 6 mile South Jetty constructed during 1885-1913, and 3) a 0.5 mile Jetty A constructed in 1939. Approximately 11 million tons of quarried stone have been used to construct and maintain three MCR jetties. Figure A1- 25 through Figure A1- 31 illustrates the gradual changes both in location and depth in the navigation channel and the entrance channel bathymetry over time.

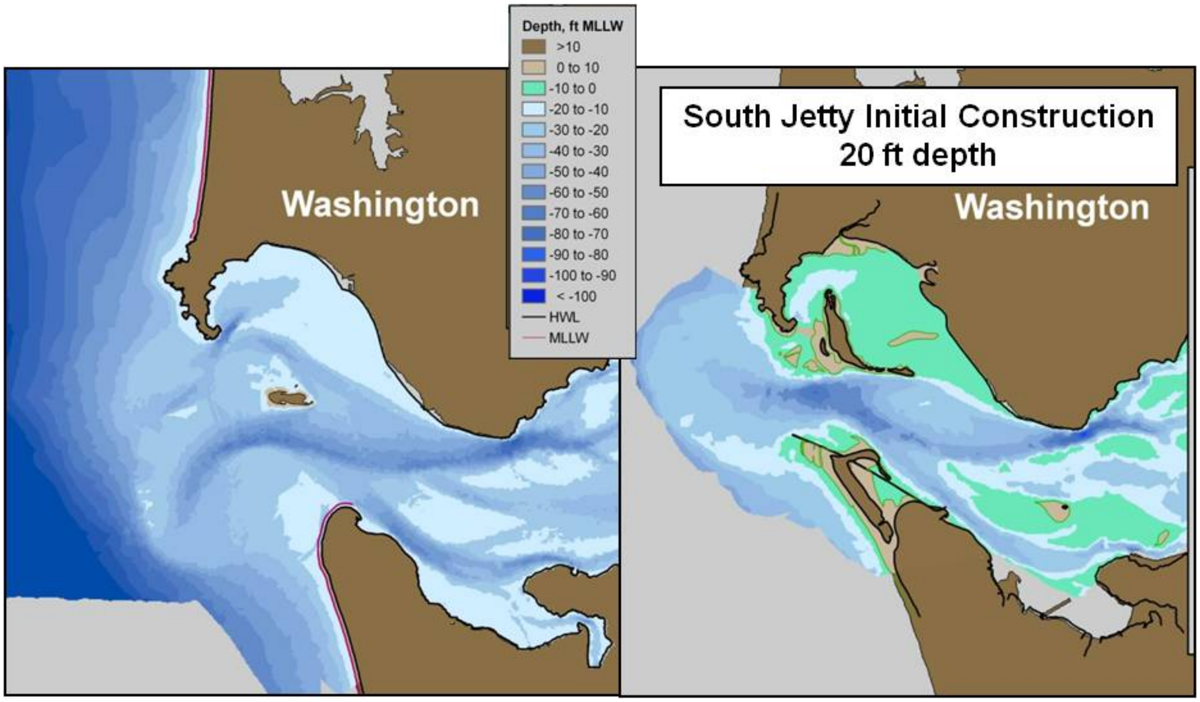


Figure A1- 19. MCR Inlet and Bathymetry Change from 1866 to 1899 (Byrnes, 2006)

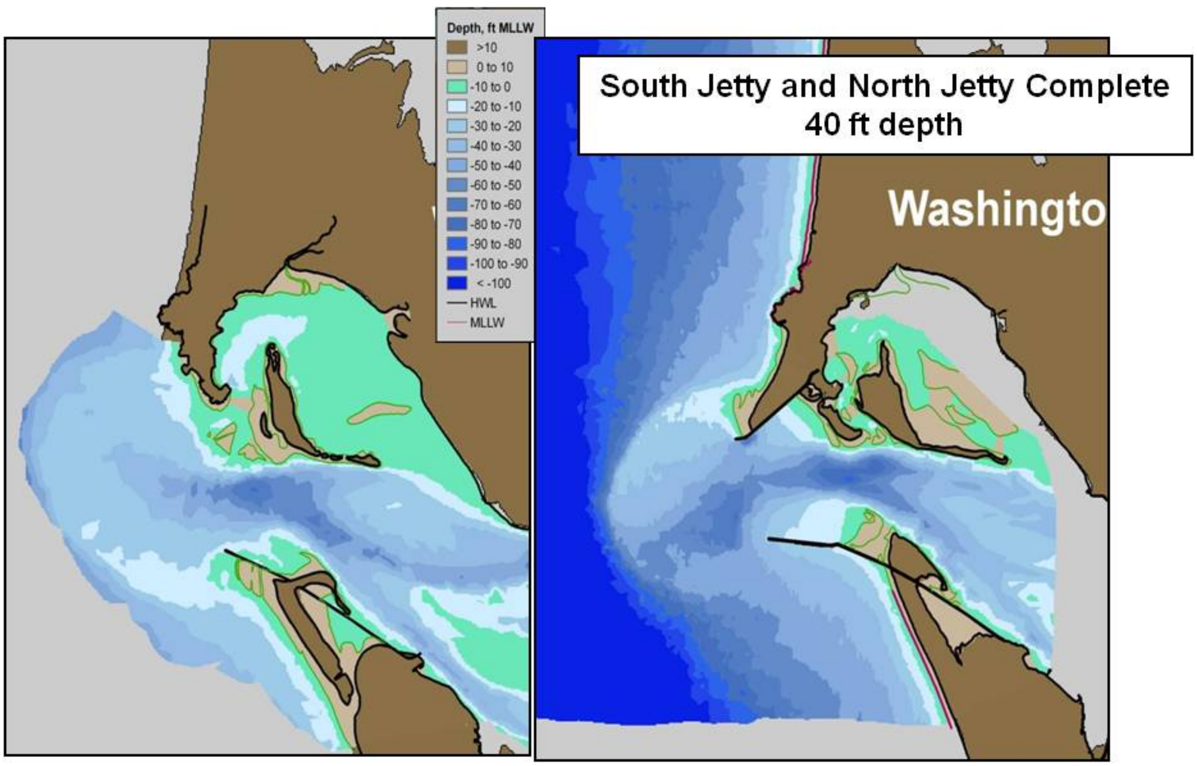


Figure A1- 20. MCR Inlet and Bathymetry Change from 1899 to 1926 (Byrnes, 2006)

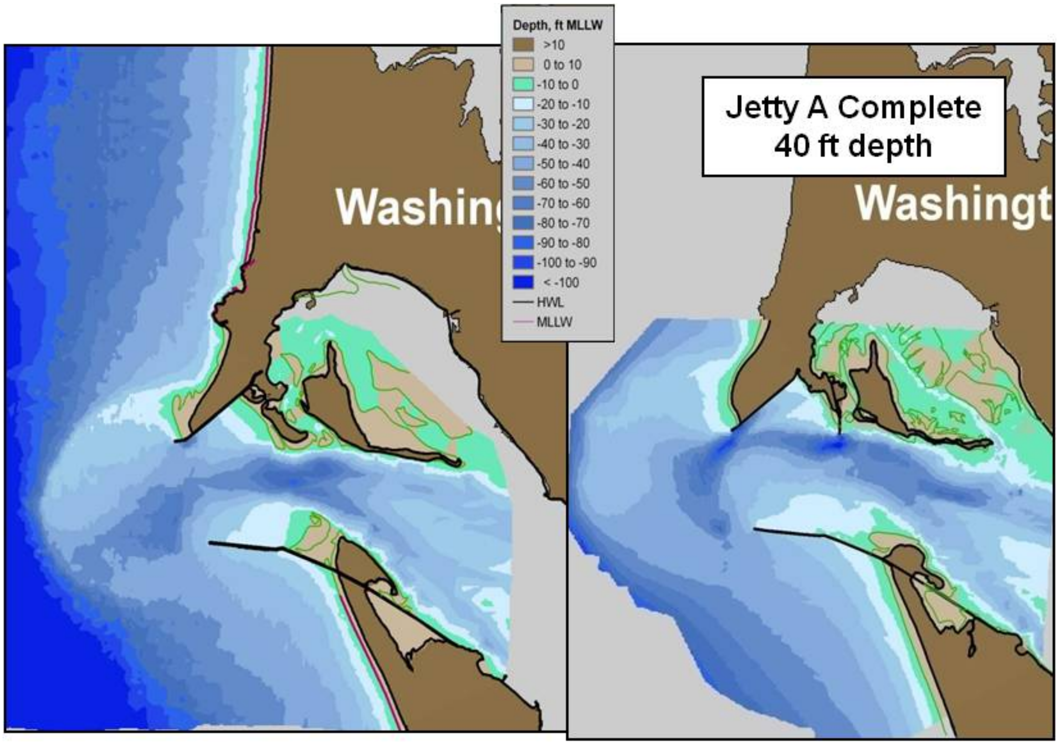


Figure A1- 21. MCR Inlet and Bathymetry Change from 1926 to 1944 (Byrnes, 2006)

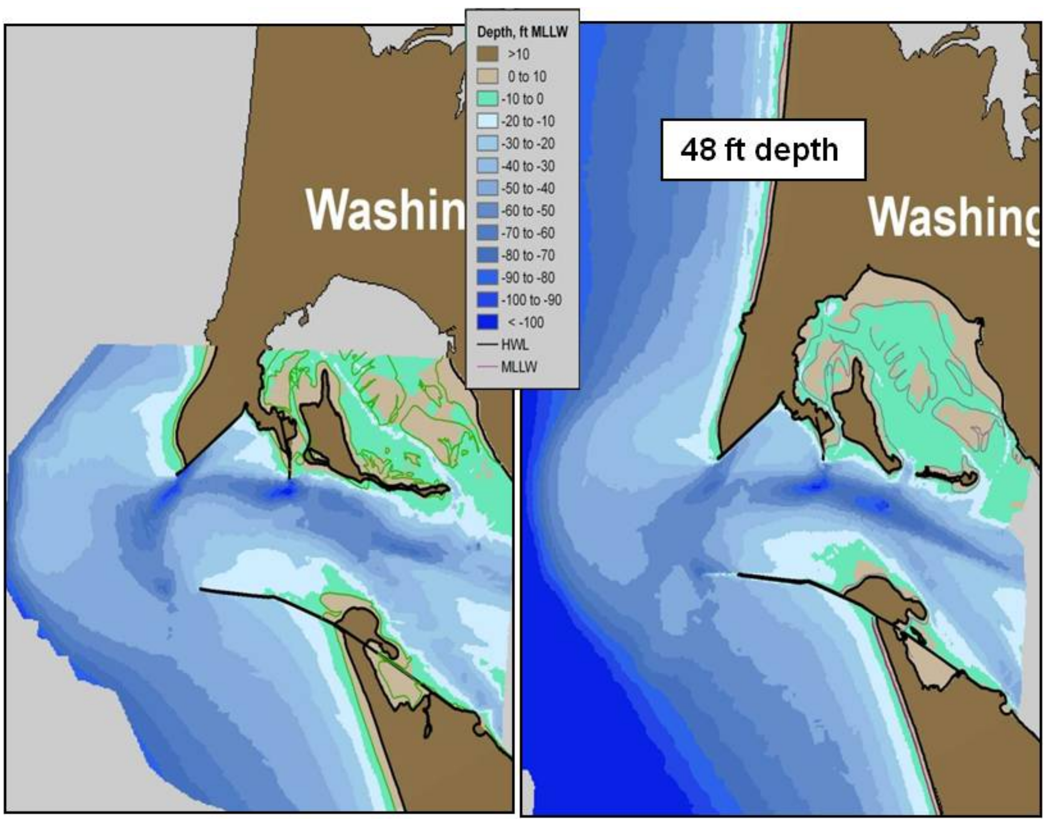


Figure A1- 22. MCR Inlet and Bathymetry Change from 1944 to 1958 (Byrnes, 2006)

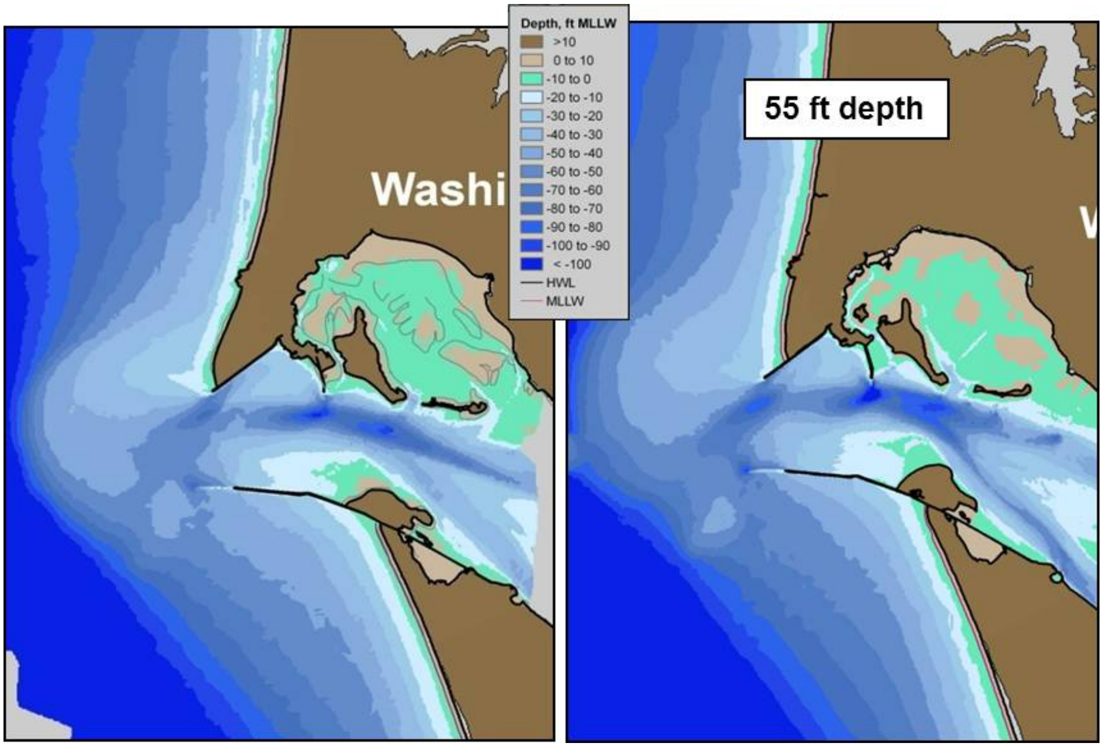


Figure A1- 23. MCR Inlet and Bathymetry Change from 1958 to 2003 (Byrnes, 2006)

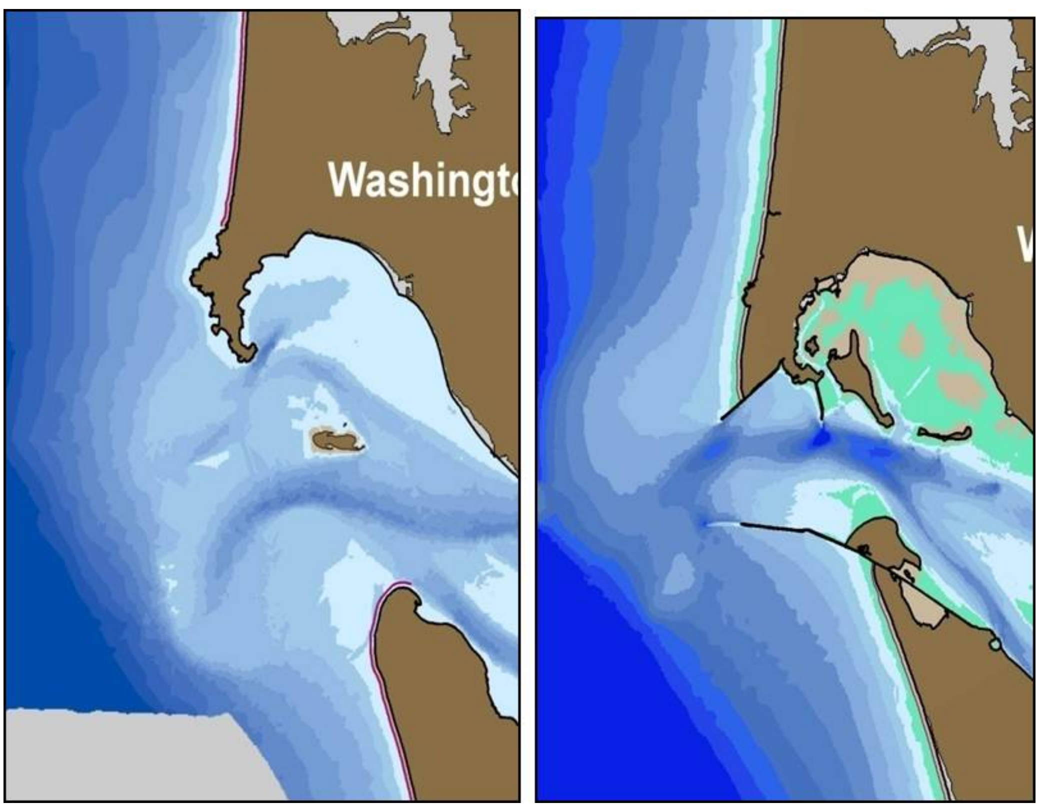


Figure A1- 24. MCR Inlet and Bathymetry Change from 1866 to 2003 (Byrnes, 2006)

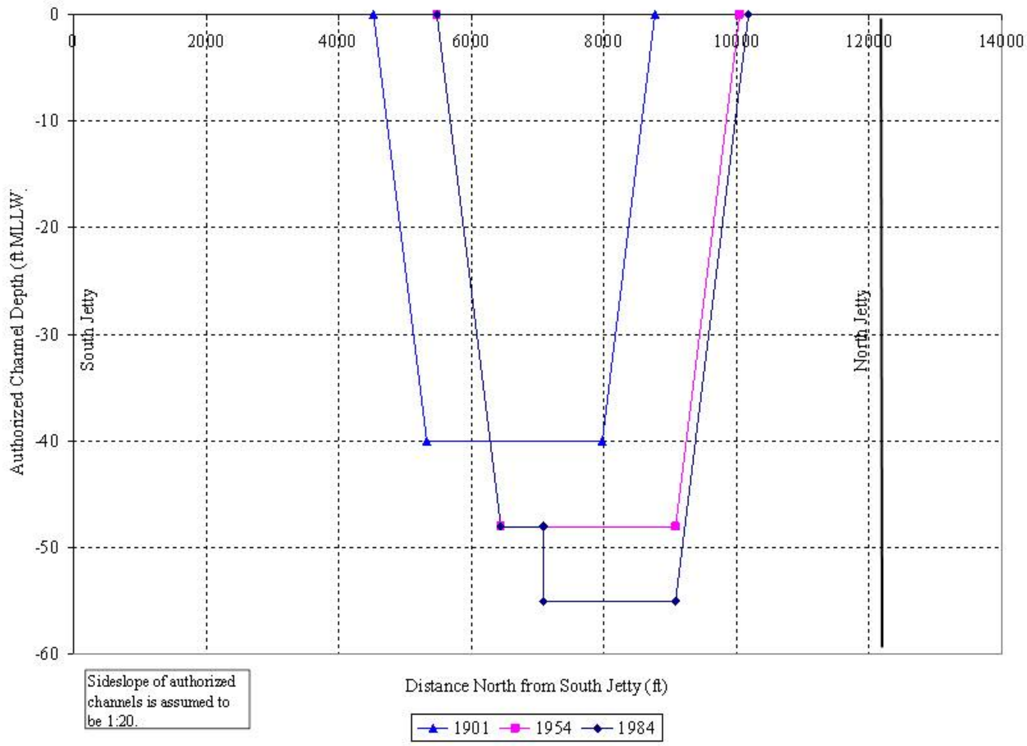


Figure A1- 25. Navigation Channel Cross Section Changes at RM 0.75

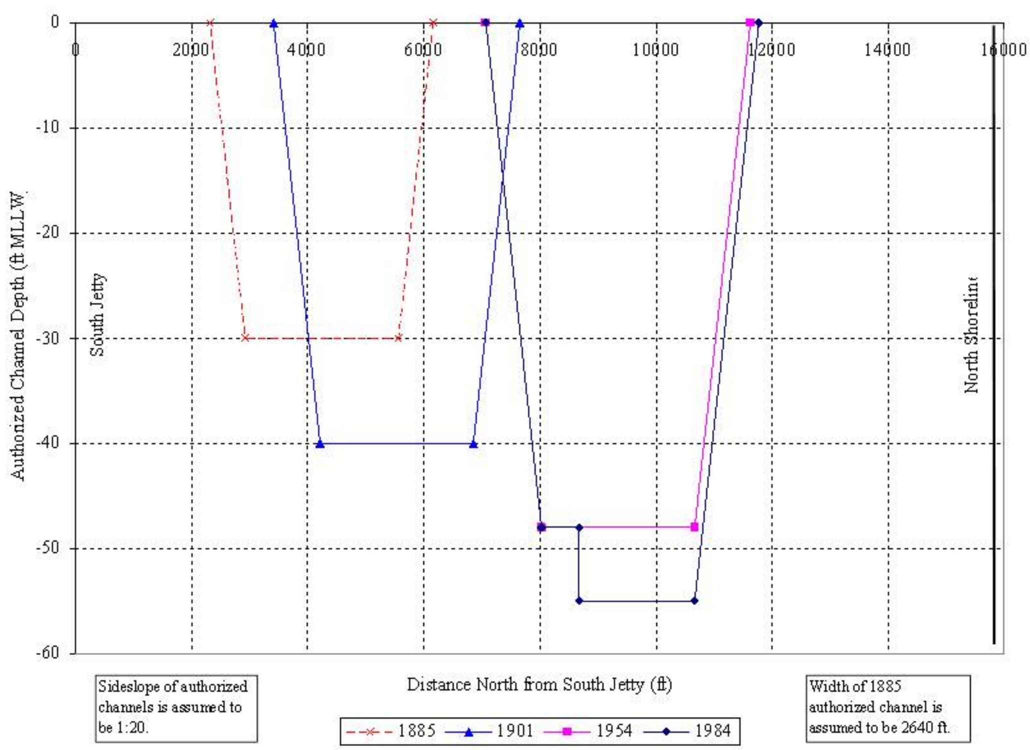


Figure A1- 26. Navigation Channel Cross Section Changes at RM 2.2

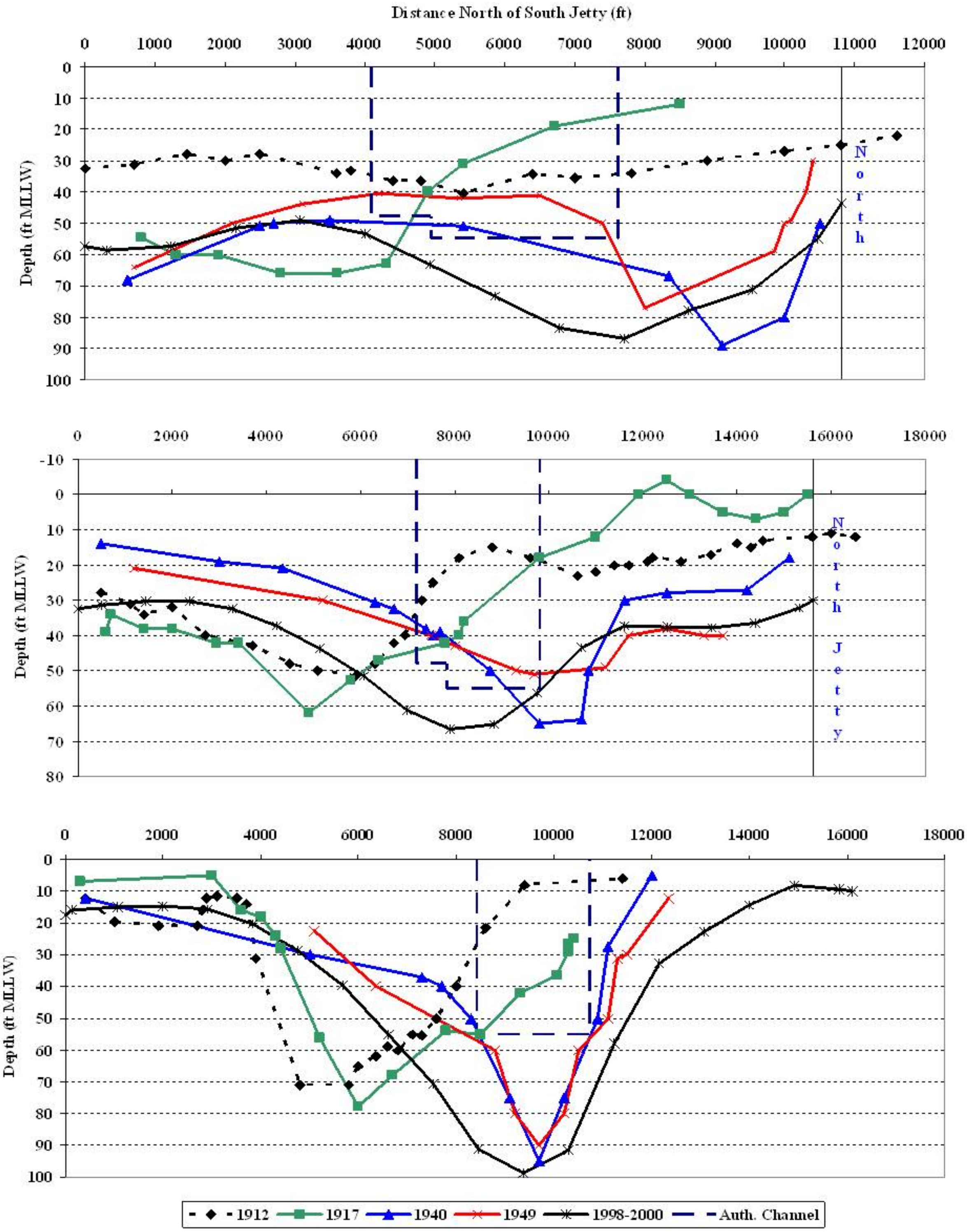


Figure A1- 27. Navigation Channel and Bathymetry Change from 1912 to 2000

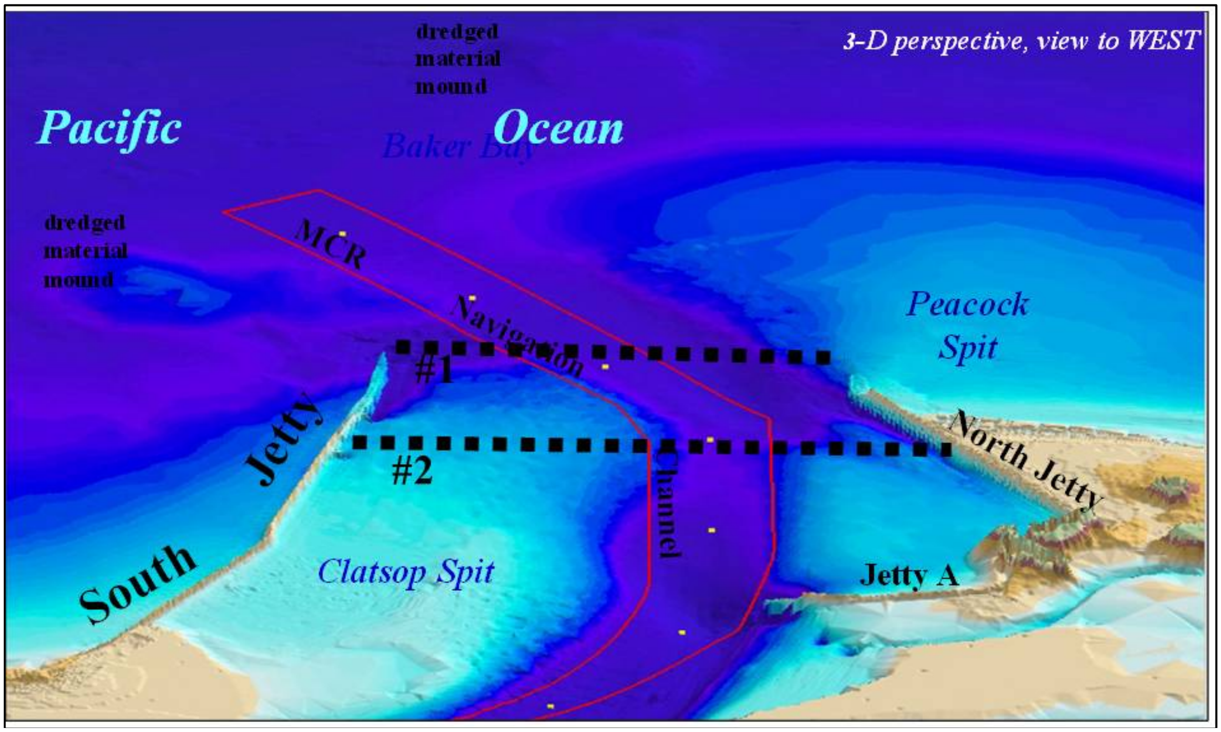


Figure A1- 28. MCR Channel X-Sections Locations

DATE	ACTION
1877	Navigation channel approved
1882	30' depth authorized
1885	19' depth channel
1895	31' controlling depth
1899-1902	navigation channel realigned
1905	40' depth authorized
1914	24' depth obtained
1917	30' depth authorized
1918	40' controlling depth
1919	3000' wide
1927	47' controlling depth
1930	44' controlling depth and 8000' wide
1935	35' depth obtained
1939-1955	dredging at entrance confined to Clatsop Spit
1951	channel alignment on Desdemona shoal
1954	48' depth authorized
1956	begin dredging of 48' depth and over one-half mile width
1957	48' depth obtained
1976	40' depth obtained
1977	48' depth obtained and 2640' wide, 52' entrance project initiated
1984	55' depth obtained

Figure A1- 29. MCR Navigation Channel History Milestones

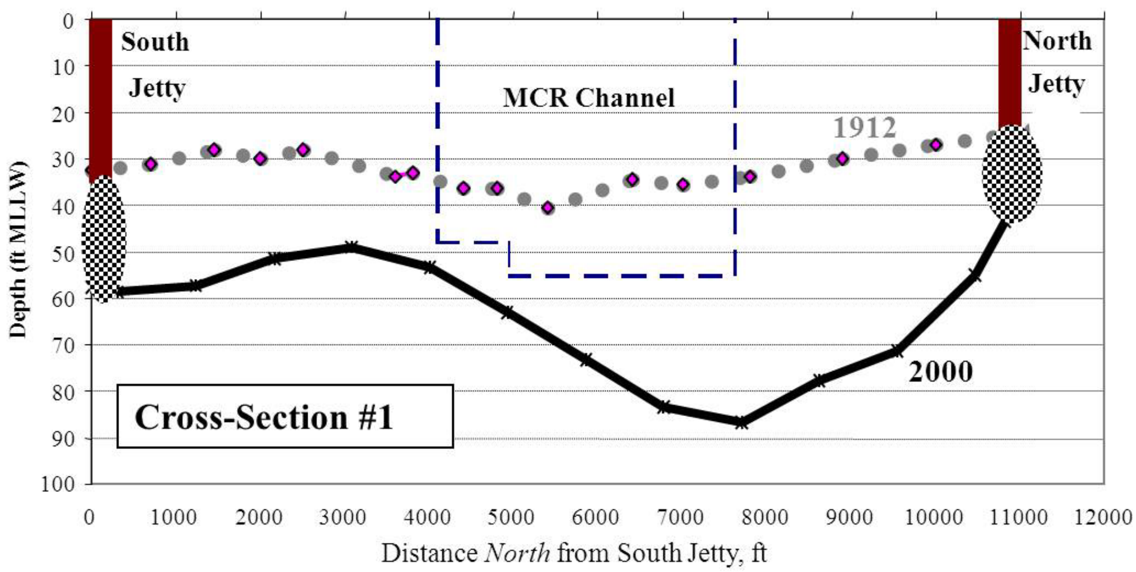


Figure A1- 30. MCR Channel X-Section #1

(View toward ocean, see figure A1-28 for X-S #1 location. Scour along toe of north and south jetties (highlighted by checkerboard shape) exceeds 12 ft and 20 ft, respectively. Since 1912, the MCR channel thalweg has migrated 3,000 ft northward toward the north jetty.)

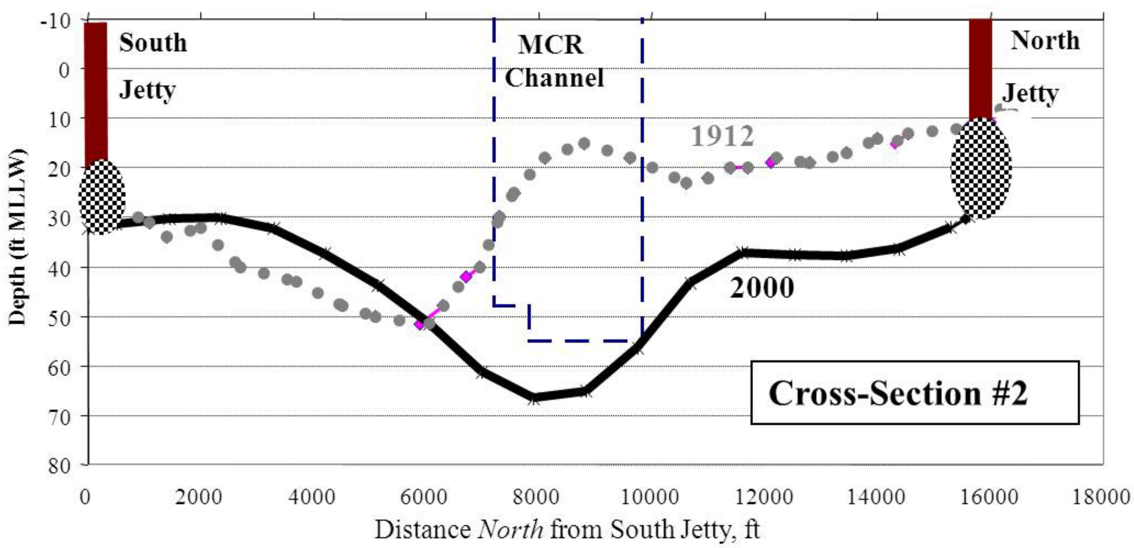


Figure A1-31. MCR Channel X-Section #2, view toward ocean, see figure A1-_28 for X-S #2 location. Scour along toe of north and south jetties (highlighted by checkerboard shape) exceeds 20 ft and 10 ft meters, respectively.

Figure A1- 31. MCR Channel X-Section #2

(View toward ocean, see figure A1-28 for X-S #2 location. Scour along toe of north and south jetties (highlighted by checkerboard shape) exceeds 20 ft and 10 ft meters, respectively.)

Over the last 120 years, the re-direction of currents through the jettied entrance of MCR resulted in the discharge of greater than 400 million cubic meters of sand from the estuary to the ocean and resulted in re-orientation of the tidal inlet. Much of the present-day Peacock Spit and Clatsop Spit were formed by sand discharged from MCR during/after jetty construction. However, these spits and tidal shoals have been eroding since the completion of jetty construction (1939). The water depth along each jetty varies from 0 at the root (landward tie-in) to >65 ft along the head (seaward terminus). The present forcing environment at the MCR inlet exposes the jetties to severe conditions particularly during the winter months (NOV- MAR), when intense maritime extra-tropical low pressure systems buffet the coast. During winter storms, the coastal water level can be perturbed by a potential 10 ft combined-transient storm surge allowing 33 ft high waves to attack the seaward end of the jetties. The wintertime sea state affecting MCR is characterized by large swell approaching from the northwest to southwest combined with locally generated wind waves from the south to southwest. The tides at MCR are mixed semi-diurnal. The 7.5-ft average diurnal tide range combined with an annual average Columbia River flow rate of 4,500 m^3/sec can produce peak estuarine flow through the MCR that exceeds 40,000 m^3/sec during ebb and flood tide. A tremendous amount of sediment transport can occur at the inlet and along the jetties when storm waves and storm-induced current interact with the inlet's estuarine circulation.

b. MCR Construction Timeline

1881. Proposed project to build a strong pile-dike, 3 feet above low tide, 8000 feet long, and 20 feet wide along a line previously established along the south side. The structure will start near the northeast corner of Fort Stevens, following the 12-foot curve; the dike will be directed a little westward of the outer part of the headland of Cape Hancock. It is stated that work should commence soon (during the summer and autumn) because channel maintenance is dependent upon building up Clatsop Spit.

1883. A jetty plan has been approved by the Board from the south cape of the entrance on the spit. A survey was conducted in October and November of the south cape, Point Adams, to extreme low water. The jetty will extend from Point Adams and make the distance between the outer end of the jetty and Cape Disappointment the same as the distance between Chinook Point and Point Adams. The Board stated that any structures placed in the river should not harm the river and should keep the channel open using the tide; therefore, the jetty should not obstruct the entry of the flood tide. It was recommended that jetty construction should begin as soon as possible. The jetty design calls for a crest elevation at low water level. The estimated depths of the various jetty sections from the landward end are: 5000 ft - less than +6 ft, 7500 ft – +6 ft to +11 ft, 4000 ft – +11 ft to +16 ft, and 7500 ft – +16 ft to +21 ft. The jetty crest elevation was designed to be at low water level because of the violence of the waves that could harm a higher jetty. The logic is that a higher jetty could be built, if needed later, by placing more stone upon the existing jetty. A jetty height to mid-tide level was suggested but not recommended because the lower jetty would be quite effective in directing the ebb tide and would interfere less with the flood tide. A higher jetty would result in higher maintenance costs due to the jetty being more exposed to wave action.

1884. The improvement plan for MCR was approved by the act of July 5, 1884 to maintain a channel 30-feet deep at mean low tide by constructing a low-tide jetty, about 4.5 miles long, from near Fort Stevens, on the South Cape, to a point about 3 miles south of Cape Disappointment.

1886-1896. Original construction of South Jetty from Fort Stevens (Station 25+80) across Trestle Bay and Clatsop Spit to Station 250+20. Rock is placed with a natural slope to an elevation of between 4 and 12 ft (MLLW), crest width is roughly 10 ft. "The jetty, of a brush-mattress and stone ballast, was built for 1,020 feet from ordinary highest tide-line, and minor constructions added." Material has filled along the south side of the jetty, moving the shoreline seaward. The highest tide-line is located at tramway Station 30+50. A 115 ft long spur was built landward of the jetty for shore protection. A 510 ft long sand-catch, consisting of heavy beach drift and loose brush, was built on the south side of the landward end of the jetty to continue filling the old outlet of a lagoon at the extreme end of Point Adams. The stone in the jetty was originally dumped in ridges, but the waves have flattened and compacted the rocks to a width of 50 ft. The report indicates that there is an urgency to extend the jetty in order to prevent further deterioration of the bar-channel.

1889. The jetty is now under construction for 1.5 miles. Clatsop Spit has more material visible at low water and the river channel has a tendency towards a straight course out to sea. Tillamook Chute is being closed. Sand is building up south of the jetty adjacent to and in front of the mattresses as they are constructed.

1890. Jetty construction is 3.25 miles underway. Jetty elevation is at MLLW for about 3 miles. 1.25 miles of tramway needs to be constructed. Clatsop Spit is building up; the outflowing waters are being concentrated over the channel bar. Station 25+80 is considered the beginning of the jetty. The jetty mattress has been advanced from Station 99+04 to Station 194+08. The jetty elevation is at MLLW to Station 170+00. From Station 170+00 to the end of the mattress work, there is about 9 feet of rock on top of the mattress. At Station 65+00, there were signs of sinking and a large amount of rock had to be dumped in place.

1903-1913. Extension of South Jetty. Crest elevation of jetty is raised to +10 ft MLLW from Station 210+35 to Station 250+20, and rock is placed from Station 250+20 to Station 375+52, elevation increasing in steps to 24 ft MLLW. Crest width is 25 ft and side slopes are natural slope of rock. A seaward bend in the jetty is added and called the "knuckle."

1913-1917. Original construction of North Jetty from Station 0+00 to Station 122+00. Side slopes are 1V:1.5H and crest width is 25ft. Crest elevation varies from 15ft to 32 ft MLLW.

1931-1932: Repair of South Jetty from Station 175+00 to Station 257+68.7 (shoreline to knuckle), side slopes are 1V:1.5H, crest elevation is 24 ft MLLW, and crest width is 24 ft. This is the first maintenance for the South Jetty. The jetty had been flattened to about low water level. 2.2 million tons of stone was placed in the super-structure. The work was completed in 1936. The end of the jetty would unravel 300 ft or more, so a solid concrete terminal was constructed above low water level. The terminal is located 3900 ft shoreward of the original jetty end that was completed in 1913.

1933-1934. Repair of South Jetty from Station 257+68.7 to Station 305+05 (knuckle to middle of outer segment). Two-level cross section with crest elevations of 17 and 26 MLLW. Crest width of each level is 24 ft. Side slopes are 1V:1.5H on channel side and vary from 1V:1H to 1V:1.75H to 1V:2H on ocean side.

1935-1936. Repair of South Jetty from Station 305+05 to Station 353+05 (middle of outer segment to existing end). Similar design to 1933 repair.

1936. Stone/asphalt cone-shaped terminal constructed on South Jetty from Station 340+30 to Station 344+30. Crest width of approximately 50 ft and elevation varied between 23 and 26 ft MLLW. Side slopes are 1V:2H.

1937-1939. Repair of North Jetty from Station 68+35 to 110+35. Crest elevation is 26ft MLLW and crest width is 30ft. Side slope is 1V:1.25H on ocean side and 1V:1.5H on channel side.

1939. Original construction of Jetty A from Station 40+94 to 96+83. Crest width is 10 ft from beginning to Station 53+00, 30 ft in width and elevation of 20 ft MLLW from this point on. Four pile dikes completed at Sand Island.

1940. Repair of South Jetty with replacement rock in locations as needed.

1940-1942. South Jetty repair from Station 332+00 to 343+30. Addition of concrete terminal and stone foundation. Crest elevation between 8 and 20 ft MLLW and crest width between 50 ft and 75 ft, 10 in. Side slopes determined by concrete terminal shape.

1945-1947. Repair Jetty A from Station 78+00 to Station 96+00. Crest elevation built to 20 ft MLLW with a crest width of 40 ft.

1948-1949. Repair 300 ft of Jetty A from Station 92+35 to 95+35 with a crest elevation of 20 ft MLLW, a crest width of 30 ft, and side slopes of 1V:1.25H.

1951. Repair of Jetty A from Station 91+50 to Station 93+00 with a crest elevation of 20 ft MLLW, a crest width of 30 ft, and side slopes of 1V:1.5H.

1952. Repair of Jetty A from Station 90+00 to 94+00 with a crest elevation of 20 ft MLLW, a crest width of 30 ft, and side slopes of 1V:1.5H.

1958. Repair of Jetty A from Station 41+00 to Station 79+00. Crest elevation raised to 20 ft MLLW and a crest width of 20 ft from Station 41+00 to 56+00. Crest width is 30 ft from Station 61+00 to Station 79+00.

1961-1962. Repair of Jetty A from Station 50+00 to 90+50, with no repairs from Station 68+00 to Station 76+50. Crest elevation was built with a 10% grade from 20 ft MLLW to 24 ft MLLW between Station 50+00 to Station 68+00. The crest elevation was raised to 24 ft MLLW between Stations 76+50 to 90+50.

1961. South Jetty repair from Station 194+00 to Station 249+00 (before knuckle, current stationing). Crest elevation varies from 24 ft MLLW to 28 ft MLLW, and crest width is 30 ft. Channel side slope is 1V:1.25H and ocean side slope is 1V:1.5H. Repairs occurred from Station 38+00 to 93+00 (old stationing). Elevation at 38+00 is +24 ft MLLW, and then is increased with a 0.5% grade up to +28 ft MLLW for the remainder of the repair section. The centerline of the repairs is located 13 ft north of the centerline of the original jetty design. The design crest width is 30 ft. The north slope is 1:1.25 and the south slope is 1:1.5.

1962-1965. Repair of South Jetty from Station 249+00 to Station 314+05 (beyond knuckle). Crest elevation begins at 28 ft MLLW and transitions to 25 ft MLLW for most of section. Side slopes vary from 1V:1.5H to 1V:2H and crest width is 40 ft (this appears to be the furthest seaward intact portion of current jetty). Repairs were from Station 93+00 to 157+50 (old stationing). The crest elevation is +28 ft MLLW at Station 93+00, then decreases to +25 ft MLLW at Station 95+00, then continues with this elevation to the end of the repairs. The crest width is 40 ft and has a slope of 1:1.5 from Station 93+00 to 152+00. The slope then transitions to 1:2 from Station 152+00 to 154+00. The centerline of the repair is 15 ft south of the trestle centerline.

1965. Repair of North Jetty from Station 89+47 to Station 109+67 with a crest elevation of 24 ft MLLW and crest width is 30 ft. Side slopes vary from 1V:1.5H to 1V:2H.

1982. Repair of South Jetty from Station 194+00 to Station 249+00 (segment before knuckle). Crest elevation varies from 22ft MLLW to 25ft MLLW. Crest width varies from 25 to 30 ft, and side slopes are 1V:1.5H. The crest elevation varies from +22 ft at Station 38+00 to +25 ft at Station 80+35 (old stationing). From Station 44+50 to 80+35, the crest width is 30 ft, and the slope is 1:1.5. The centerline of the repairs has a 10 ft maximum variance to the north for the South Jetty control line. Between Stations 80+35 and 93+00, the centerline of the repairs is the same as the South Jetty control. The crest elevation is +25 ft, the width varies between 25 and 30 ft, and the slope is 1:1.5.

2005. Interim repair of North Jetty from Station 55+00 to 86+00. Crest elevation used was +25 ft MLLW with a sideslope of 1V:1.5H.

2006. Interim repair of South Jetty from Station 223+00 to 245+00. Crest elevation used was +25 ft MLLW with a sideslope of 1V:2H.

2007. Interim repair of South Jetty from Station 255+00 to 285+00. Crest elevation used was +25 ft MLLW with a sideslope of 1V:2H.

c. Overall Jetty System Function

The function of the MCR jetties has evolved since initial construction. Improvement of the MCR navigation entrance was conducted incrementally with subsequent stages being initiated as a physical need was recognized. The South Jetty was constructed first as a mid-tide jetty to a moderate length (1885-1895). Instability of the South Jetty and continued migration of the navigation channel led to recommendations to extend the South Jetty and raise it to a high tide jetty. During improvement of the South Jetty (1905-1913), it became apparent that a North Jetty would be needed to maintain a stable navigation channel.

These sequential improvements were conducted during 1885 to 1917. During the early 1930s (after both North and South jetties had been in place and significant modification of the inlet's morphology had occurred), the North Jetty became threatened by high velocity ebb tide flow which threatened to undermine the structure's channel side foundation. Concurrently, the south side of Sand Island was being eroded by increased current action. Loss of either the North Jetty or Sand Island would have rendered the inlet unsuitable for navigation. The adverse circulation affecting the North Jetty and Sand Island was motivated by the northward migration of the estuary thalweg toward Cape Disappointment. In the late 1930s, the Sand Island Pile Dikes and Jetty A were constructed by USACE to stabilize the evolving inlet. The pile dikes stabilized Sand Island, preventing detrimental effects on Baker Bay and inlet navigation. Jetty A prevented the northward migration of the inlet's thalweg while deflecting ebb away from the North Jetty and flood current away from Sand Island. Collectively, all three jetties and the Sand Island pile dikes now function in concert to balance the large scale ocean processes affecting the entrance. Through the evolution of the inlet and its morphology, Jetty A now also serves as a breakwater to protect Sand Island and the Ilwaco entrance into Baker Bay from large ocean waves.

Since the original jetty construction, several large physical process changes have altered the current and projected future reliability of the system. These large process changes gradually impact the stability of the structures and the reliability of the system. It has been shown that as increased depths are secured in the improved navigation channel, larger waves are able to enter the channel and attack the jetties in addition to undermining the sandy foundation upon which they rest. These increased depths primarily affect the channelside of the jetties, and in particular, the North Jetty which is closer to the navigation channel. Along the landward half of the North Jetty, another de-stabilizing flow path has developed through the structure as tidal flow moves through the structure to the eroded lagoon behind the structure.

In addition another apparent large process change has been a gradual increase in the wave climate both in terms of storm wave height as well as number of large storms occurring in a given year. Concurrent with the increase in storm climate and the larger interior waves and currents, foundation erosion has accelerated both seaward and adjacent to the jetties. During 1993 to 2000, the 40 ft contour on the ebb tidal shoal receded landward at a rate 7 times faster than during 1930 to 1993, as shown in Figure A1- 32. As the ebb tidal shoal recedes, the wave and current regime at the entrance and jetties changes.

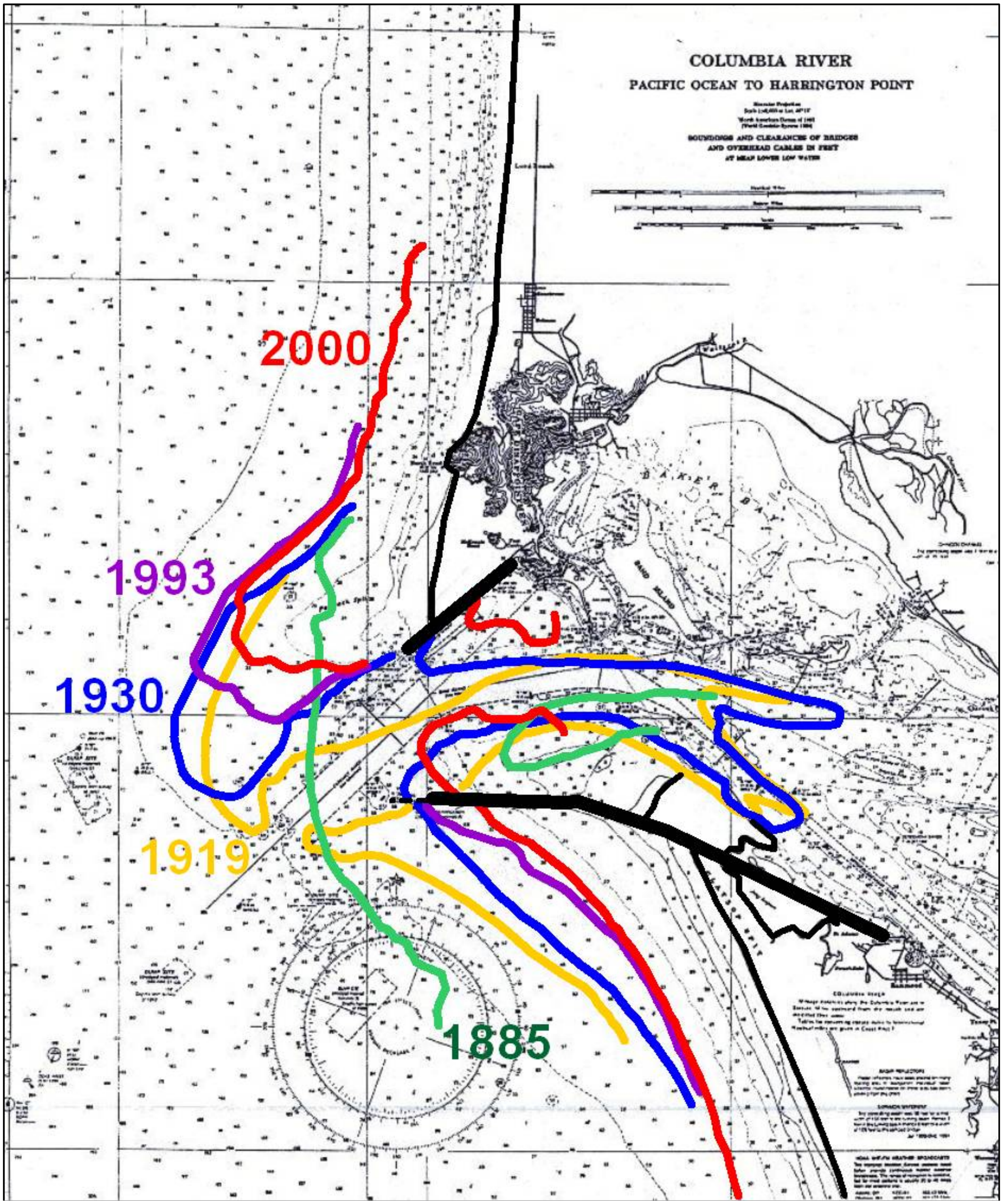


Figure A1- 32. Map of -40 ft contours around MCR Over Time – 1885 to 2000

The principal function of the MCR jetties is to secure a consistent navigation channel across the bar at MCR. If the reliability of the MCR channel is jeopardized due to jetty deterioration, then the jetty is considered to have "failed" and timely repair is merited. It is important to note that if a jetty deteriorates without significantly reducing the reliability of the MCR navigation channel, then the jetty is not considered to have "failed" and there is no need to expedite repair. However, cumulative and systemic jetty deterioration can result in a project failure.

d. MCR Dredging and Environmental Forcing

Successive Congressional authorizations have tasked the Corps of Engineers with deepening and maintaining the channel at the MCR; from a depth of -30 ft MLLW (1885) to -55 ft MLLW (1984). Since 1904, hopper dredges have dredged over 200 million cy at MCR. The dredged sand has been placed in ocean dredged material disposal sites (ODMDS, see Figure A1- 12). The present maintenance dredging requirement at the MCR is about 4 million cy/yr. While some of the dredged sand has been placed on or near the tidal shoals, a considerable volume of dredged sand is placed away from the tidal shoals. The disposal of dredged sand has historically been viewed as a wasting operation. Targeted use of the dredged sand to augment the tidal shoals has not been a focus of the MCR dredging program. The cost of dredging the MCR channel (and disposing of sand at the ODMDS) varies from $3.00 to $4.00 a cubic yard. The incremental cost of placing dredged sand on the MCR tidal shoals to prevent foundation erosion of the jetties is estimated to be $ 0.30/cy.

The orientation of the shoals/spits at MCR has changed due to waves and currents; the morphology and coastal processes at MCR are linked. Eddies that form within MCR arise due to the interaction of flow with the jetties and the morphology and greatly influence flow and shoaling within the channel. The littoral dynamics north and south of MCR are drastically different than at "open coast" areas away from the entrance. Depending on the regional wind field, the "coastal current" up-drift and down-drift from MCR can attain speeds of 3 ft/s. As the tidal shoals continue to recede (erode), the jetties will be exposed to larger waves and more vigorous currents. To make matters worse, the regional wave climate along the Northwest Pacific coast has become more severe in the last 10 years due to El Nińo, La Nińa, and decadal oscillation. The offshore design wave height (p-val = 0.01) has been revised from 40 ft to 47 ft [Moritz 2001]. Taken together, these changes will accelerate MCR jetty deterioration.

Approximately 60% of the sand annually dredged from the MCR entrance is placed in approved nearshore or other beneficial use disposal sites. The remaining 40% of sand dredged at MCR is placed offshore beyond the littoral zone. The preference for placing dredged material at nearshore areas (within the littoral zone) is motivated by the need to maintain the littoral budget north and south of the inlet; for the purpose of sustaining the inlet's morphology. The above approach is executed within a least cost consideration. Feeding the inlet's morphology is crucial for several reasons. First, it must be noted that the morphology at an inlet is the source of sediment for adjacent shorelines. Without stable morphology (shoals and sand bars) at a tidal inlet, the adjacent shorelines will erode.

The Shallow Water Site (SWS), located off the seaward end of the North Jetty, is an U.S. Environmental Protection Agency (USEPA) designated ocean disposal site that is highly erosive. Most of the dredged material placed at the SWS is transported northward onto Peacock Spit by waves and currents. Detailed evaluation has shown that the sediment transported from the SWS onto Peacock Spit continues to be further dispersed northward toward Long Beach Peninsula. Use of the SWS ameliorates, to some extent, the erosion of Peacock Spit that has been occurring, which is believed to be a result of gradual jetty head recession. The SWS has received large quantities of disposed dredged material in recent years, as much as 3.7 million cubic yards in one year. Currently, sand placed in the eastern part of the disposal site exhibits no long-term deposition and is readily dispersed to the north, while sand placed in the western part of the disposal site disperses to the west. Dispersion in the western part of the SWS occurs to a lesser degree than the eastern part. In the western half, sand has accumulated 1-3 ft on the seafloor since 1997. Since 1997, 80% of MCR dredged sand has been placed in the SWS or NJ Site. The NJ Site is a moderately dispersive disposal site located on the river side of the North Jetty and was established to aid in stabilization of the sand shoals upon which the jetty was constructed.

At the MCR inlet, the morphology (Peacock and Clatsop spits) serves as the foundation for the jetties, and protects the jetties from severe currents and wave action. The present morphological condition is characterized by deflation: each year, the morphology is losing more sediment than it is gaining. The rate at which sediment is eroding from the MCR spits far exceeds the volume of sediment dredged each year. There are initiatives currently underway to increase the amount of MCR dredged material beneficial use to 100%. The limiting factor for placing all MCR dredged material within the littoral zone is having approved sites available to place the sand. At present, there are approved disposal sites available only for the north side of the inlet. No site currently exists on the south side of the MCR entrance.

Even if all MCR dredged material could be placed in such manner as to optimally feed the present morphology, there is not enough dredged material to stop the morphological deflation at MCR. This condition should not render nearshore placement of MCR dredged material a pointless endeavor; it is imperative that the maximum amount possible be used to help sustain the inlet’s morphology. For without this effort, the inlet will degrade at a higher rate affecting infrastructure, shoreland, and other resources at a non-sustainable pace [Kaminsky et al 2010 and Moritz et al 2003]. With this perspective in mind, it must be acknowledged that dredged material cannot be used in-lieu of stone placement for maintaining the jetties at the MCR. The 100 year old jetties have sustained significant damage over time. Physical work on the structures themselves is needed to improve their resiliency and reduce the risk of navigation disruption due to a loss in jetty function.

e. Regional Littoral Budget at MCR - Future Jetty Implications

Figure A1- 32 illustrates the time varying nature (erosion) of the tidal shoals offshore of MCR, by showing the evolution of the 40 ft (12.2 m) depth contour. The landward recession of the 40-ft depth contour highlights the susceptibility of the MCR jetties to changes in the offshore extent of ebb tidal shoals. The pre-jetty (1885) configuration of the 40-ft contour displays a fairly symmetrical shape about the inlet indicating that littoral transport of sand on the ebb tidal shoals of the MCR was relatively balanced to the north and south. By 1919, the 40 ft contour had been displaced more than 2,000 m seaward in response to phased jetty construction and the morphology had been thrown out of equilibrium due to increased tidal flow velocity in and around the MCR. On the south side of the MCR, there was no seaward displacement of the 40 ft contour. Rather, the 40-ft contour south of the MCR had been receding landward since jetty construction in 1885. Note the northern vs. southern offset (asymmetry) in the 40 ft contour for 1919 and thereafter. By 1930, waves and currents were acting on the displaced morphology to bring the system to equilibrium. The displaced tidal shoals on the north side of the MCR were being eroded and the 40 ft contour was receding landward.

The offshore extent of the 40 ft contour on the south side of the MCR has been receding landward of its 1885 position, toward the South Jetty, since jetty construction. Within the inlet, along the northern extent of the MCR, the 40-ft depth contour has been moving landward and northward, toward the North Jetty. The jetties have been undermined, ever since initial construction (1885-1917). The process of tidal shoal erosion has continued to the present (the 2000 configuration of the 40 ft contour). Note that from 1993 to 2000, the landward recession of the 40 ft depth contour was at a rate 7 times faster than during 1930 to 1993. On the north side of the inlet, it has been estimated that 2-5 mcy per year of sand is presently being eroded from Peacock Spit [Gelfenbaum et al., 2002]. Shoal material eroded from the offshore extent of the Peacock Spit is believed to be transported by ebb tidal flow northward. Some of the shoal material eroded from the inshore part of Peacock Spit is believed to be transported by flood tidal flow southward to the MCR. Most of the shoal material eroded from the offshore remnants of Clasp Spit, south of the MCR, is believed to be transported toward the south by tidal- and wave-induced circulation.

The MCR rubblemound jetties were built on flood/ebb tidal shoals, which had protected the jetties from excessive waves and currents. To a large degree, the stability of the MCR channel is related to both the jetties and the morphology of Peacock Spit and Clatsop Spit. North, South, and Jetty A foundation changes (Figure A1- 33 through Figure A1- 35) show the MCR jetties have been gradually undermined along a portion of their length since construction. As the ebb tidal shoals offshore of the MCR change shape, the nearshore wave and current regime will change; adding to the shoreline re-adjustment (recession). If these shoals continue to recede landward at the present rate, the stability of the MCR jetties and the navigation channel will be jeopardized due to the likelihood of a jetty breach (failure). The water depth along the jetty gets deeper due to scour and the jetty fails due to increased wave action and foundation scour [USACE 1881-1948].

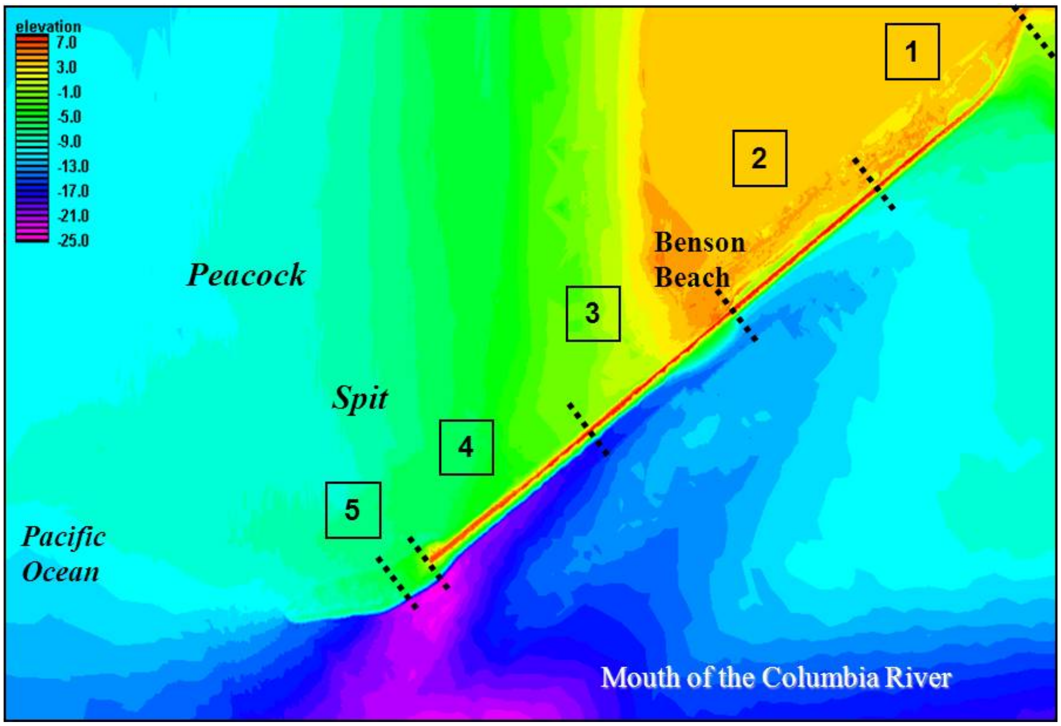


Figure A1- 33. North Jetty Bathymetry and Design Reaches

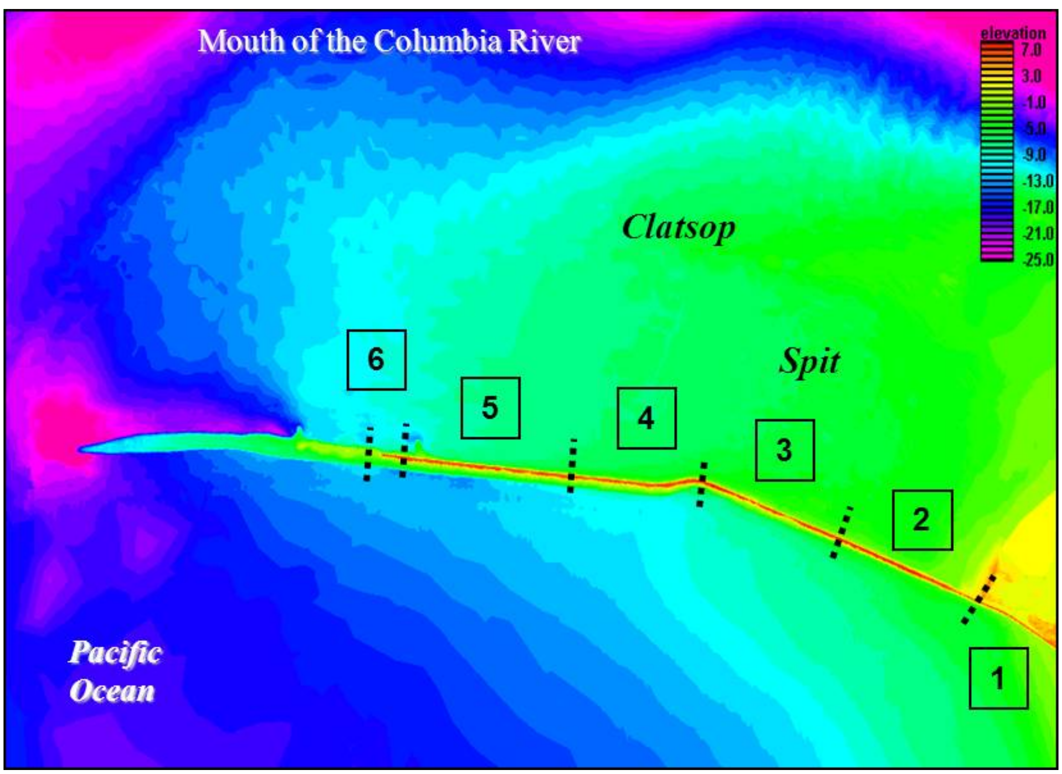


Figure A1- 34. South Jetty Bathymetry and Design Reaches

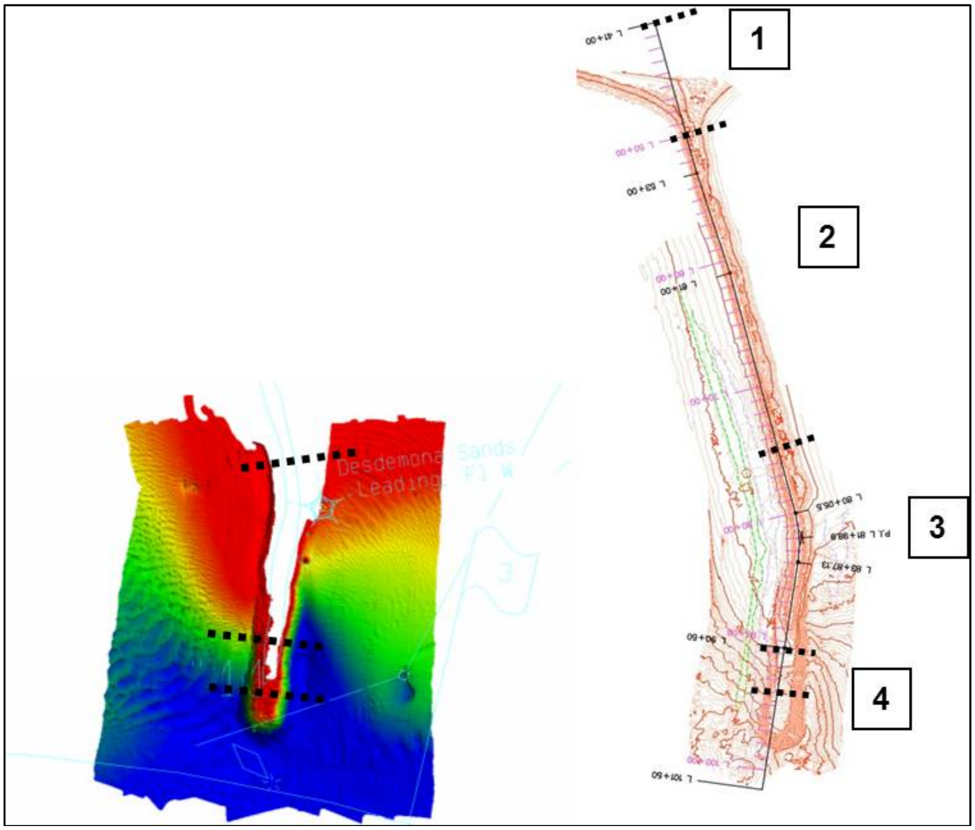


Figure A1- 35. Jetty A Bathymetry and Design Reaches

The large scale morphological changes which have occurred along the northwest Oregon and southwest Washington coast have been investigated by numerous researchers working individually and collaborating under several interagency studies. The results of these investigations lead to several conclusions. The morphological changes affecting shoreland areas are motivated primarily by the natural processes of the inlets adjacent to the shorelands experiencing change. The occurrence of a strong El Nino/La Nina event during 1997-2001 contributed to the regional changes in shoreland response observed during this period. The rapid accretion of Peacock Spit and Benson Beach soon after North Jetty construction was motivated by the processes at the MCR inlet being modified by jetty construction. To understand what the future holds for the MCR inlet and adjacent shorelands, it should be understood that the inlet has undergone a two-stage process since the time of jetty construction. Stage one was initiated at the time of jetty construction (1885), when a huge volume of sediment was discharged oceanward as the inlet width was reduced from 5 miles wide to 2 miles. Stage one was defined by a time of rapid morphological growth along the ocean margins of the inlet resulting in high rates of shoreland accretion. Figure A1- 36 through Figure A1- 40 illustrate sediment movement trends over time and the general project/inlet responses in the vicinity of the MCR inlet.

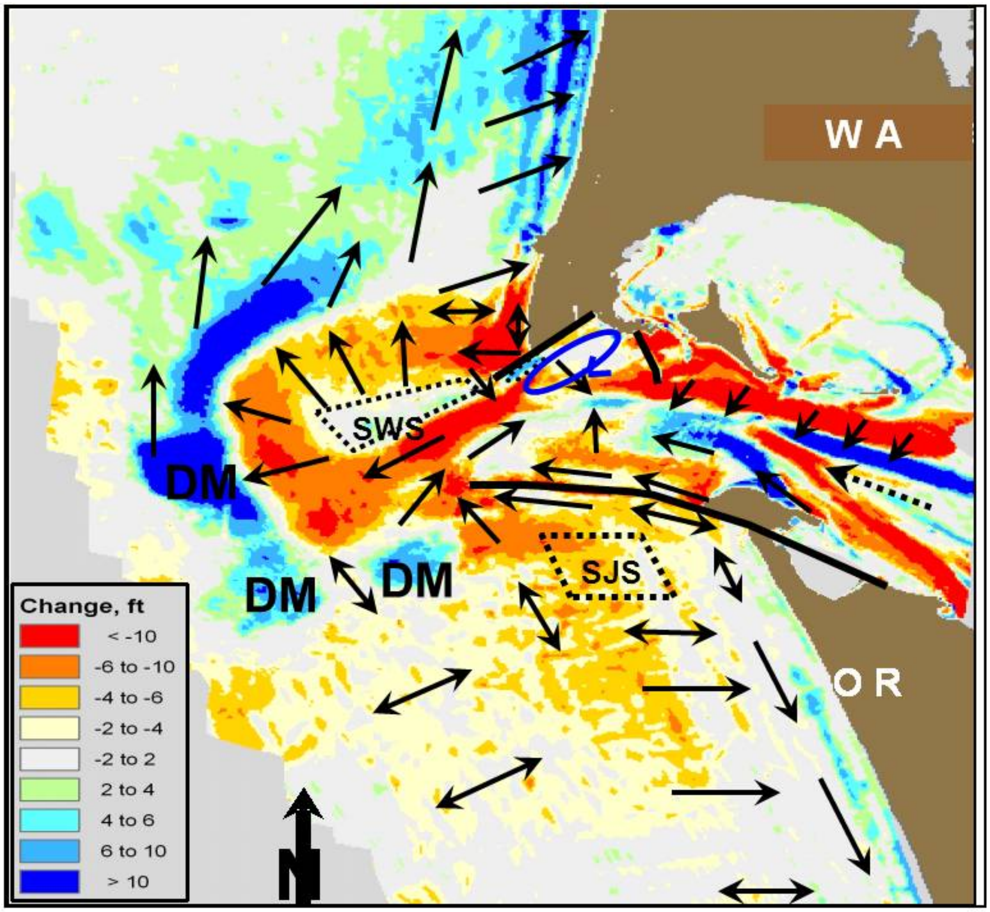


Figure A1- 36. Detailed Pathways for MCR Sediment Budget

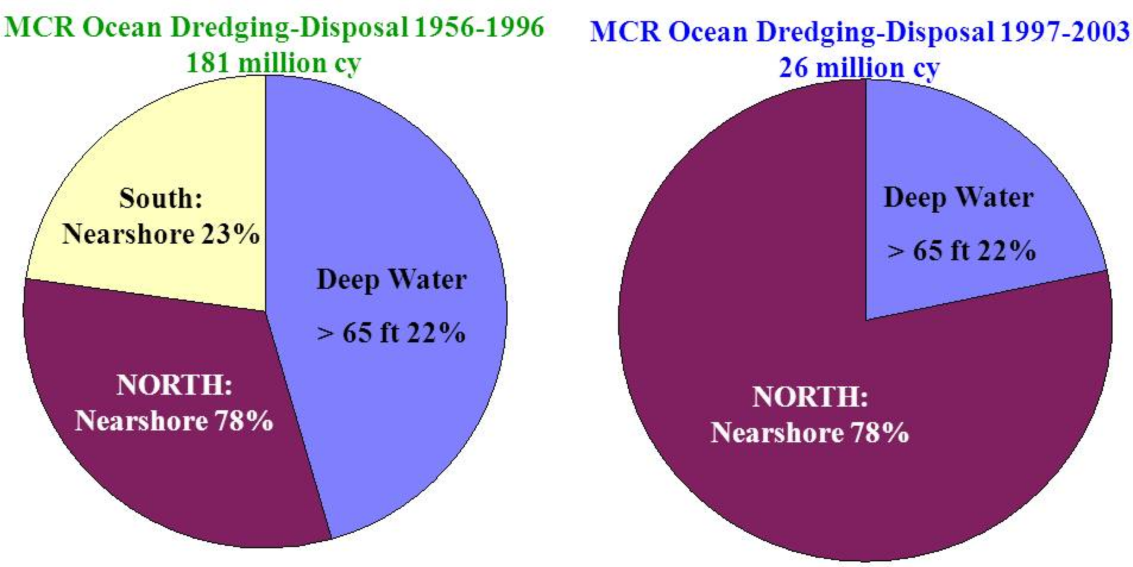


Figure A1- 37. Historical Disposition of Dredged Material at MCR

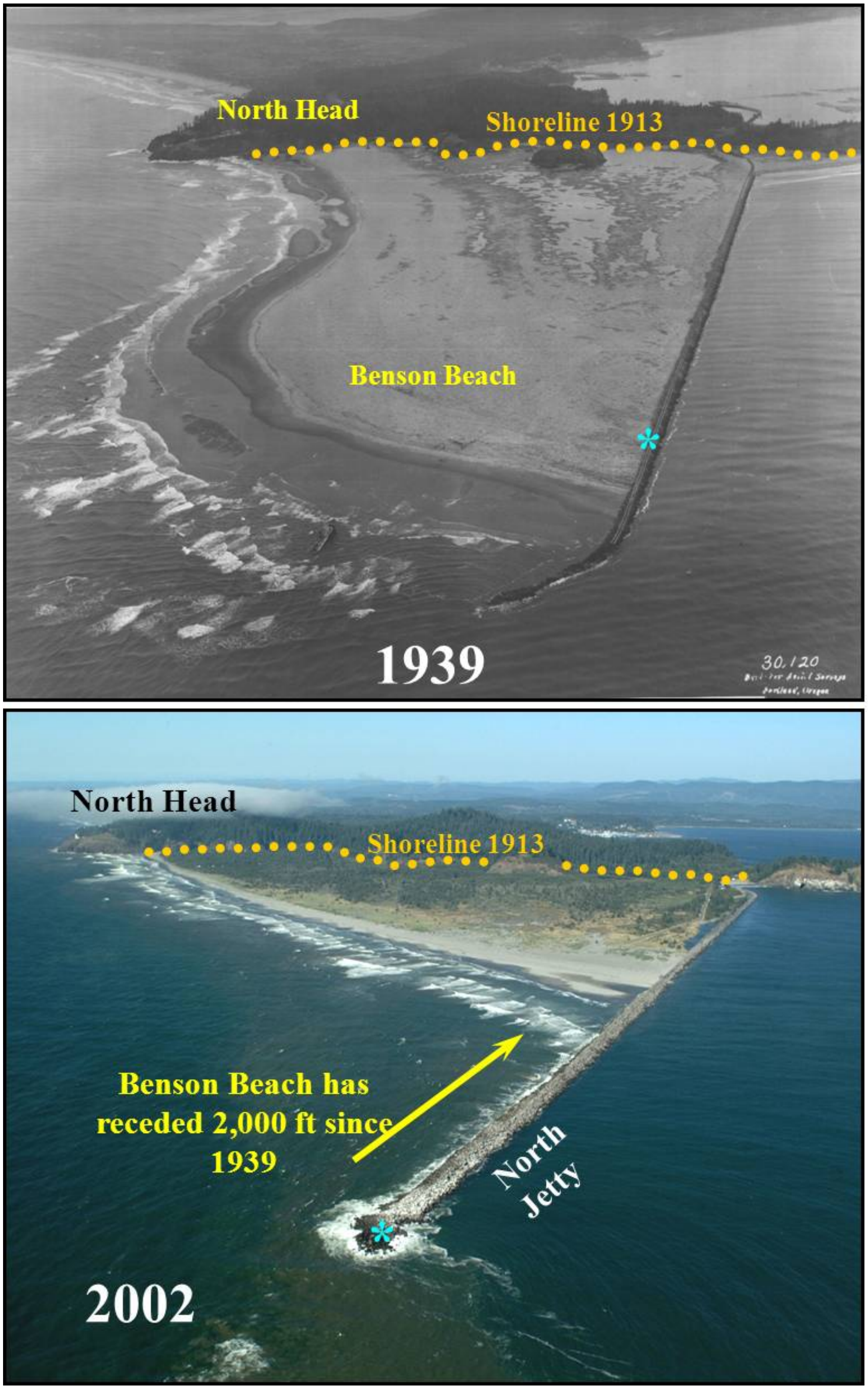


Figure A1- 38. Shoreline Response north of North Jetty

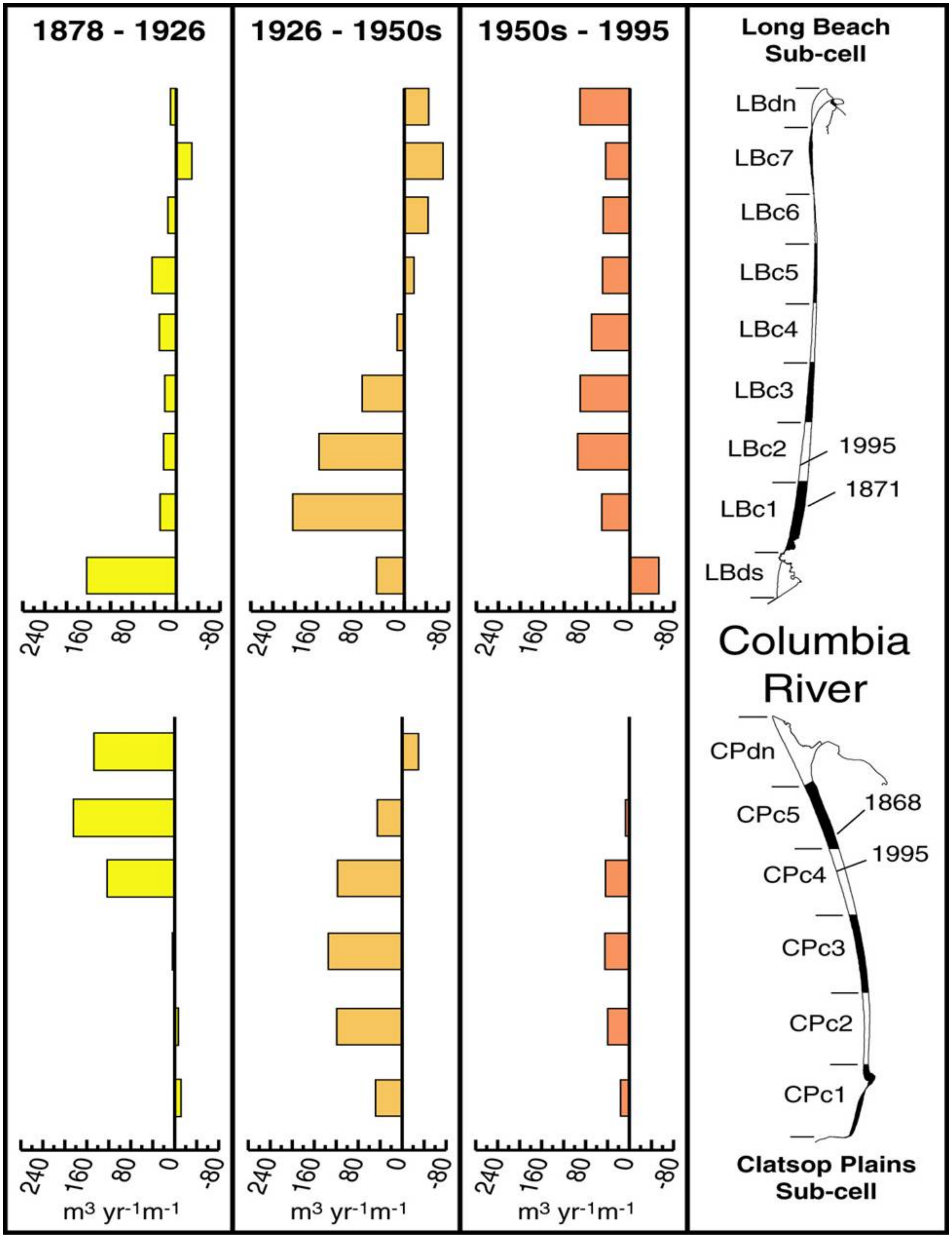


Figure A1- 39. Sediment Movement North and South of MCR – 1878 to 1995

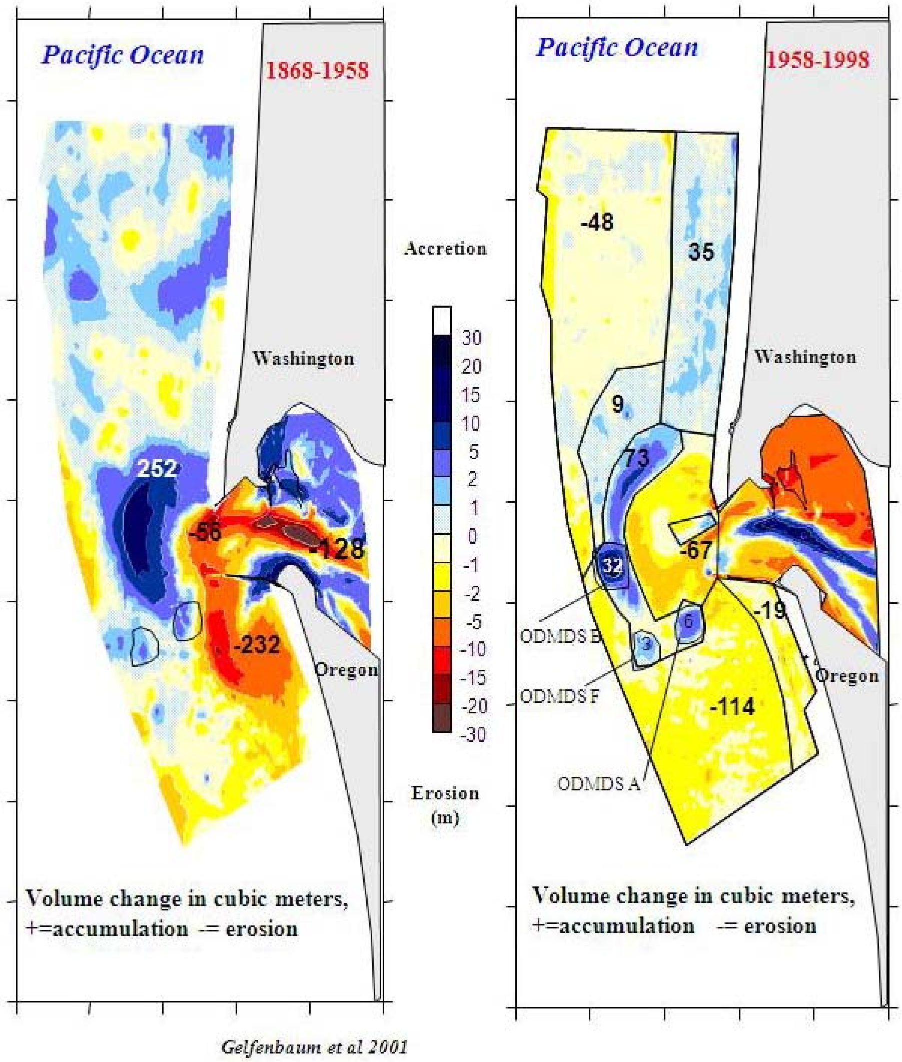


Figure A1- 40. Sediment budget deficits and surpluses around MCR over time

Stage two began shortly after the phased completion of the MCR jetties (1917) when the process of inlet en mass sediment discharge was completed (~1940). Stage two is defined as a time when the accretionary morphology, formed in Stage 1, no longer had the surplus sediment supply to continue the process of "rapid accretion." The morphology began to be re-aligned to accommodate equilibrium within the inlet's wave and current environment. In many cases, this morphological response is manifest in terms of recession; for shoals and shorelines. The Stage 2 processes continue to evolve and will persist into the future. Rehabilitation of the MCR jetties will have no calculable effect on near shore or shoreland areas beyond 1-2 miles north or south of the MCR inlet.

5. Construction and Repair History

a. South Jetty Construction

In 1884, Congress authorized the U.S. Army Corps of Engineers to construct a 4.5 mile (7.3 km) long South Jetty for the purpose of attaining a 30-ft (9-meter) deep channel across the MCR bar. The South Jetty was to extend northwesterly from Fort Stevens (on Port Adams) in a slightly convex manner along Clatsop Spit to a point about 3 miles south of Cape Disappointment. A jetty with crest elevation at mid-tide was originally considered due to the assumption that it would control currents as well as a high-tide jetty, but would cost less, and that it would contain sand better than a low-tide jetty. Table A1- 1 and Figure A1- 41 summarize construction and repair efforts for the South Jetty over the project life. Figure A1- 42 shows the original cross section design for the South Jetty. Figure A1- 43 through Figure A1- 55 illustrate historical construction and condition photos for both the North and South jetties.

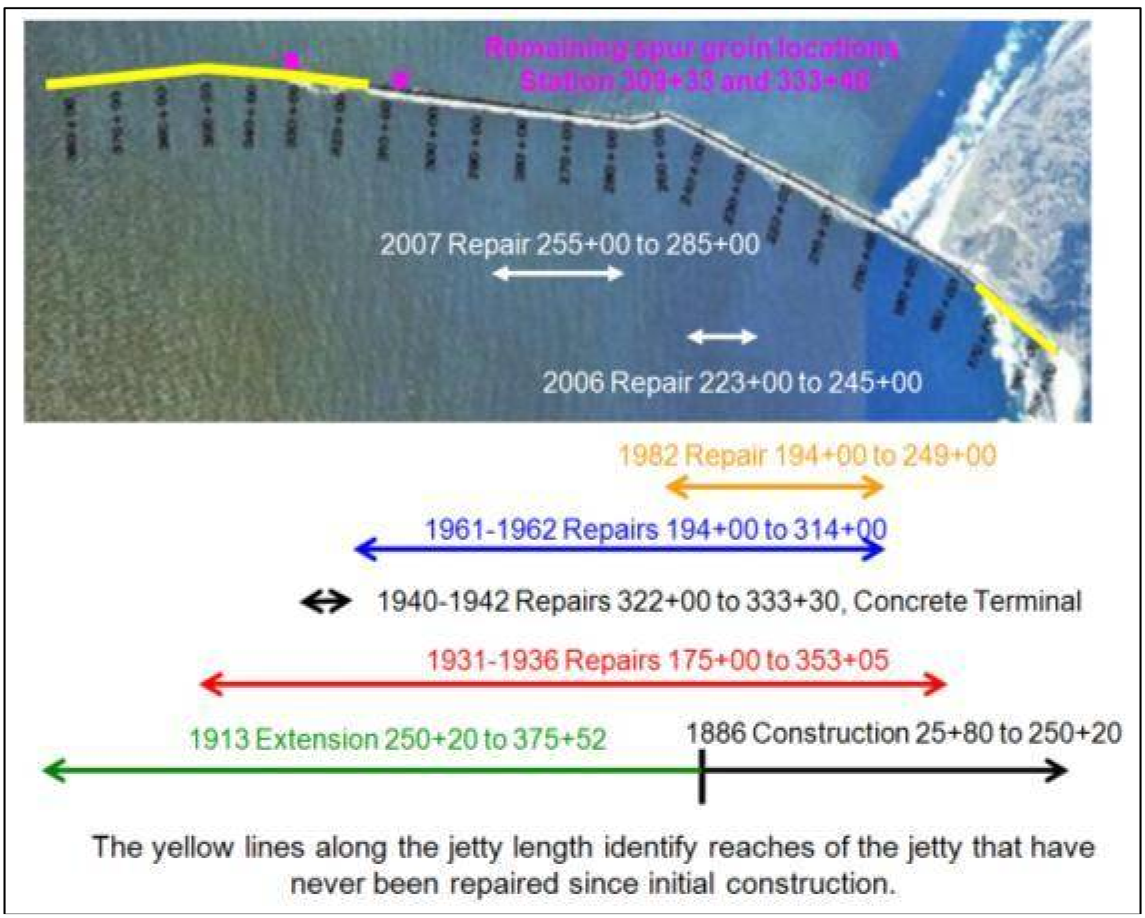


Figure A1- 41. MCR South Jetty Construction and Repair History

Table A1- 1. Construction and Maintenance Activities for the MCR South Jetty

Design Parameter	1886-1896 (original)	1903-1913 (extension)	1931-1932	1933-1934	1935-1936	1936(stone/ asph. term)	1940	1940-1941	1941-1942 (conc. term.)	1961	1962-1965
Stone Density (pcf)	~180 (varied)	~180/171.2	171.2	171.2	171.2	171.2	171.2	171.2	148	186/171.9	167.6
Side slope (V:H)											
North Side	natural slope	natural slope	1:1.5	1:1.5	1:1.5	1:2	-	w/in conc	-	1:1.25	1:1.5, 1:2
South Side	natural slope	natural slope	1:1.5	1:1,1:1.75,1:2	1:1.75,1:2	1:2	-	w/in conc	-	1:1.5	1:1.5, 1:2
Crest Elevation (ft	4 to 12	10 to 24	24	17 and 26	17 and 26	23 to 26	-	16	8 to 20	24 to 28	25 to 28
Crest Width (ft)	10	25	24	24	24	50	-	50 to 75'10"	50 to 75'10"	30	40
Armor Quantity	945,923	4,837,311	729,647	355,371	1,151,768	10635/12787	21,391	76,614	27,960	213,461	308,101
Select A											15
Class A	7 (max)		9	10	10		10	10	Comp Str:	10	10
Class B			1 to 6	1 to 6	1 to 6		1 to 6	2.5-3 (avg)	2200 psi min	5	4
Class C			<1	<1	<1			<1		<3	
Stone Source	Willamete Riv.	Bugby/Fisher	Fisher	Fisher	Fisher	Fisher	Fisher	Fisher	-	Youngs River Falls/Fisher	Fisher
Stone Type	Basalt	Basalt/ Andesitic	Andesitic Basalt	Andesitic Basalt	Andesitic Basalt	Andesitic Basalt	Andesitic Basalt	Andesitic Basalt	-	Basalt/ Andesitic	Andesitic Basalt
Beginning Station	25+80	250+20	175+00	257+68.7	305+05	340+30	where	339+60	332+00	194+00	249+00
Ending Station	250+20	375+52	257+68.7	305+05	353+05	344+30	needed	341+60	343+30	249+00	314+05

Additional Structures	Year Complete	Location	Length	Elevation
Groin 1	1893	228+00	500	DL to bottom
Groin 2	1893	156+00	600	DL to bottom
Groin 3	1895	88+00	1000	DL to bottom
Groin 4	1895	52+00	1000	DL to bottom
Shore Revetment	1896	25+80	3955	16.5 to 12
Groin 6	1913	309+33	~110 ?	8
Groin 7	1913	333+46	~90?	9

newer	38+00	93+00
stationing	93+00	158+05

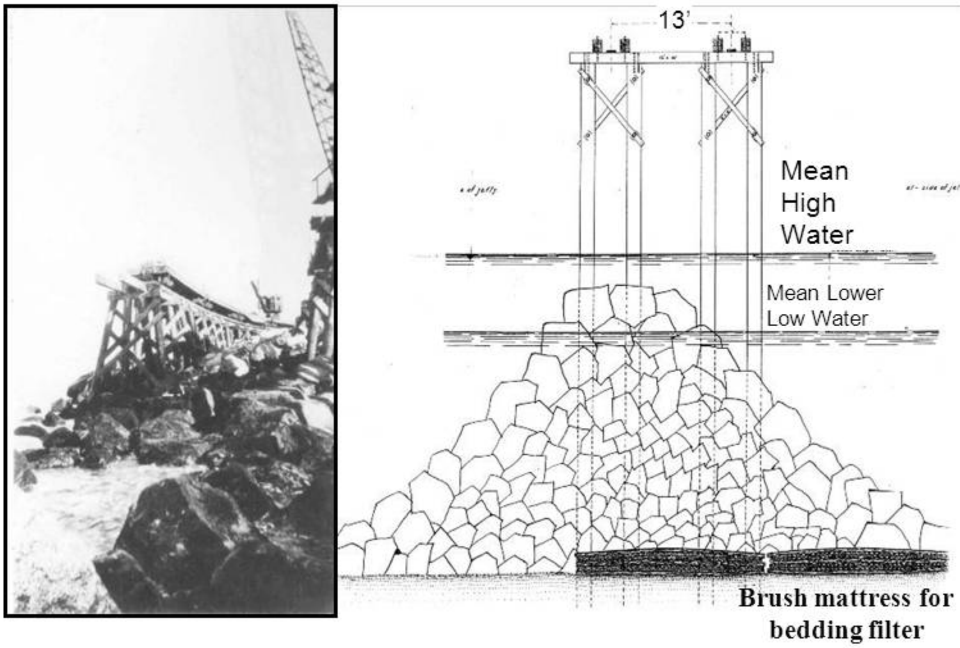


Figure A1- 42. Design section for original jetty construction

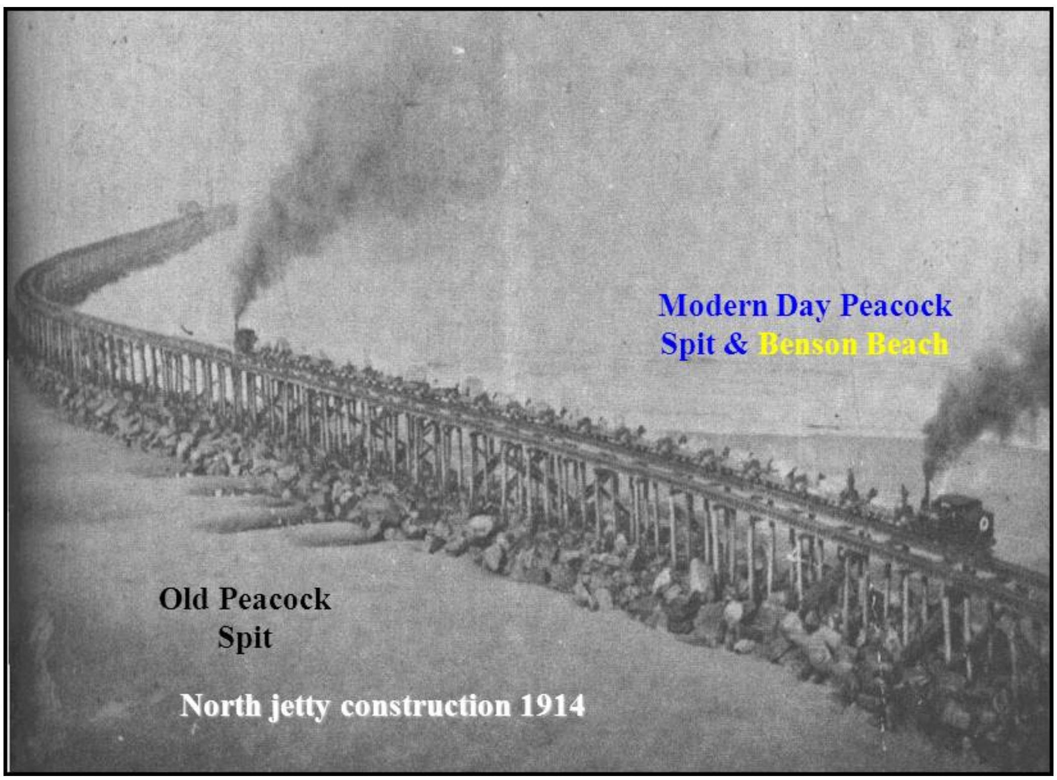


Figure A1- 43. Trestle-based original construction of MCR North Jetty

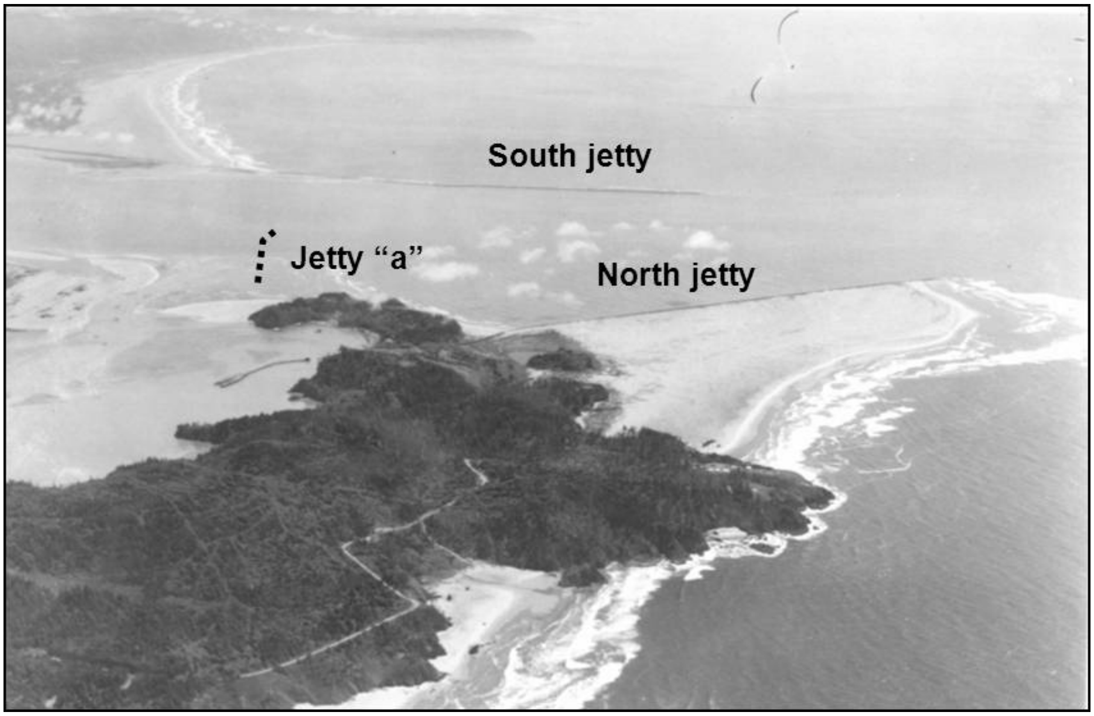


Figure A1- 44. Mouth of Columbia River 1928 view to south

Mouth of Columbia River, Oregon; south jetty; old enrockment 2½ miles west of Clatsop Spit; rock in place at least 21 years; July, 1934. 200′ wide on top.

Figure A1- 45. South Jetty Deterioration – 1930s

Mouth of Columbia River, Oregon; south jetty; finished section near the knuckle; Oct. 25, 1932. Single track.

Figure A1- 46. Finished construction of South Jetty repair – 1932

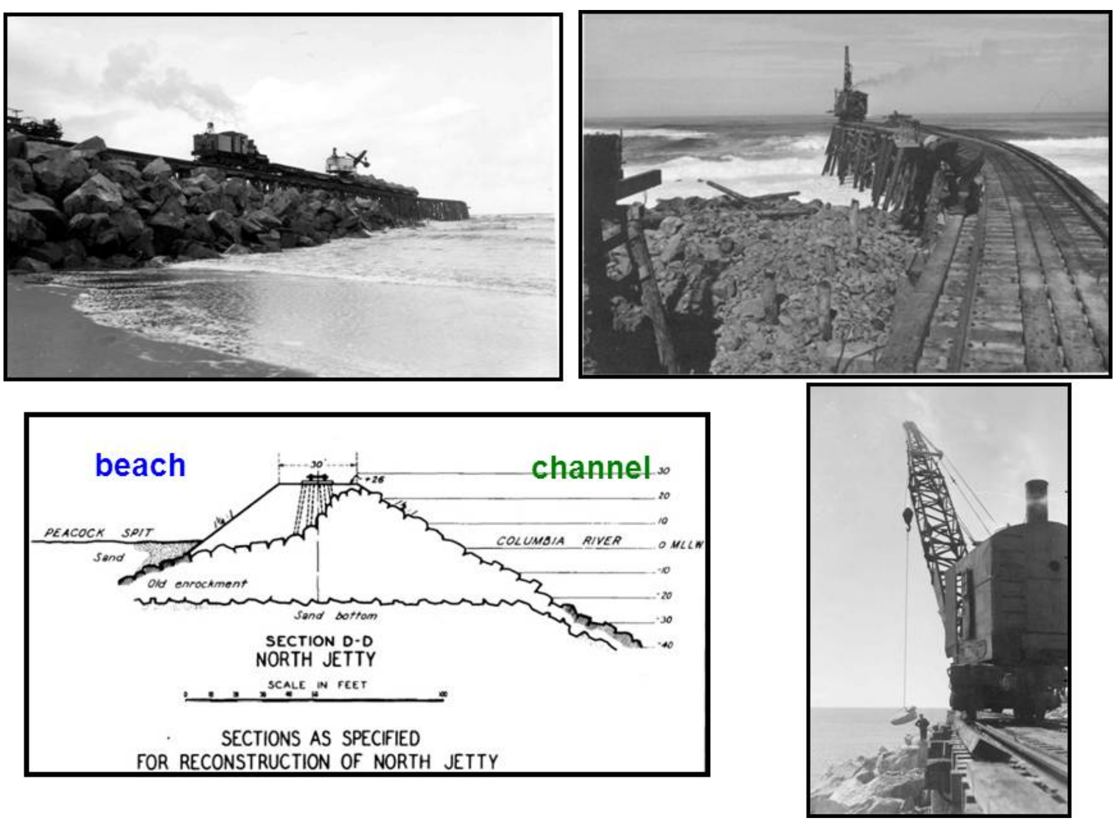
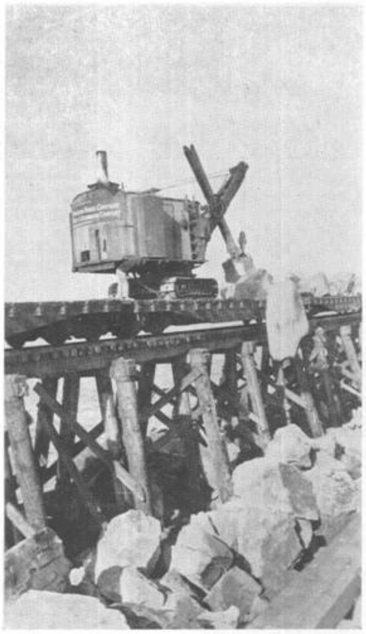
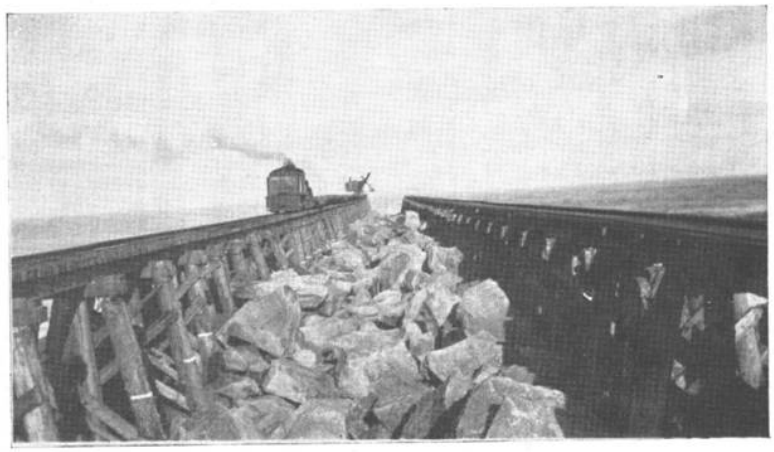


Figure A1- 47. North Jetty repair photos – 1930s



Mouth of Columbia River, Oregon; south jetty; ¾-yard shovel unloading small rock from flat cars; July, 1934.



Mouth of Columbia River, Oregon; retopping south jetty; tracks 45 feet between centers; July, 1934.

Figure A1- 48. South Jetty repair photos – 1930s

M.C. R. South jetty. Concrete terminal block.

Figure A1- 49. South Jetty concrete monolith construction photos – 1940s

Figure A1- 50. South Jetty repair photos – 1930s.

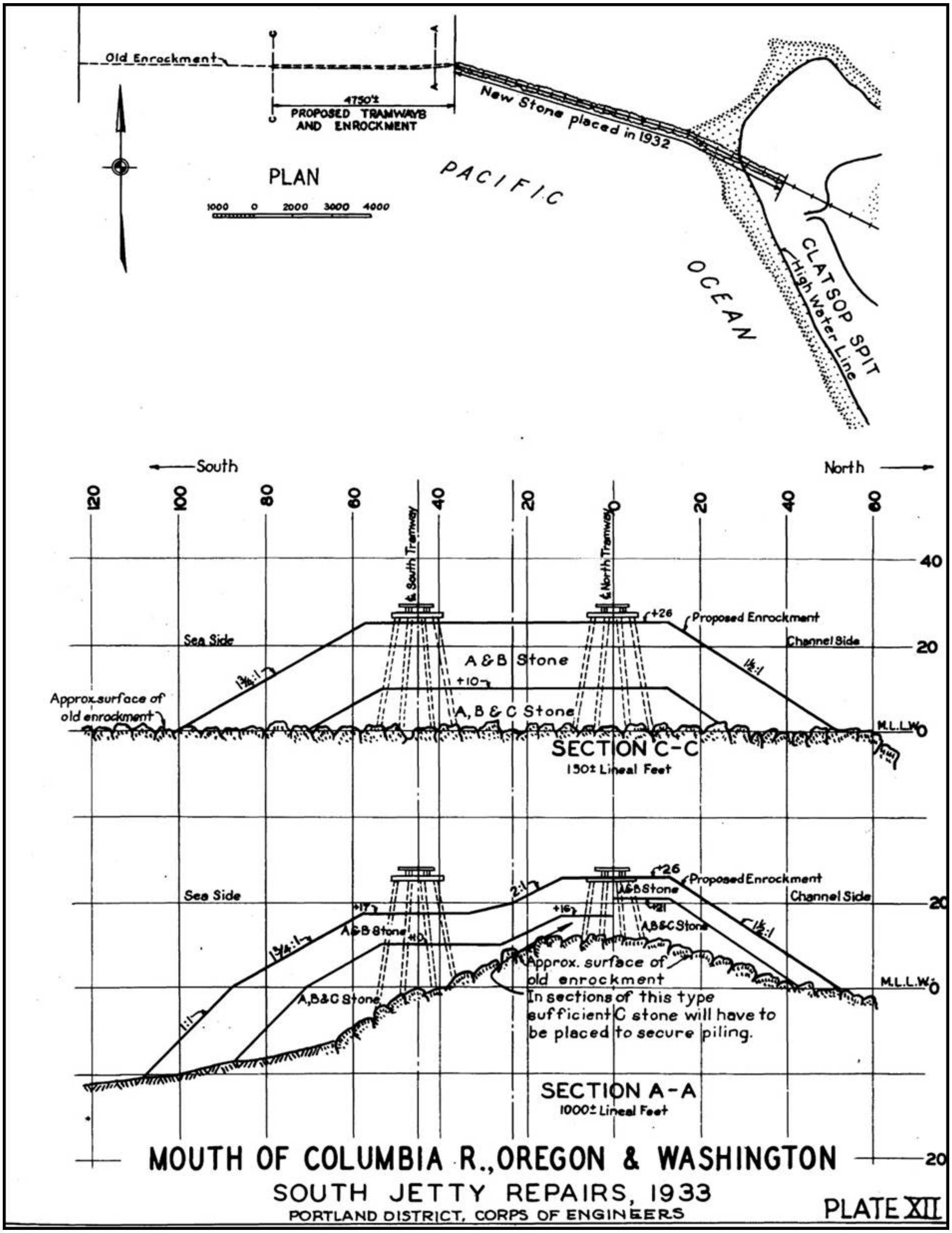


Figure A1- 51. South Jetty Repairs - 1933

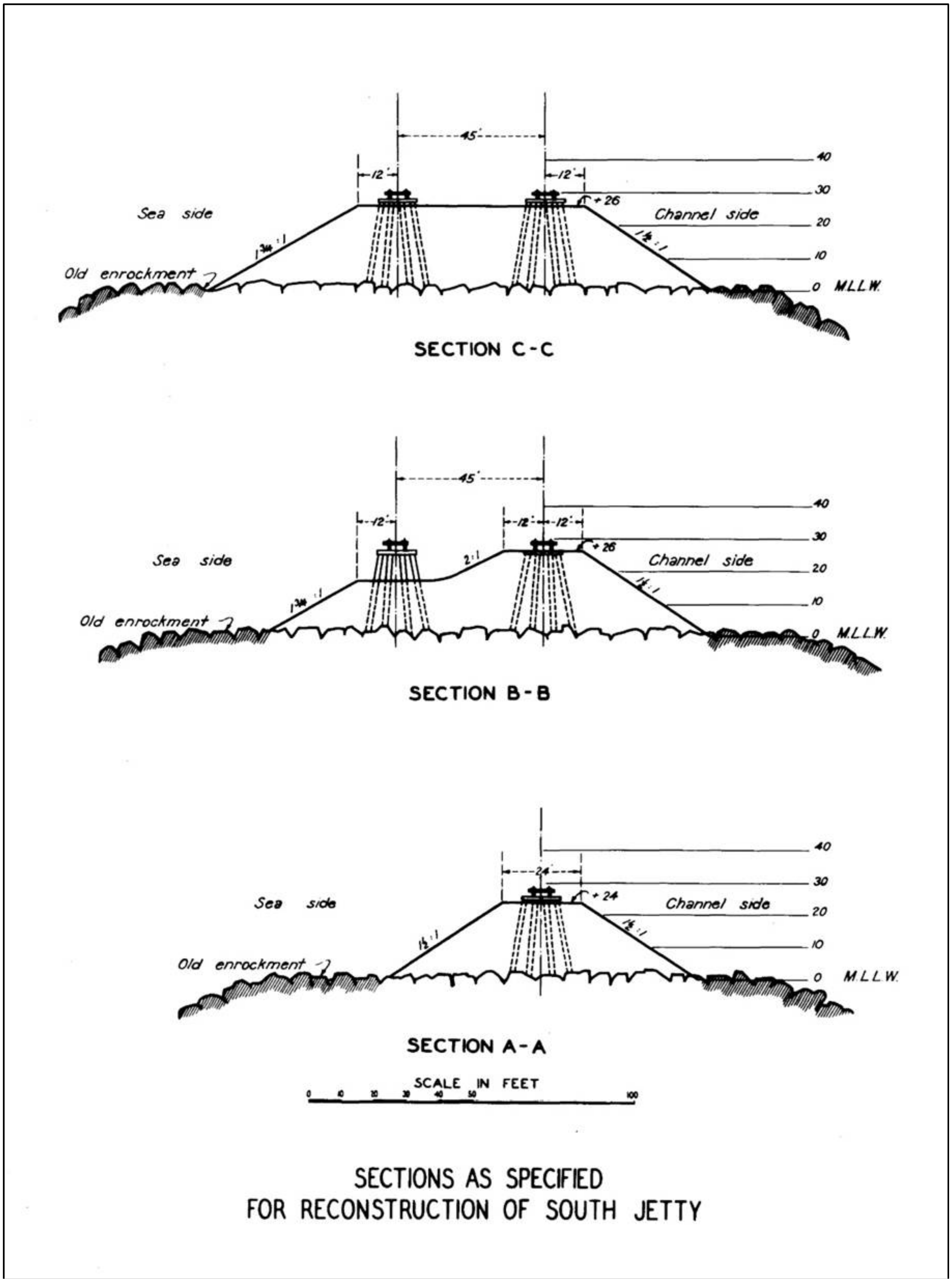


Figure A1- 52. South Jetty Repair Cross Sections – 1930s

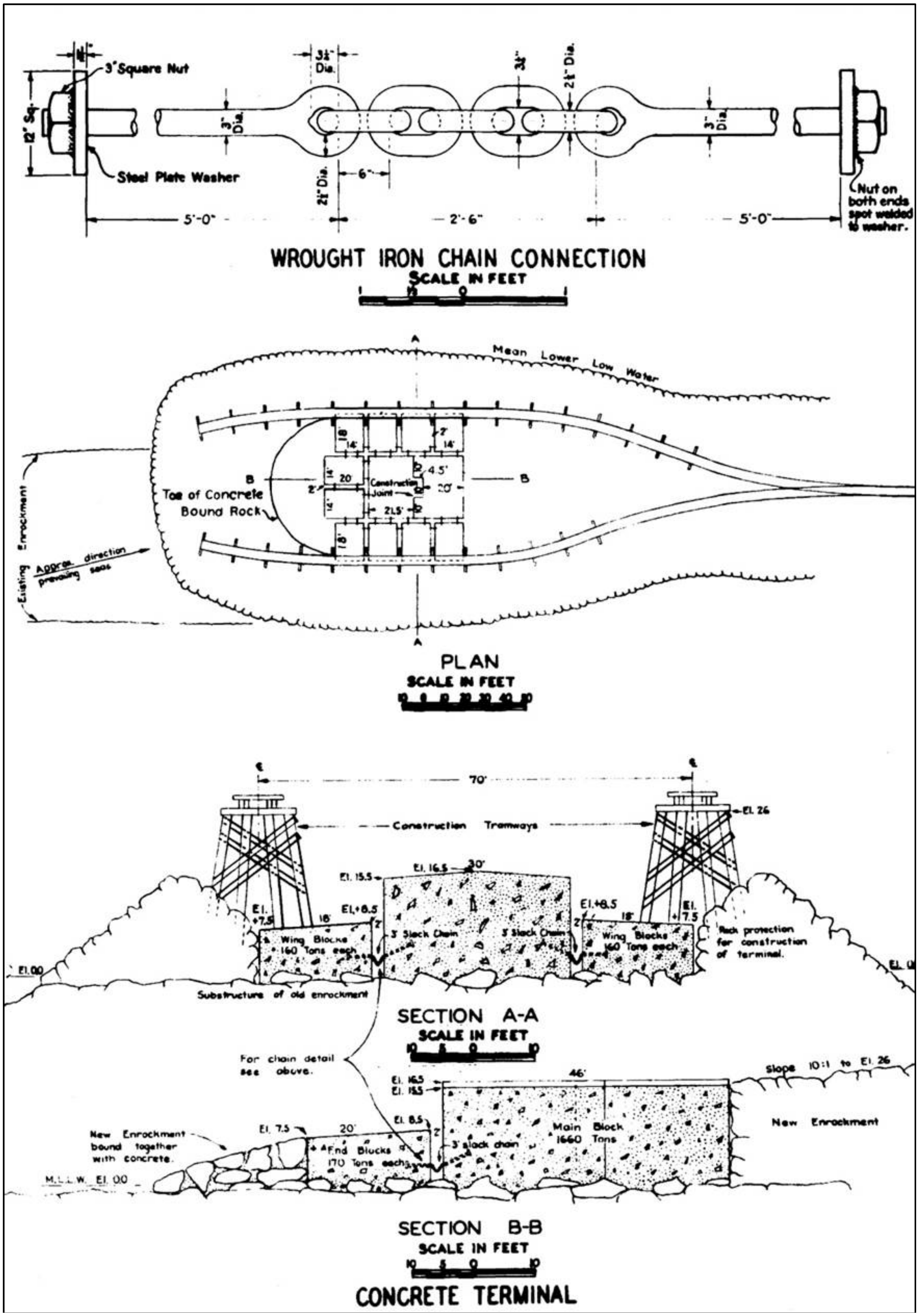


Figure A1- 53. South Jetty Concrete Terminal Details

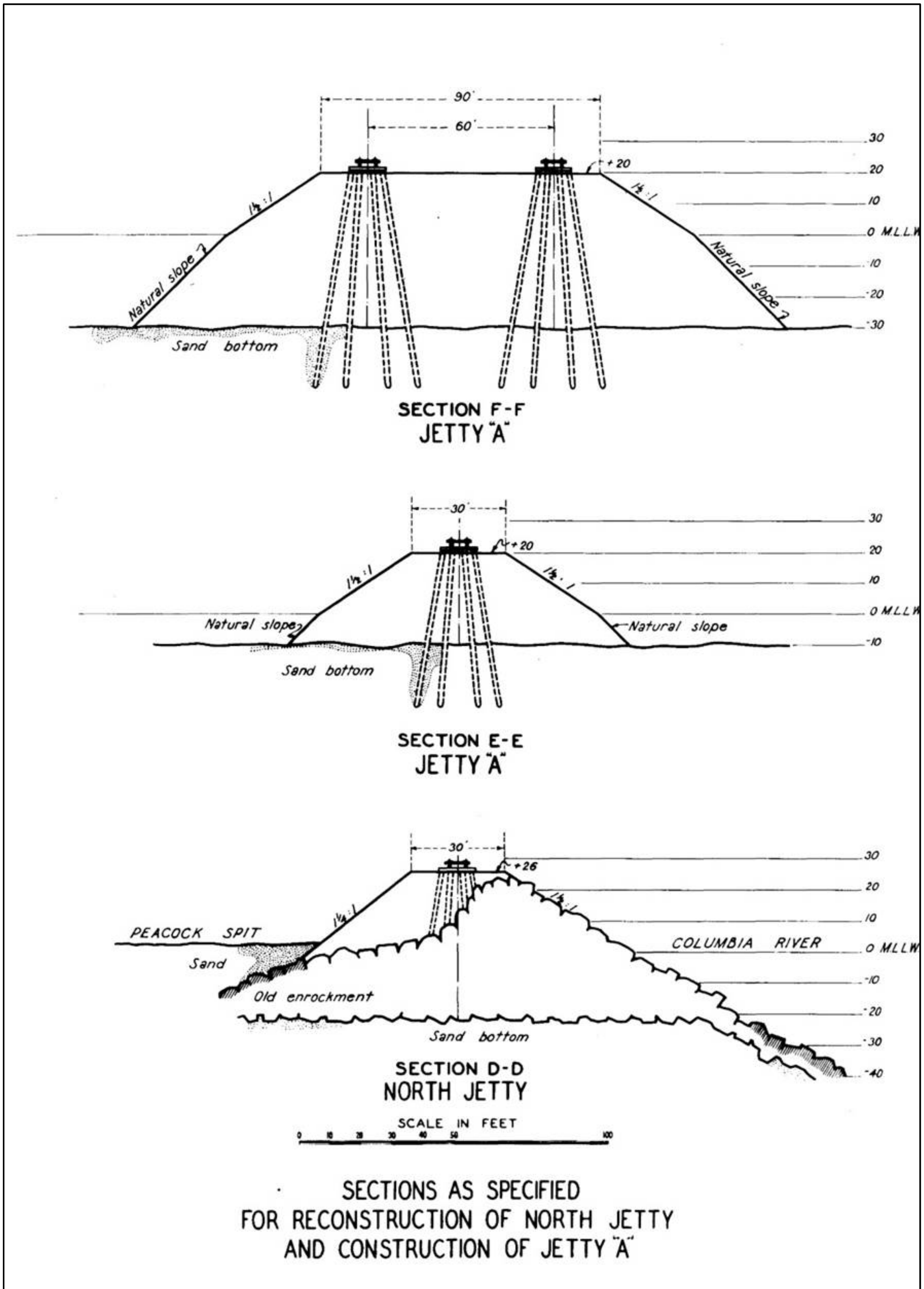


Figure A1- 54. Cross Section Repairs for North Jetty and Jetty A - 1939

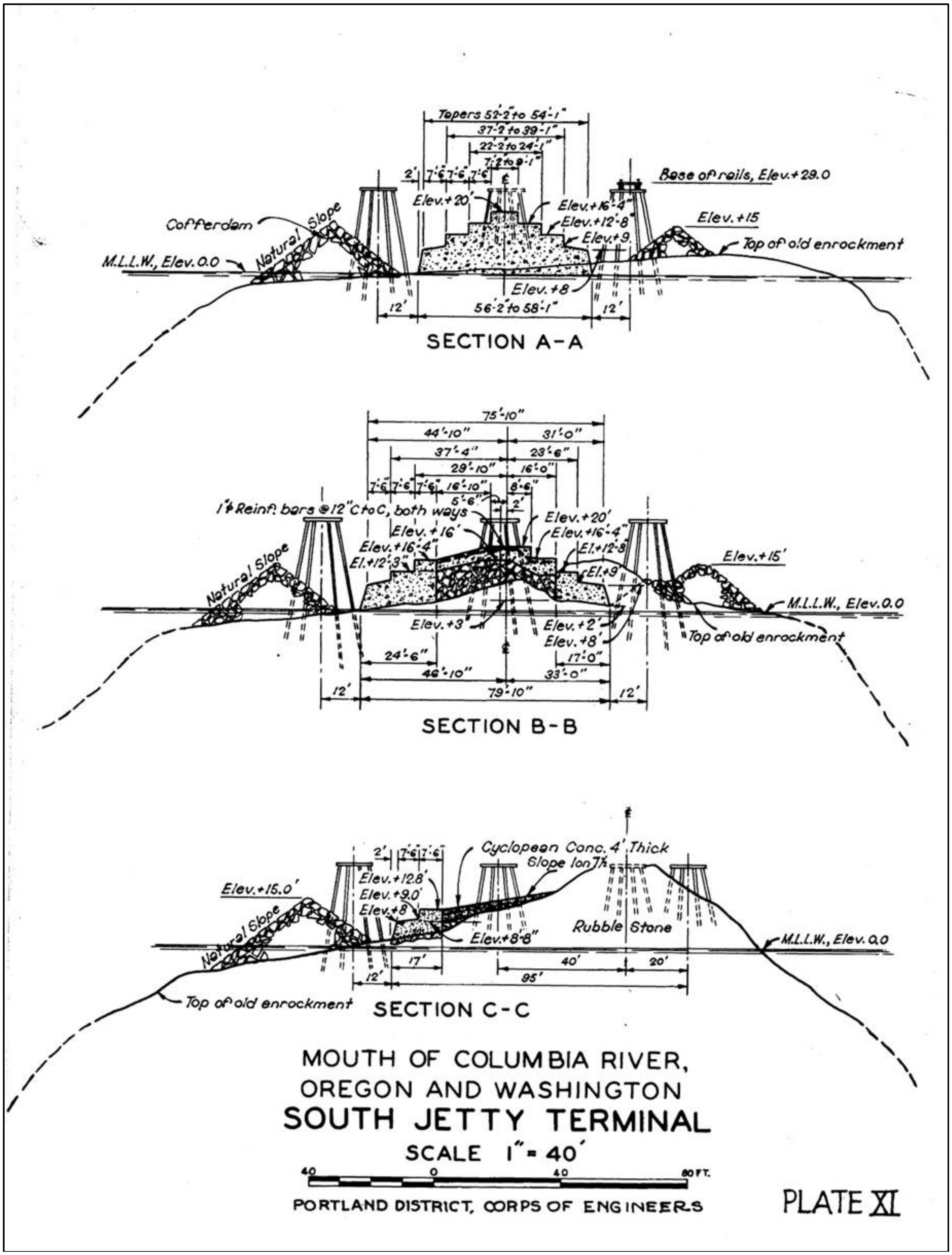


Figure A1- 55. South Jetty Terminal Sections

Originally, the crest elevation of the South Jetty was constructed to mid-tide elevation (3 to 5 ft above MLLW) and crest width was 10 ft. Figure A1- 42 shows the design cross-section and construction method used to construct the South Jetty. Emphasis was given to ensure a proper “bedding” layer underneath the jetty to establish a stable foundation. The maximum size of armor stone was 7 tons, based on professional judgment and limitation of the tramway equipment. The finished side slope of the jetty was approximately 1V:1H (natural slope). Improvements during jetty construction included the addition of four rock spur-groins (100-1000 ft long) on the north side of the South Jetty (at Station 52, 88,156, and 228) to prevent scour and undermining of the jetty and increasing the jetty crest elevation. From shore to Station 120, the jetty crest elevation was increased to 12 ft MLLW to reduce wave overtopping, prevent shoal migration, and protect the tramway. The crest elevation was sloped down from +12 ft MLLW (at Station 120) to +4 ft MLLW at Station 250+20. The 4.5-mile long South Jetty was begun in 1885 (at Station 25+80) and completed in 1895 (Station 250+20, known as the “knuckle”). A rock revetment was constructed east of the South Jetty root (along Station 0-25) to prevent erosion flanking of the jetty by waves and currents. Construction of the original South Jetty required 946,000 tons of stone, which was placed using a trestle-supported tramway with locomotives, side-casting cars, and crane. Stone was delivered to the tramway by barge. Before commencement of the South Jetty, there was no dominant channel though the MCR and the controlling depth was about -20 ft MLLW.

Upon completion of the original South Jetty, a well-defined channel had developed through the MCR with controlling depth of 30 ft. However, by 1902, all traces of a channel had disappeared and the governing depth over the bar reverted to 20-22 ft. In 1903, the Board of Engineers recommended that Congress authorize the Corps of Engineers to enact the following: A) the South Jetty be extended 2.5 miles in length toward the west and the jetty crest be raised to 10 ft MLLW or higher; B) a 2.5 mile long North Jetty be constructed on Peacock Spit (after completion of the South Jetty extension); and C) commencement of dredging at the bar, if needed. It was specified that the North and South jetties be 2 miles apart at their ends. The object of the recommended improvements was to obtain a channel 0.5 miles wide through the MCR with controlling depth of 40 ft below MLLW.

In 1905, Congress authorized the Corps to implement the Board of Engineers’ 1903 recommendations, for the purpose of attaining a 40-ft (12.2-meter) deep channel 0.5 miles (0.82 km) wide across the bar. Repairs were made to the original 4.5-mile long South Jetty (Station 175-250) using 410,000 tons of stone. Construction of the 2.1-mile long extension (Station 250 to Station 375) required 4.48 million tons of stone at a 1913 total cost of $7,618,764. Work on the 6.62-mile long South Jetty was completed in 1913. The alignment of the South Jetty extension was intended to extend the seaward location of the channel by following the shallow waters of Clatsop Spit as far as possible without making significant changes in the direction of the structure. It was thought that if the 2.1-mile long extension were constructed in continuation of the straight-line direction of the original jetty, the velocities of the ebb and flood tides would be significant enough to undermine the jetty foundation, unless groins were incorporated. South jetty extension was expected to prevent the ebb flow from losing energy and dissipating over Clatsop Spit, but instead to be guided toward the existing channel and help maintain its depth. It was expected that the extension would hold Clatsop Spit in position and allow it to build up by impeding the entrance of sand into the channel. The curvature of the jetty at the "knuckle" was intended to encourage deposition of sand along the channel side of the jetty, so that the installation of groins would not be necessary.

As completed in 1913, the South Jetty had an average crest width of 10 ft and an elevation of +10 ft MLLW along the inner 2.65 miles (Station 25-165) of the jetty. The outer 4 miles of the jetty (Station 165-375) had an average crest with of 25 ft and elevation of +24 ft MLLW. The finished side slope of the jetty was approximately 1V:1.5H (natural slope). An increased jetty crest elevation was needed to prevent wave overtopping damage to the lee side of the jetty, reduce sediment transport over the jetty, and protect the construction tramway from wave action. Stone size was the same as used for the original jetty (max size was 7 tons). Two (2) submerged rock groins (extending northward 200 ft from the jetty centerline) were constructed at the outer area of Station 309 & 333, to prevent scour along the north side of the jetty toe. It is noted that these two rock groins have been instrumental in stabilizing the outer end of the South Jetty toe since time of construction (see Figure A1- 56 and Figure A1- 57).

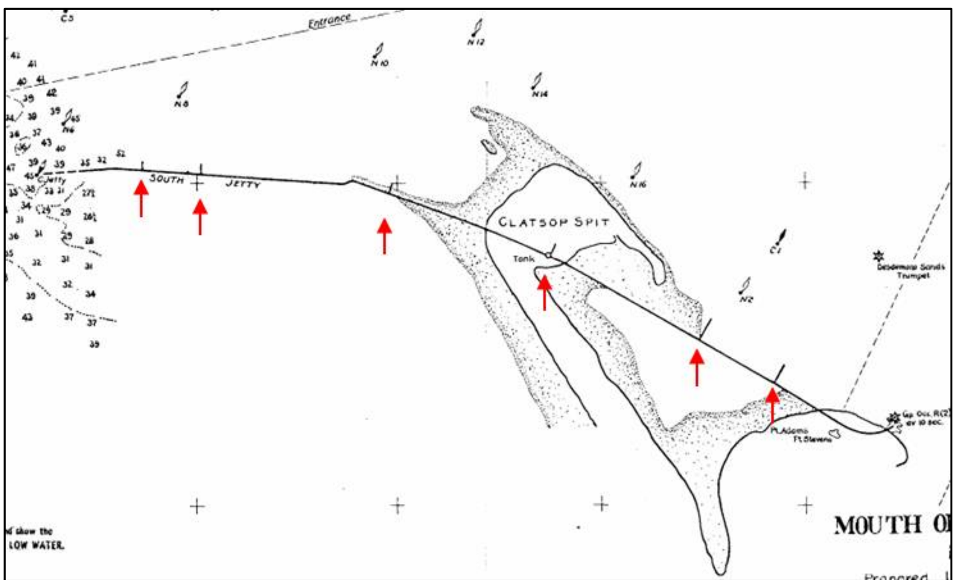


Figure A1- 56. Spur Groin Construction Along Channel Side of South Jetty

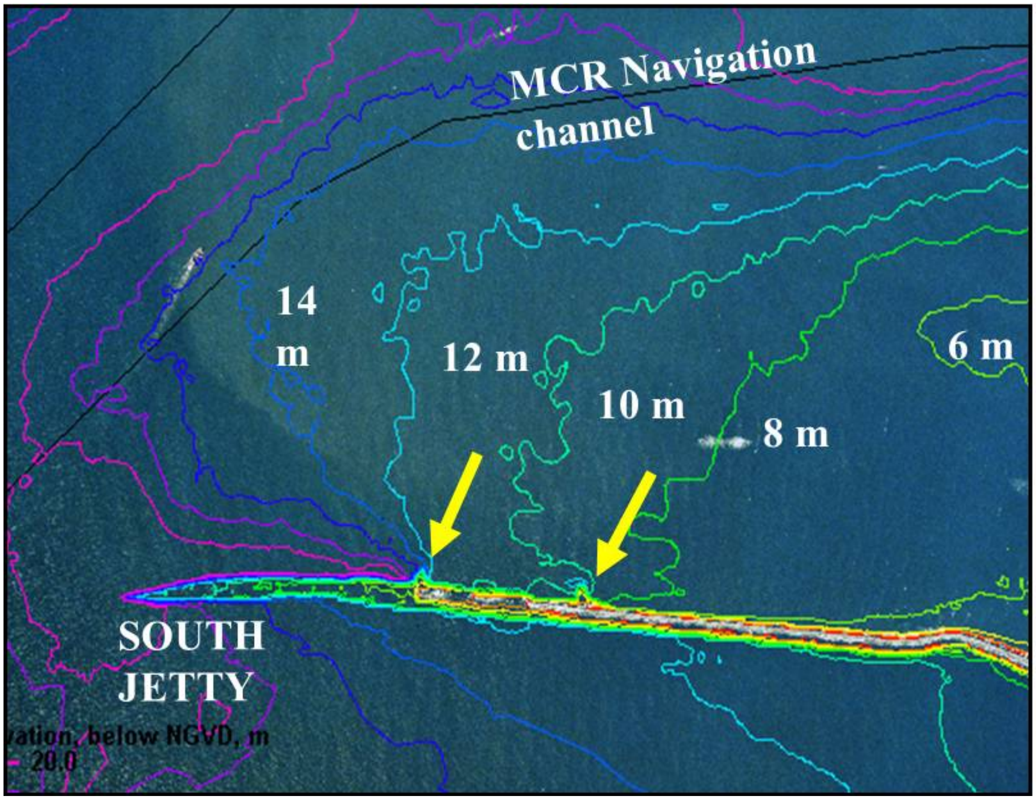


Figure A1- 57. Current Configuration of Outermost South Jetty Spur Groins

b. North Jetty Construction

As noted above, Congress authorized construction of the North Jetty through the Rivers and Harbors act of 1905. Construction of a North Jetty was needed to limit the northward migration of the navigation channel, in response to South Jetty construction during 1885-1913. The direction of the jetty was to follow approximately the shallow waters southwesterly across Peacock Spit without a sudden change in direction to a point roughly 2 miles north of the end of the South Jetty. Heavy scour along the jetty toe was expected and taken into account during the design phase, by incorporating additional bedding stone.

The Corps of Engineers began North Jetty construction in 1913, after completion of the South Jetty. The North Jetty was completed in 1917 (Figure A1- 58). The North Jetty extended southwest from Cape Disappointment (sta 0+00) along Peacock Spit for about 2 miles (Station 107), then turned westward for about 1,700 ft and terminated at Station 122. The 2.35 mile long North Jetty required 2.95 million tons of stone. The stone was placed using a trestle-supported tramway with locomotives, side-casting cars, and crane. Stone was delivered to the tramway by barge. The same cross-section shown in Figure A1- 42 was used for the original North Jetty construction, except that the crest elevation was at +28-32 ft MLLW. Crest elevation along the landward 3,000 ft of the North Jetty was +15 ft MLLW. Jetty crest width was 25 ft. Maximum armor stone size was 7 tons. The finished side slope of the jetty was approximately 1V:1.5H (natural slope).

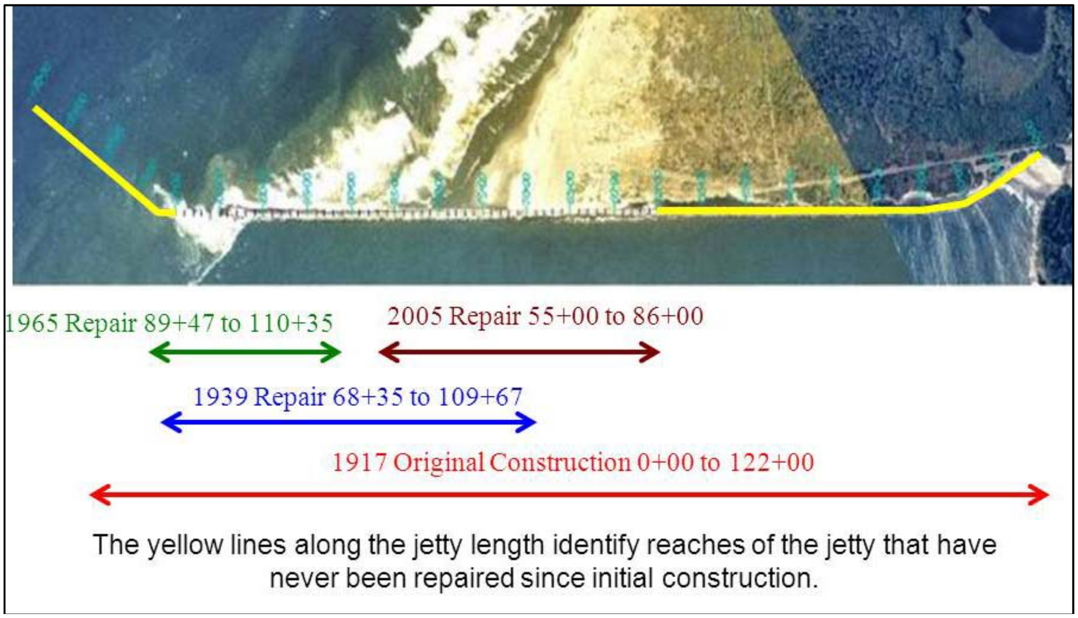


Figure A1- 58. MCR North Jetty Construction and Repair History

Upon completion of the North Jetty in 1917, the North and South jetties would function as a system to: A) constrict the MCR entrance to 2 miles wide at the terminal ends of the jetties, at which point the velocity of tidal flow would minimize the formation of shoals within the MCR entrance channel; and B) "hold" and prevent channel-ward encroachment of existing entrance shoals - Peacock Spit along the north side of the MCR entrance channel and Clatsop Spit along the south side of the channel. By 1917, the MCR navigation channel had attained a controlling depth of -40 ft MLLW and channel width was 1,000 ft. By 1937, the controlling depth was -46 ft MLLW and the distance between 40-ft depth contours along the channel centerline was 8,000 ft. The two-jetty system at MCR stabilized the inlet and enabled maintenance of an engineered entrance with a nominal amount of dredging. Table A1- 2 and Figure A1- 58 summarize North Jetty construction and repair history.

Table A1- 2. Construction and Maintenance activities for the MCR North Jetty

Design Parameter	1917	1939	1965	2005
Stone Density (pcf)	167	167	167	167 - 180
Structure Side slope (V:H)				
North Side	1:1.5	1:1.25	1:1.5 to 1:2	1:1.5
South Side	1:1.5	1:1.5	1:1.5 to 1:2	1:1.5
Crest Elevation (ft MLLW)	15 to 32	26	24	25
Crest Width (ft)	25	30	30	30
Armor Stone Quantity (tons)	2,946,449	247,233	136,935	
Select A Size (tons)			24	
Class A Size (tons)	50 lbs to 7 tons*	10	15.1	10
Class B Size (tons)		3.5	8	
Stone Source	Fisher	Skookumchuck	Fisher	Young's River Falls, Abe Creek, Phipps, Fisher, Turner, Washougal, Columbia Granite
Stone Type	Andesitic Basalt	Diorite	Andesitic Basalt	Multiple
Beginning Station	0+00	68+35	89+47	55+00
Ending Station	122+00	110+35	109+67	86+00

c. Jetty A Construction

During the early 1930s (after both North and South jetties had been in place and significant modification of the inlet's morphology had occurred), the North Jetty became threatened by high velocity ebb tide flow which threatened to undermine the structure's channel side foundation. Concurrently, the south side of Sand Island was being eroded by increased current action. In the late 1930s, the Sand Island Pile Dikes and Jetty A were constructed by USACE to stabilize the evolving inlet.

Original construction was conducted with Diorite rock from Station 40+94 to 97+36. From the beginning of the structure to Station 53+00, the jetty was just a small armament feature with a crest width of 10 ft. The jetty from 53+00 to 92+86 was 30 ft wide at an elevation of +20 ft MLLW. The centerline of the jetty was centered along the railroad trestle. At 92+86, the railroad trestle diverges into two trestles. The centerline of the jetty appears to be the center of the two trestles. Table A1- 3 and Figure A1- 59 summarize the construction and repair history for Jetty A.

Figure A1- 59. MCR Jetty A Construction and Repair History

Table A1- 3. Jetty A Construction and Repair History

DESIGN PARAMETER	1939	1945-47	1948-49	1951	1952	1958	1961-62
Stone Density(pcf)	160	160	160	145	145	145	145
Structure Side slope (V:H)							
East Side	1:1.5	1:1.5	1:1.25	1:1.5	1:1.5	1:1.5	1:1.5
West Side	1:1.5	1:1.5	1:1.25	1:1.5	1:1.5	1:1.5	1:2
Crest Elevation (ft MLLW)	16-20	20	20	20	20	20	20-24
Crest Width (ft)	10-90	40	30	30	30	20-30	30
Armor Stone Quantity (tons)	233,708	63,125	30,000	6,994	25,005	92,399	161,098
Class A Size (tons)	10	6	5	500lbs to >5 tons	5*	10	10
Class B Size (tons)	1 to 6	1 to 4	1 to 4	25lbs to 1 ton	100lbs to 4tons	3	4
Class C Size (tons)	< 1	100lbs to 1 ton	100lbs to 1 ton			100lbs to 1 ton	<2
Stone Source	Skoo.	Naselle	Skoo.	Cape D.	Cape D.	Cape D.	Cape D.
Stone Type	Diorite	Basalt	Diorite	Basalt Breccia	Basalt Breccia	Basalt Breccia	Basalt Breccia
Beginning Station	40+93.89	78+00	92+35	91+50	90+00	41+00	50+00
Ending Station	96+83	96+00	95+35	93+00	94+00	79+00	90+50**

Multiple partial repairs were conducted during the 1940s to the 1960s. In 1958 they repaired approximately 3,800 ft of the inner end, from Station 41+00 to Station 79+00. The structure had degraded to an elevation of +15 to +20 ft MLLW and was rebuilt to +20 ft MLLW from 41+00 to 56+00 with the baseline on the centerline of the old trestle. Station 56+00 to Station 61+00 is a transition period where the centerline of the repair changes from 25' to the right of the baseline to 10' left. From 61+00 to 79+00 the crest width was 30'.

In 1960, they repaired approximately 3,150 ft of the outer end. The section was rebuilt to +24 ft elevation, from degraded elevations of +10 to 15 ft. A memorandum established a cap stone weight of 17.6 tons based on a wave height of 15.5 feet and a specific gravity of 2.4. The size considered for the 1960-1961 repairs was a 6-ton minimum and at least an average weight of 10 tons. Past designs allowed for the placing of Class B and C stones in the armor layer. The armor layer was designed to have Class A stone placed along the westerly/ocean slope and over the crest of the jetty. Class A and B stone would then be placed along the easterly/Baker Bay slope. Select Class A stone, weighing more than 15 tons, should be placed between Stations 90+00 and 90+50.

A 1960 design memorandum states that the history of repairs of the jetty "suggests major deficiencies in past construction." The design stated that since the jetty "is principally serving as directional current training and not as wave protection, the structure would adequately fulfill all requirements if the repairs were to end at Station 91+00 rather than 95+50. For the same reason, the height of jetty repair between Stations 78+00 and 91+00 should be held to elevation +20." Past designs allowed for the placing of class B and C stones in the armor layer. In the 1960 repair, only class A stone was allowed on the westerly slope and over the crest of the jetty. Rock in the armor layer was also individually placed with a crane, as opposed to being dumped onto the jetty from the trestle and tramway. Sta 41+00 to Sta 79+00, repaired in 1958, received considerable damage due to overtopping waves. Breaks in the jetty expose the jetty to further damage. The design report states that it was believed that the first damage to the jetty was due to subsidence caused by scouring of sand from around the jetty base resulting in armor stone displacement. Smaller rock was then exposed to waves, which resulted in further displacement.

A small armament was built from Station 49+93.89 until Station 53+00 according to plan drawings and the 1961 Design Memorandum. The jetty was then built to an elevation of 20 ft MLLW out to Station 92+86. From 92+86 to 97+36 a second trestle was built and the jetty crest width was built wider, with a crest width at the end of 90 ft. There have been six repairs since original construction. The centerline of the jetty has not remained the same throughout the repairs.

d. MCR Morphology Response to Jetty Construction

Figure A1- 19 through Figure A1- 22 illustrate how the MCR entrance evolved from a pre-jetty configuration in 1885 to a post-improved configuration in 1950, 33 years after jetty completion. In 1885, the unstable entrance was controlled by a relatively symmetrical yet dynamic ebb tidal shoal (Middle Sands), exposed flood tidal shoals, and a westerly-directed primary channel with controlling depth less than 25 ft. Note on Figure A1- 17 the tidal shoals on which the South and North jetties were constructed (Peacock Spit on the north and Clatsop Spit on the south).

The first phase of South Jetty construction was completed in 1895, with the jetty head terminating 4.5 miles offshore from Fort Stevens (Point Adams). By 1902, the South Jetty had facilitated significant landward re-distribution of Clatsop Spit on the south side of the entrance and offshore re-distribution of Middle Sands (and Peacock Spit) on the north side of MCR. Much of Clatsop Spit had been re-distributed along the South Jetty and points south for a distance 3 miles, creating a large above water (subareal) sand fillet. These shoal morphology changes were due to the modification of waves/currents/circulation within the MCR by South Jetty construction. The second phase of South Jetty construction was completed in 1913, producing a 6.6-mile long jetty. The full-length South Jetty promoted additional landward migration of Clatsop Spit, with water depths increasing along the outer end of the South Jetty.

The ebb-tidal shoal located on the northern side of the entrance (what was once Middle Sands) continued to be transported offshore, effectively decreasing the water depth offshore on the north side of MCR. In 1917, the 2.35-mile long North Jetty was completed, producing significant changes in morphology along the north side MCR. As the North Jetty was being constructed on top of a newly reformed Peacock Spit, shoal material was transported further offshore (west) of the inlet and was deposited along the northern side of the jetty while significant erosion/scour was occurring along the south side of the jetty.

By 1950, much of Peacock Spit (middle sands in 1885) had been dispersed offshore and to the north, and the inshore part of Clatsop Spit had shifted northward more than 3 km. The offshore part of Clatsop Spit, that was present in 1885, was displaced landward onto the south shore of MCR. Adjacent coastal shorelines north and south of MCR had experienced offshore accretion that exceeded 600 m since jetty construction (1885). The reformation of morphology had pushed the MCR channel north toward the North Jetty. Figure A1- 18 shows the scouring effect of channel migration upon the North Jetty. Jetty “A” (1939) and the Sand Island pile dikes (1928-32) were constructed to prevent additional northward migration of the MCR channel and disruption of the North Jetty. The redistribution of MCR tidal shoals, as noted above, has affected the foundation of the MCR jetties, necessitating 11 different jetty repair events.

e. Previous Rehabilitation Activities - North and South Jetties

The construction of jetties at the MCR produced significant morphological changes of the shoals on which the jetties were built, as noted above. Morphology change of the channel and tidal shoals changed the wave and currents patterns at MCR. In some cases, sand spits accreted along the landward flanks of the jetties resulting in the shore attachment of Peacock Spit along the north side of the North Jetty and Clatsop Spit along the South Jetty. Accretion of sand along the jetties acted as a barrier to waves and currents and protected the jetties. Offshore of the jetty root, significant erosion of tidal shoals occurred (along the jetties) following jetty construction. Severe scour of the jetty toe resulted, which destabilized areas of the north and south jetties due to undermining and jetty side slope re-adjustment. Jetty scour/undermining was problematic along the outer 2 miles of the South Jetty and along most of the south side of the North Jetty. Loss of the tidal shoals offshore and along the jetties allowed for increased wave action to directly impinge on the jetties. Wave action at the ends of the jetties (and other jetty locations) increased from pre-jetty conditions, due to increased water depth, destabilizing the armor stone due to increased wave action. The 7-ton armor stone used for jetty construction was no match for the winter storm waves of the northeast Pacific Ocean. The finished side slope for both jetties (1V:1.5H) was too steep for resisting wave action and undermining of the jetty toe due to scour. The heads of the jetties were particularly vulnerable due to focusing of wave action and scour. Results of jetty destabilization were first manifest on the South Jetty by 1920. Significant deterioration of the North Jetty became evident by 1930.

1931-1942 Rehabilitation. Due to the high cost of tramway construction and maintenance, jetty repair work was deferred during 1917-31. By 1920, the outer 2.5 miles of the South Jetty crest had been beaten down by wave action and scour to 4 ft MLLW. By 1931, the elevation of the South Jetty crest was at approximately MLLW from Clatsop Spit (Station 170) seaward to the jetty head (Station 375). The degradation of the South Jetty allowed significant re-distribution of Clatsop Spit along the north side of the South Jetty. Much of the sediment emanating from Clatsop Spit was transported northward and eventually deposited within the southern flank of the navigation channel. By 1931, the outer 1,500 ft of the North Jetty had been beaten down to about 3 ft MLLW and some settlement had occurred along its entire length. Except the outer end, the North Jetty had stood up rather well due to the accretion of sand along its northern side which by 1932 had extended to the jetty head (Figure A1- 38).

The first (and most significant) effort to rehabilitate the South Jetty was undertaken by three separate contract actions during 1931-1936. The total length of reconstructed jetty was 3.4 miles, beginning at Station 175 and ending at Station 353. As rehabilitated in 1936, the above waterline part of the South Jetty extended to within 3,300 ft of the end of the jetty as completed in 1913. During 1931-36, a total of 2.21 million tons of stone was placed. The stone was placed using tramway, dump cars, and a 25-ton crane. Stone was delivered to the tramway by barge. Average production of stone placement was 75,000 to 100,000 tons/month. To prevent future wave damage, the larger armor stone that was placed on the South Jetty during the 1931-1936 rehabilitation ranged between 6-25 tons. Average armor stone size was 9 tons. The armor stone size was chosen based on profession judgment and equipment limitations. Rehab crest width ranged between 24–70 ft and crest elevation was 26 ft MLLW. Even before repairs could be completed, it was realized that the outer 3,000 ft of the South Jetty could not be maintained due to continual stone loss from the jetty. In 1937, Station 350-353 (340-344) was rebuilt using 10,600 tons of armor stone impregnated with 12,800 ton of asphalt-sand mix. The asphalt bound jetty head performed poorly.

By 1941, the end of the rehabilitated South Jetty (Station 338-353) had been reduced to 0 ft MLLW elevation by wave action and toe scour/undermining. In an effort to form a stable jetty head, a massive concrete terminal was constructed during 1941-42. The terminal was 50-75 ft wide x 300 ft long with elevation +8 to +20 ft MLLW (requiring 14,000 cy of concrete and 76,000 tons of stone) and was constructed at Station 331 to form an armored cap. At present, most of the concrete terminal has been displaced by scour and wave action. Only the outer 100 ft of the concrete terminal remain today secured by relic stone (from previous repairs) and the rock groins along the north side of the jetty. The 1931-42 rehabilitation sequence was the last time that the tramway method of repairs was used on the South Jetty. A remnant of the concrete terminal presently forms the seaward-most extent (above water line) of the South Jetty, at Station 331 4,400 ft shoreward of the 1913 maximum offshore extent (Station 375).

The first effort to rehabilitate the North Jetty was undertaken during 1938-40. The total length of jetty reconstructed was 4,200 ft, from Station 68 to Station 110 using 243,833 tons of stone. Along most of this reach, the north side of the jetty had resisted wave action due to the accumulation of sand (Benson Beach, Figure A1- 38). However, the south side of the jetty was damaged due to undermining from current action and direct exposure to waves. All of the stone placed on the jetty trunk during the 1938-40 rehabilitation, was along the northern side to maximize the effectiveness of establishing a rebuilt cross-section. Each side of the jetty head received equal amounts of stone (Station 108-110). The stone was placed using tramway, dump cars, and a 25-ton crane. Stone was delivered to the tramway by barge. Armor stone size ranged between 6-25 tons. Average armor stone size was 9 tons. The armor stone size was chosen based on professional judgment and equipment limitations. Rehabilitated crest width was 30 ft and crest elevation was 26 ft MLLW. A concrete terminal (width of 70 ft and elevation 17 ft MLLW, using 3,280 cy of concrete) was constructed from Station 118-120 (approximately) to establish a secure jetty head. The seaward-most 1,400 ft of the North Jetty (Station 120-124) was not rehabilitated. By 1964, the North Jetty concrete terminal had been reduced to 0 ft MLLW or less. The 1938-39 rehabilitation sequence was the last time that the tramway method of repairs was used on the North Jetty. By 1964, north concrete terminal had broken into several pieces and settled to 6 ft MLLW. At present, the remnants of the concrete terminal have been beaten down to below –10 ft MLLW.

1960-1982 Rehabilitation. The South Jetty was repaired during 1961-1965 and in 1982. During 1961-65, approximately 521,000 tons of stone were used to repair the South Jetty between Stations 194-314. This was the first time that an empirical design approach (Hudson equation) was used to define armor stone size for the South Jetty in terms of incident wave height and jetty side slope. In 1961, jetty repairs were enacted along Station 194-249 and addressed the most severe damage, which had been sustained along Station 232-242, where the South Jetty crest had been reduced to 3-10 ft MLLW. Within this area, the jetty had been damaged by wave action to a degree such that the north side of the jetty had sustained damage by wave overtopping. Other areas along Station 194-249 had experienced a general damage trend due to wave action and scour/undermining along the south side of the jetty. Between Stations 194-249, the South Jetty was rebuilt with crest width and elevation of 24 ft and 24 ft MLLW, respectively. Jetty side-slope for the repair was 1.5H:1V on south side and 1:25H:1V on north side. An equal proportion of stone was placed on the north and south sides of the jetty. During 1961, a total of 213,461 tons of stone was placed. During 1962, Station 249-314 was repaired using a crest width of 40 ft and elevation of 25 ft MLLW using 308,000 tons of stone. Most of the stone was placed along the southern side of the jetty. Stone was placed using land-based crane and jetty haul road. The maximum (average) size of armor stone was 25 (10) tons.

The last time the South Jetty was repaired was in 1982 when 77,000 tons of stone was placed along Station 194-249 (same as the 1962 repair). Most of the stone was placed along the southern side of the jetty, to address wave damage. The amount of stone placed per unit length of jetty in 1982 (at 14 tons/ft) was less than 1/3 of any repair effort conducted on the MCR jetties, and represented an attempt to affect bonafide jetty repairs. Refer to Figure A1-60 for repair effort comparison. Armor stone size averaged 13 tons (max/min was 25/8 tons). The repair template had a crest elevation of 25 ft, crest width of 30 ft and side slope of 1.5H:1V. Stone placement was by land-based crane and jetty haul road. Stone was delivered to the job site by barge.

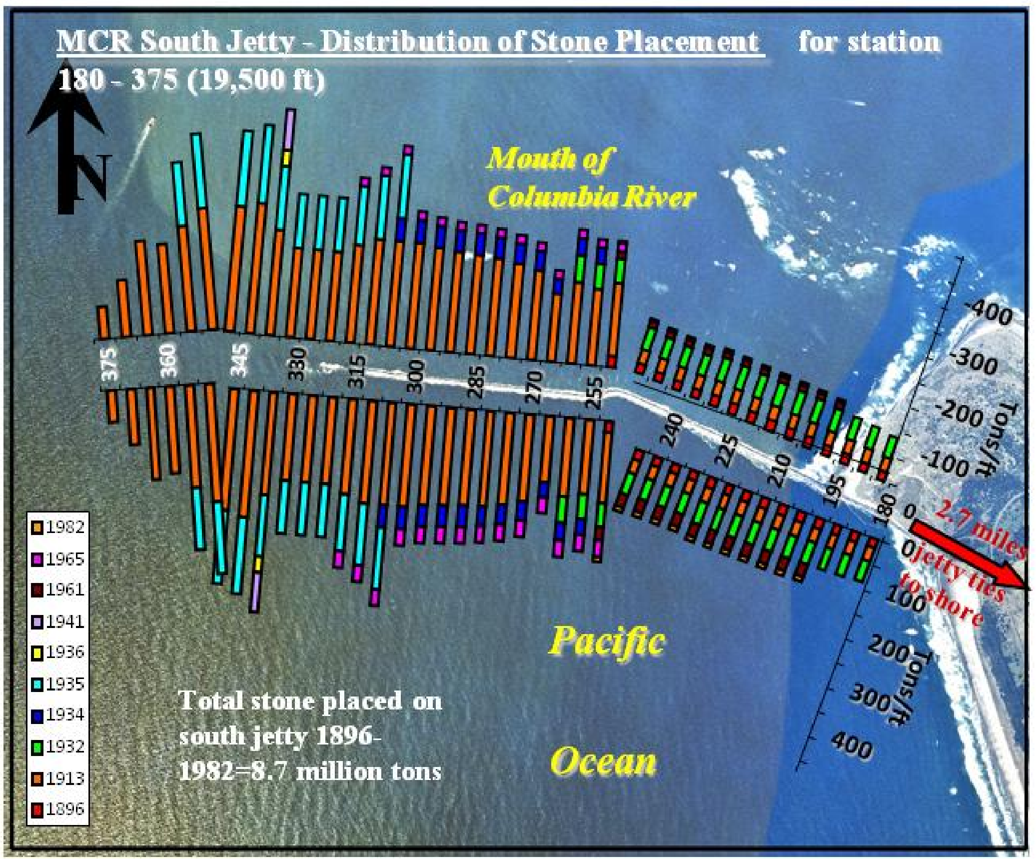


Figure A1- 60. South Jetty Distribution of Stone Placement

The last time the North Jetty was repaired was in 1965 when 132,000 tons of stone was placed along Station 89-110. Refer to Figure A1- 61 and for repair effort comparison. In 1964, the head of the North Jetty had been beaten back by wave action and undermining to sta 103. The original jetty head had terminated at Station 124. Along much of the southern side of the jetty, the outer armor stone had sloughed into the river exposing smaller core stone. In 1964, it was assumed that the southern side of the North Jetty was not exposed to wave significant attack. It was further assumed that the exposed core stone on the south side of the jetty was not subject to wave-induced damage. The armor layer along the north side of the jetty was missing between Station 98-103. The 1965 repair was needed to address damage along the southern side of the jetty caused by undermining of the jetty toe, and re-establish a stable jetty head. This was the first time that an empirical design approach (Hudson equation) was used to define armor stone size for the North Jetty in terms of incident wave height and jetty side slope. Model studies conducted by WES in 1963 indicated that rehabilitation of the North Jetty to its outer end would affect an improvement in flow patterns around the North Jetty such that less shoal material would deposit within the MCR navigation channel. Much of the repair effort was dedicated to re-establishing a secure jetty head.

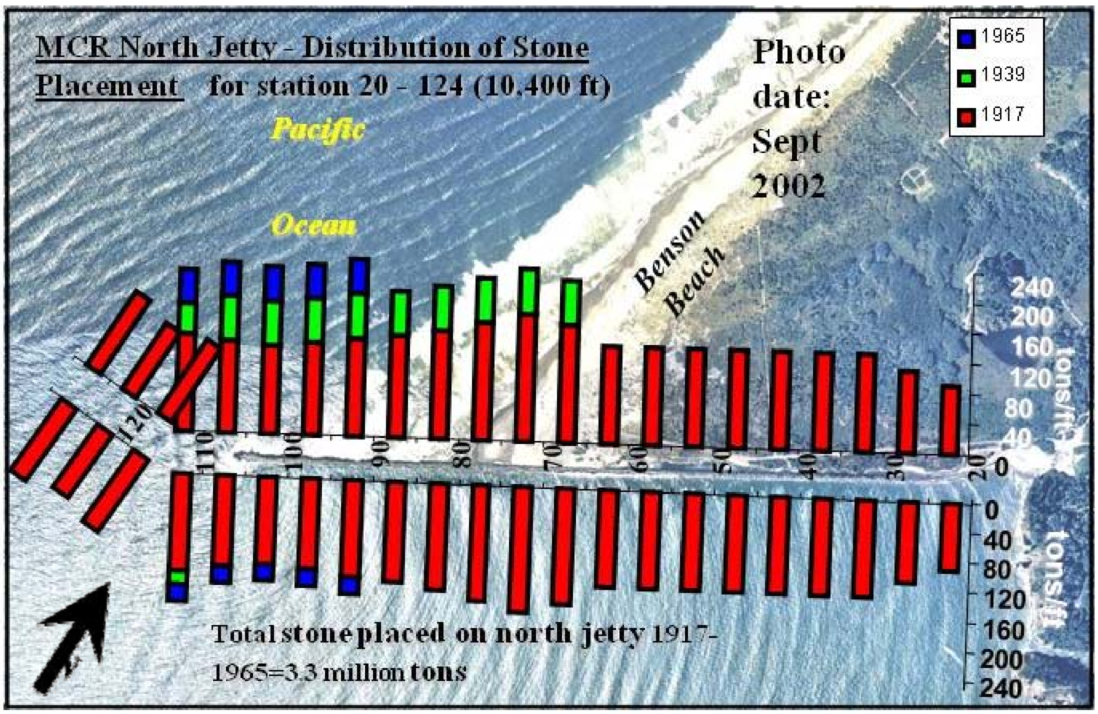
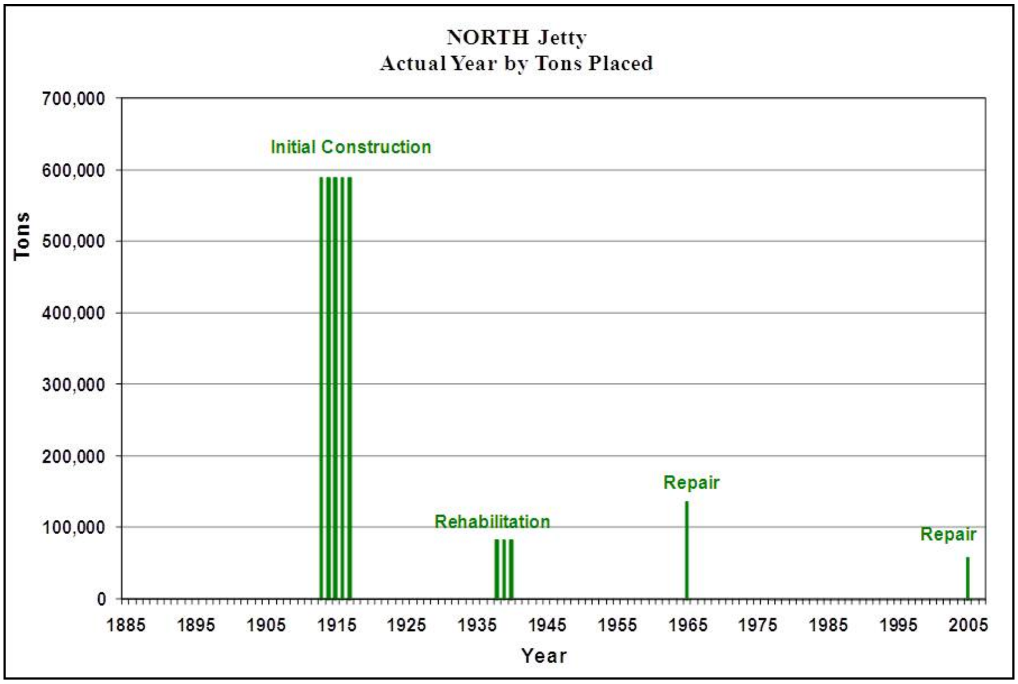


Figure A1- 61. North Jetty Distribution of Stone Placement

Most of the stone was placed along the North Jetty trunk was placed along the northern side, to efficiently re-establish a jetty cross-section. The exposed core stone along the south side was not believed to be vulnerable to wave attack, and significant water depth along the southern side of the jetty precluded an efficient cross-section renewal. Armor stone size ranged between 15-25 tons. The repair template had a crest elevation of 24 ft and crest width of 30 ft. Stone placement was by land-based crane and jetty haul road. Stone was delivered to Ilwaco by barge and transported 2 miles by truck to the job site.

Figure A1- 62 through Figure A1- 64 illustrate the actual year-by-year stone tonnage for construction rehabilitation and repairs for the North Jetty, South Jetty, and Jetty A, respectively.



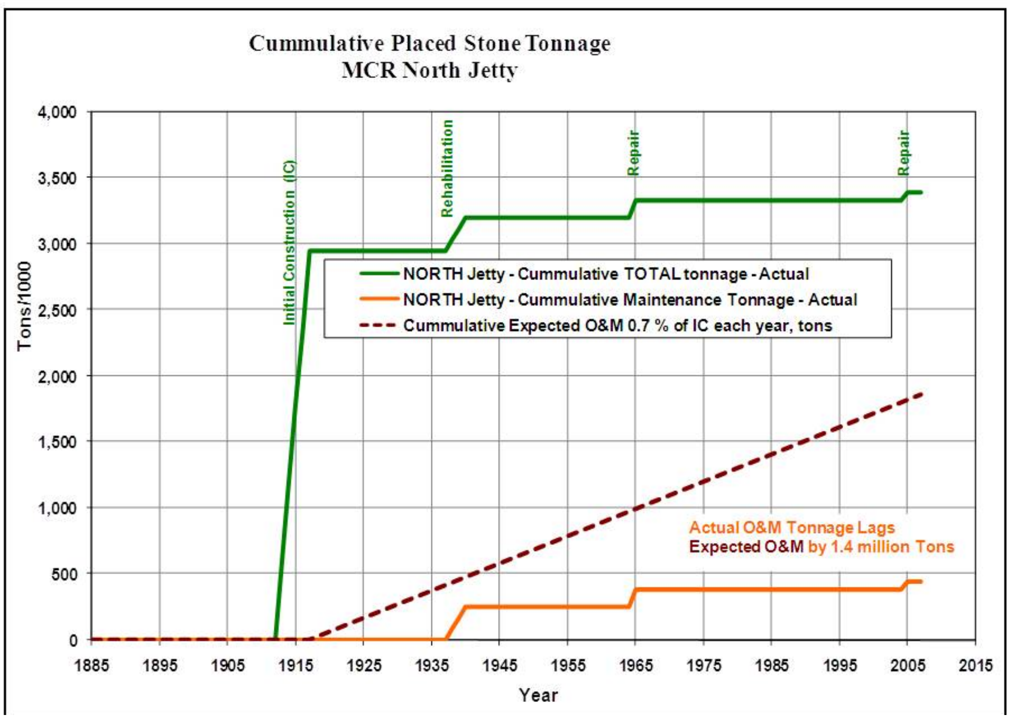
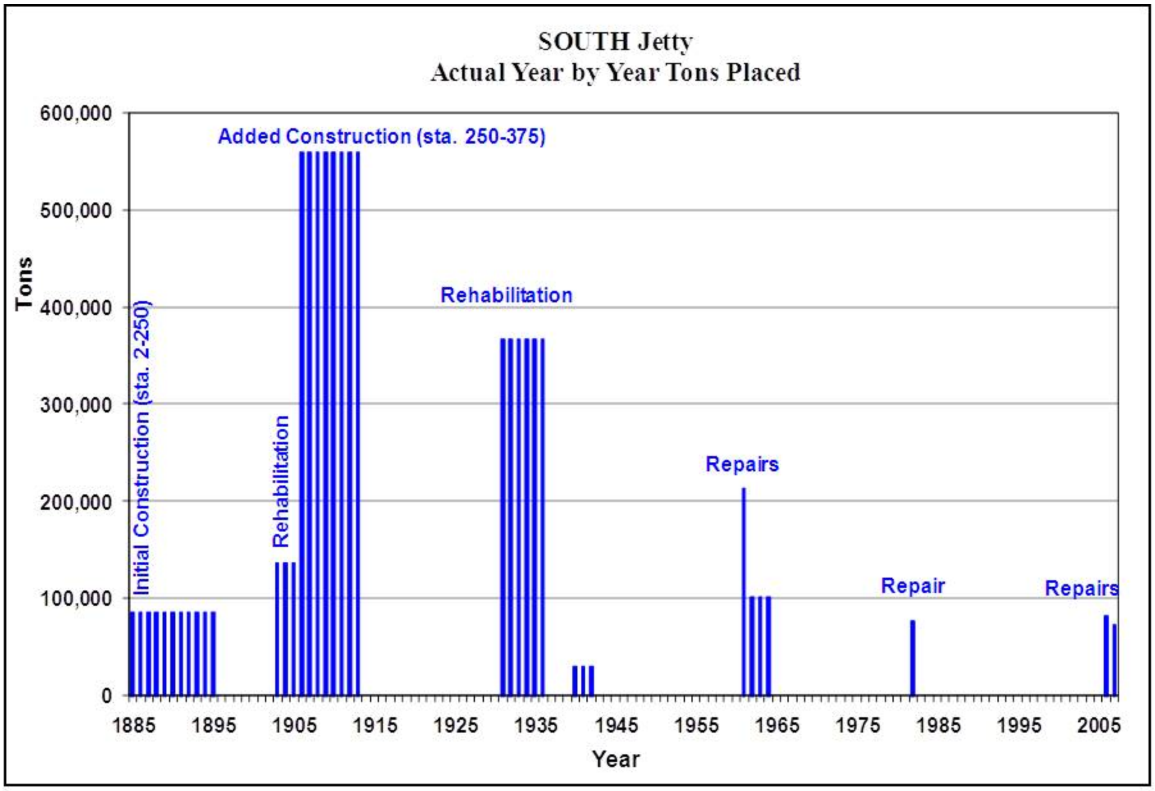


Figure A1- 62. North Jetty Actual Stone Placement Quantities



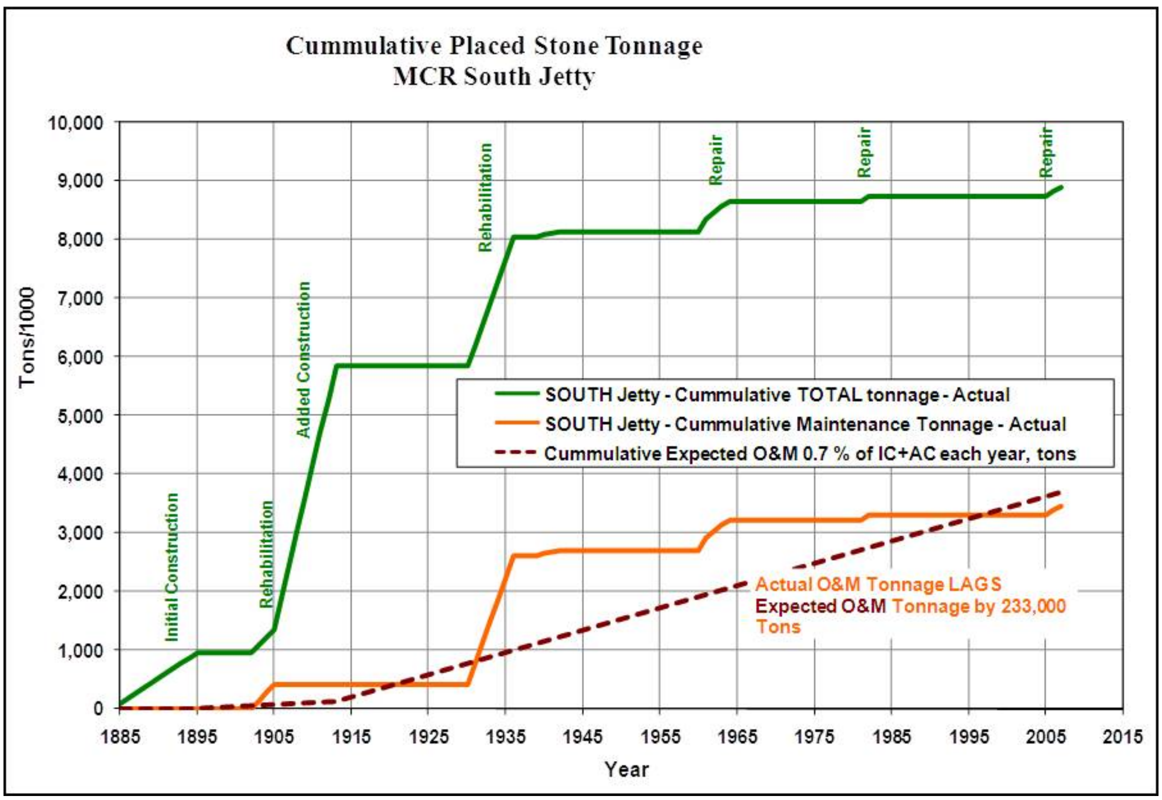
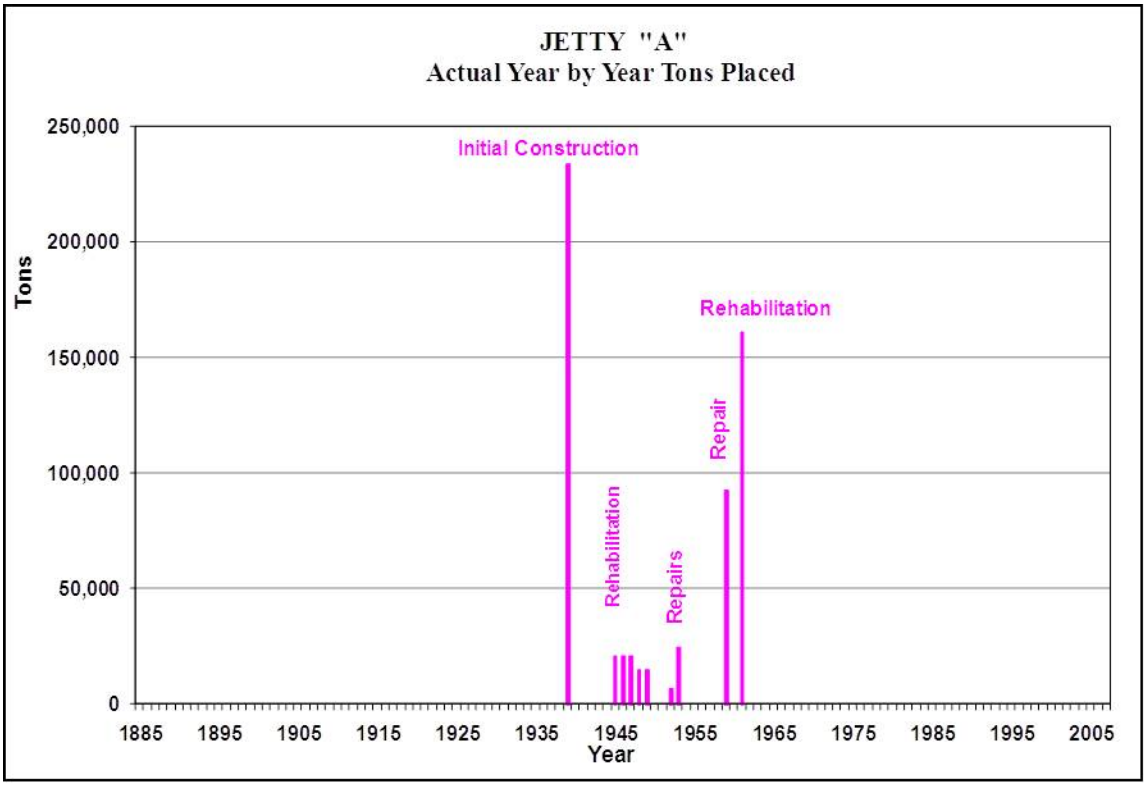


Figure A1- 63. South Jetty Actual Stone Placement Quantities



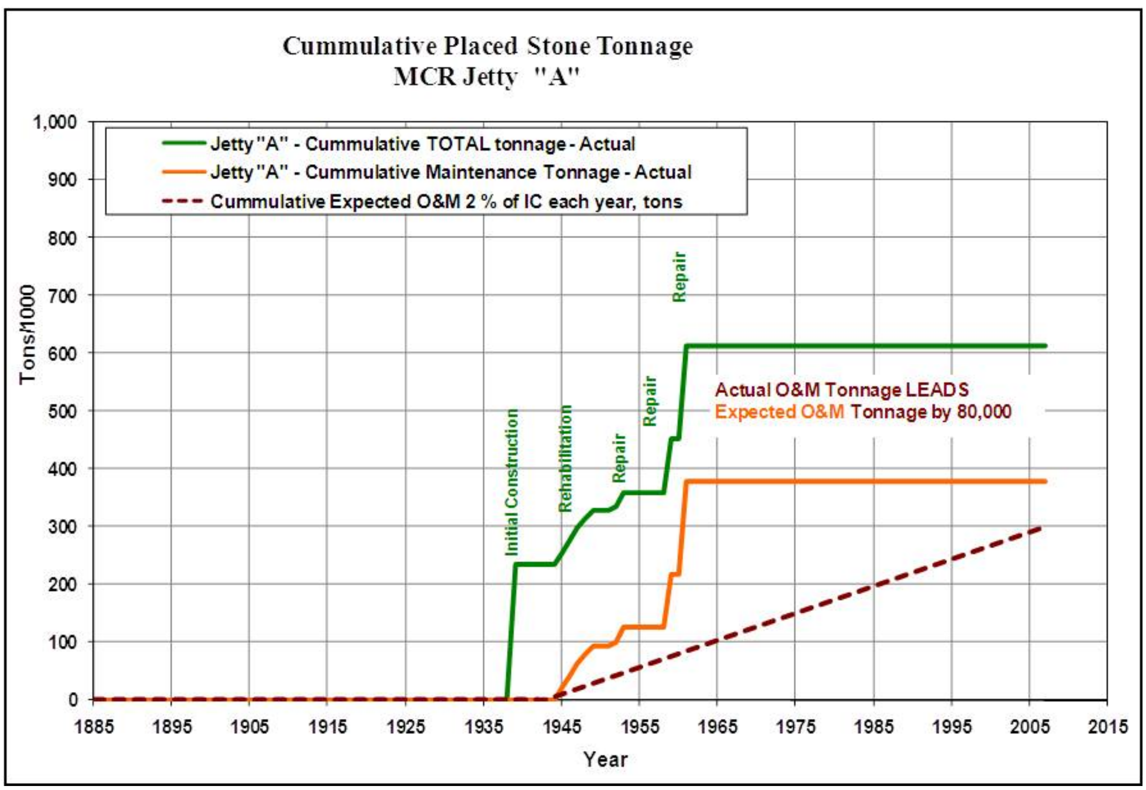


Figure A1- 64. Jetty A Actual Stone Placement Quantities

f. Evolution of Structures and Morphology

Much of the present-day morphology at MCR (Peacock Spit and Clatsop Spit) and adjacent shorelands was formed by sand discharged oceanward during/after jetty construction. This dynamic produced an imbalanced condition with transient morphology features extending far offshore into the dissipative energies of waves and currents. In this regard, the reformed spits and tidal shoals have been eroding ever since jetty construction. The erosion trend of sand spits/shoals at MCR is problematic for the long-term stability of the jetties, the cost-effective reliability of the MCR project, and the supply of sediment to adjacent littoral areas north and south of the inlet. The resiliency of the MCR jetties is related to the stability of the morphology on which they are founded and vice versa. If the jetty foundation washes away, jetty reconstruction is problematic.

The stability and navigability of the inlet is tied to a stable morphology at the inlet, which in turn is secured by fully functioning jetties. If the jetties fail to function adequately, the inlet's morphology can destabilize; much of the sediment could be released back into the interior of inlet drastically suppressing the sediment budget of the adjacent shorelands and littoral areas. The goal of jetty rehabilitation will be to restore structural integrity of the jetties without affecting local or regional littoral sediment transport. The objective of jetty rehab would be to have no negative impact to Clatsop Spit, Peacock Spit or littoral cell sediment budget. Failure to implement jetty rehab at MCR could result in impacts to the regional sediment budget, particularly if jetty lengths are allowed to continue to recede. Should a jetty experience an enhanced loss in function (related to a breach), the regional sediment budget could be significantly affected.

The underwater shoals on which the MCR jetties were constructed are considered to be crucial project elements, as summarized in the following excerpt [USACE 1903]. *"The jetty is a long, thin, narrow backbone of solid material, resting upon a very doubtful foundation, against which the forces in action at the locality have accumulated large quantities of the shifting sands. These shoals in turn have been able to break the force of the waves and protect the jetty from destruction. The jetty's safety and the permanence of the present favorable condition of channel over the bar depend upon the amount of this sand that can be accumulated."* The stability of the MCR channel is related to both the jetties and the morphology of Peacock Spit and Clatsop Spit.

As the seabed along the jetty toe is eroded by scour, jetty stone along the toe "falls" into the scour hole. The scour hole propagates, and more jetty stone falls into the scour hole. The continual loss of stone from the jetty toe can lead to an unraveling effect that migrates upward along the jetty slope; initiating a creeping slope failure within the jetty cross-section. Near the water surface, armor stone is eventually displaced by the creeping slope failure exposing the jetty core to wave action. Wave action acting on small core stone and non-interlocking armor stone then dismantles the jetty.

The forcing environment affecting the jetties today is not the same now as it was 70 or 100 years ago. At the time of jetty construction and shortly thereafter, the jetties were protected by the broad shallow sand shoals on which they were built. Incident waves were severely depth limited along much of each jetty and currents were reduced, by the presence of shallow shoals. In some localized areas, jetty construction promoted shoaling along the jetty, further protecting it from wave and current action. In other areas, jetty construction motivated rapid dispersal of the sand shoals near the jetty, allowing larger waves and currents to affect the structure. The seaward terminus of each jetty experienced rapid deterioration immediately after initial construction, due to the jetty head extending off the inlet's shoals, exposing it to severe current and wave action.

During the initial phases of South Jetty construction, the meager cross-section employed along the most of the jetty's exposed length (mid-tide jetty crest elevation of +7 ft MLLW and crest width of 15 ft, with maximum size armor less than 10 ton) did not withstand the forces encountered and had to be rebuilt using an increasingly resilient cross-section. In some cases along the South Jetty, the repair cross section was based on a compound slope to increase jetty resiliency. The standard repair cross-section for MCR jetties had evolved to one based on crest elevation of +23 ft to +30 ft MLLW, crest width of 23 ft, and nominal armor size ranging between 9-20 tons. A larger repair cross section was based primarily on the need for the jetty to resist exposure to increasingly vigorous environmental loading and provide added resiliency after the structure becomes damaged.

The environmental loading along the MCR jetties has been increasing over time (since jetty construction) because of the evolving inlet and supporting morphology. As the inlet's post-jetty construction transient morphology has been eroded, large waves are able to get closer to shore; depth limited wave height along the jetties has increased. Along some reaches, the depth limited height affecting the jetties has increased by >30% since initial construction. At the same time, the foundation along various reaches of each jetty has been compromised due to erosion of the shoals on which the jetty is founded. Vertical scour along the toe of the MCR jetties has exceeded 35 ft in some reaches [Moritz et al., 2007]. The extent over which the jetties continue to experience increased forcing continues to change and constitutes a non-stationary loading condition. A significant proportion of the remaining above waterline elements of each jetty are in a deteriorated condition and the condition is worsening with time. "Just in time" repairs ($26 million) were recently completed in 2007 to address the most acute damage along limited reaches of the north and south MCR jetties, to prevent loss of jetty function (breach) and attendant interruption of navigation through the MCR. Based on the present damage trend and a lean maintenance strategy, the MCR jetties appear to be approaching a condition of continual repair.

The effective heads of all three jetties at MCR have been receding landward since the time of initial construction. The process of jetty head recession has facilitated the transport of littoral sediment into the inlet. The loss of this sediment from the coast has reduced the supply available to the littoral budget, deflated the morphology along the jetty root (exposing the jetty to more deterioration), and has added sediment to the MCR dredging requirement. The current head positions of the North, South, and Jetty A are 2200 ft, 6200 ft, and 900 ft shorter than authorized lengths.

The shoreface expression of Peacock Spit (Benson Beach) has receded approximately 40 ft/year for the past 4 years. This observation is based on active monitoring of the shoreface along Benson Beach using the ARGUS system at North Head light house (http://www.planetargus.com/north_head). Large scale bathymetry change of Peacock Spit during 1997-2007 has resulted in the seabed being lowered by 2-4 ft, with the exception of the areas within and 1 mile northward adjacent to the SWS. These areas have experienced no net erosion. In some cases areas, nearby areas affected by dredged material placement at the SWS have gained 2-4 ft of elevation. The bathymetry of Clatsop Spit (western flank, along South Jetty) has been lowered 4-10 ft during 1997-2007. The shoreface expression of Clatsop Spit (along the north side of South Jetty) has been receding at 2-20 ft per year, depending upon location. The shoreface immediately south of the South Jetty is receding landward at a variable rate of 0-20 ft per year.

6. Existing Condition of Structures and Morphology

a. General

To evaluate the existing jetty condition, a digital elevation model (DEM) was developed. The MCR DEM describes the present surface of each jetty and the bathymetry of MCR. The DEM was used to compare the existing condition of each jetty to the 'as-built' (or 'as-repaired') cross-section template. Assessments of North and South Jetty performance, present functionality, and reliability were made using the existing condition DEM.

b. MCR Digital Elevation Model

A substantial effort was undertaken by USACE Portland District to produce a detailed DEM for the MCR. The overall DEM was produced from data collected using three surveys with different methods during 2006:

1. Conventional single beam fathometry was used to survey bathymetry within and outside the main inlet of MCR. The conventional bathymetry survey was controlled using DGPS and NOAA tidal corrector.
2. Multi-beam fathometry was used to survey the submerged areas of the jetties. The multi-beam survey was controlled using RTK-DGPS.
3. Controlled aerial topographic mapping was used to survey the exposed (subareal) areas of the jetties. The aerial photography that was used for topographic mapping of the jetties was controlled using ground reference points with the aircraft camera being tracked using RTK-DGPS with an inertial measurement unit.

The nominal resolution of the DEM for bathymetry within and outside the inlet in water depths less than 230 ft is horizontal and vertical accuracy of ± 1.5 ft and ± 1.0 ft, respectively. The jetties were mapped at a resolution less than 3 ft (horizontal and vertical accuracy is ± 1.5 ft m and ± 1.5 ft). Positional reference for the MCR jetties is based on the original centerline alignment and jetty stationing. This means that the jetty stationing used in this report begins at the true landward most point for each jetty and no offsets are included within the centerline alignment. The MCR DEM was used to compare the present structural condition of the jetties to the as-built condition. The present condition of the jetties was evaluated by "cutting" cross-sections through the DEM every 10 ft, along the center line of each jetty. The reliability analysis of the MCR jetties (see Appendix A2) was made possible by the accurate definition of the present jetty condition. Numerical modeling for wave transformation and hydrodynamic circulation utilized the MCR DEM.

c. Maintenance History and Template Deficit

The existing condition and robustness of the MCR Jetties can be characterized by looking at the maintenance history as well as the current cross section deficit of each jetty compared to a standard or typical design template. The maintenance history of each jetty was outlined in Chapter 1 and Appendix A2. Figure A1- 65 through Figure A1- 67 summarize that information in approximately 50 year increments, a typical design life for a coastal structure. Also plotted on those figures is the estimated expected maintenance for the jetties over that same time period using a 0.7% x construction volume per year of structure life. Given the performance life of the North and the South jetties, 93 and 115 years, respectively, and the extreme exposure of the structures, more maintenance stone would have been expected over their life. In particular, the last 50 years has seen a reduction in maintenance activity at the jetties. Some of the repair activities for Jetty A utilized readily available but under-sized stone for maintenance activities which is reflected in the fairly large stone volume placed on the structure over its lifetime.

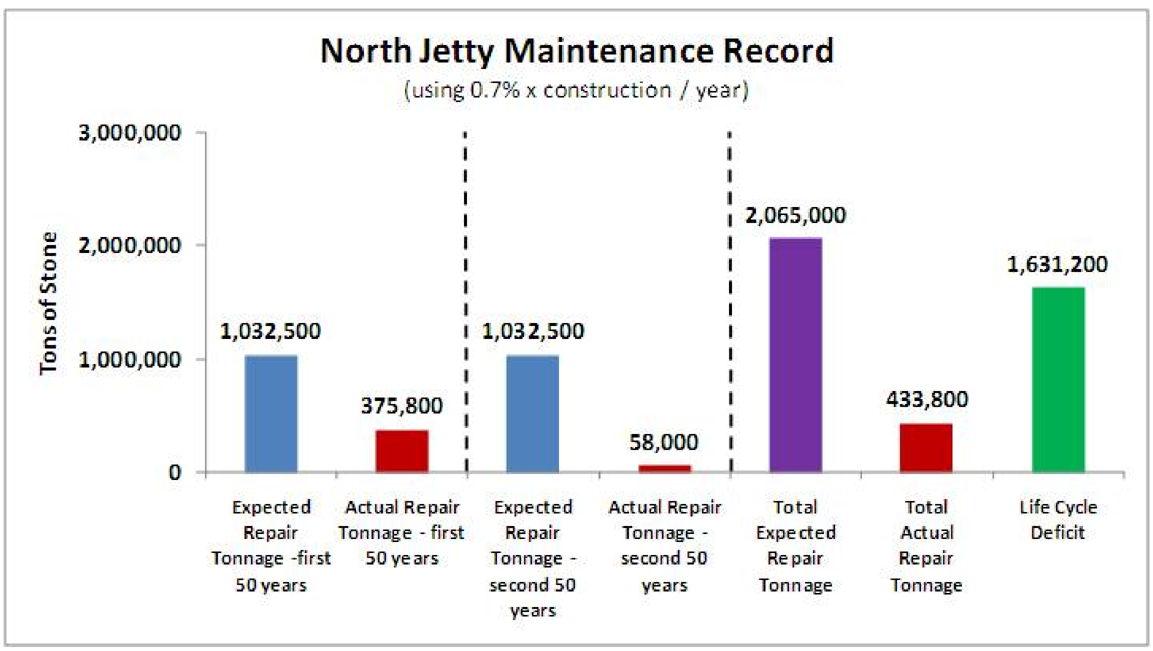


Figure A1- 65. North Jetty Maintenance Record Total Summary

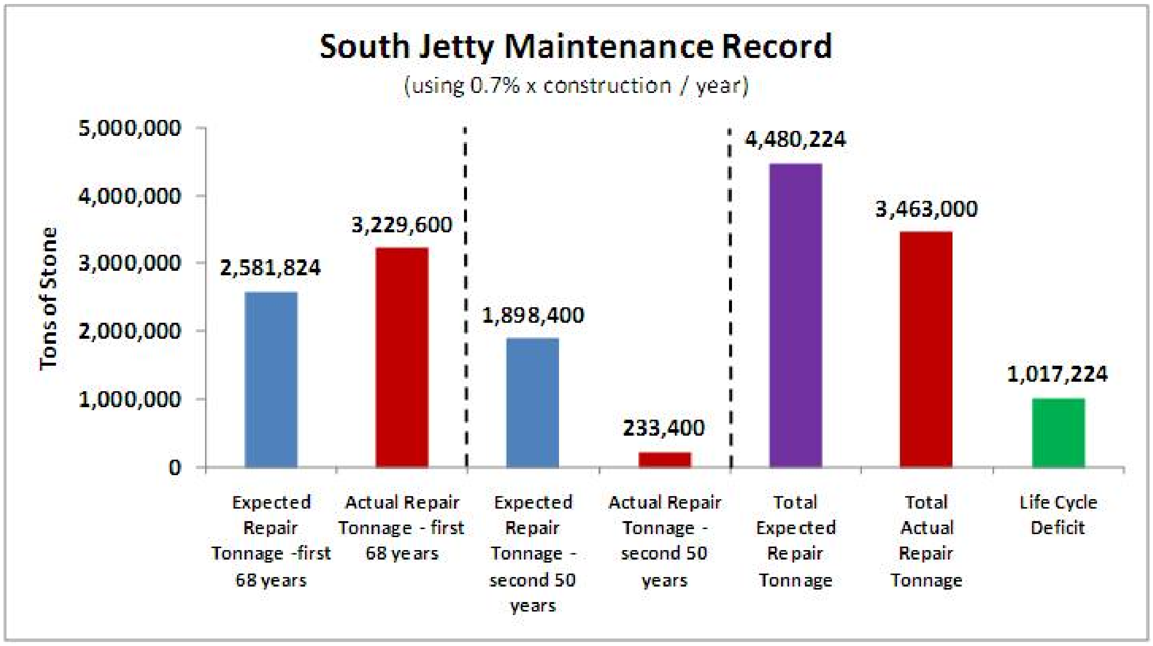


Figure A1- 66. South Jetty Maintenance Record Total Summary

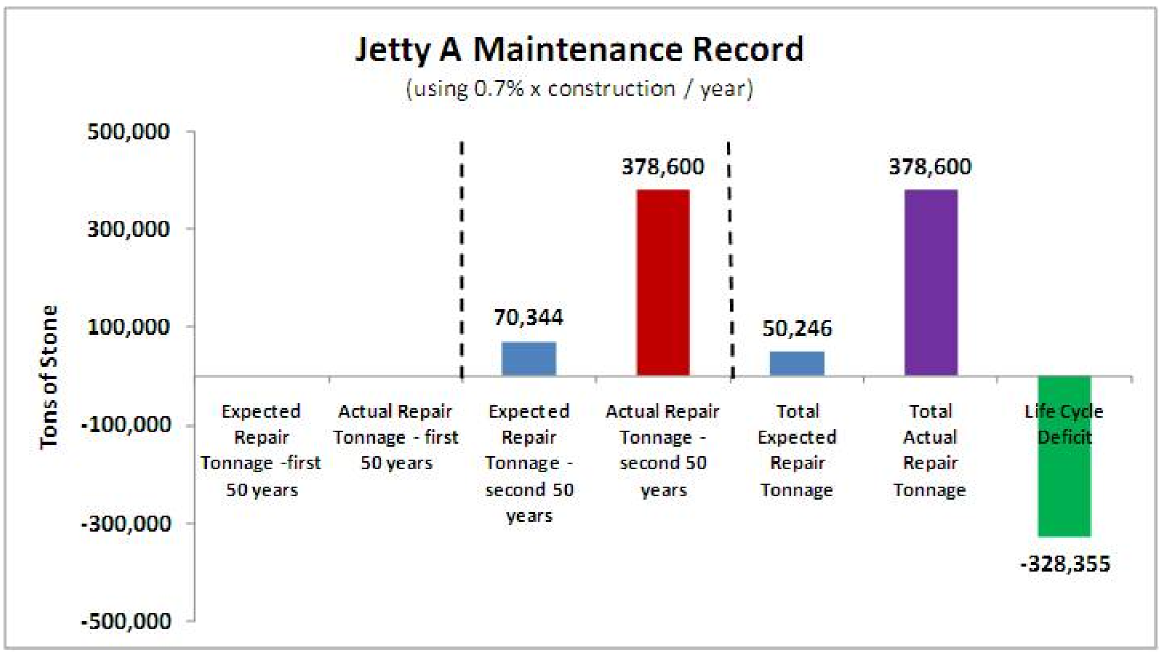


Figure A1- 67. Jetty A Maintenance Record Total Summary

Another measure of the existing rubblemound structure condition would be to simply calculate the deficit of stone volume between the existing structure surface and a standard or typical design template. Figure A1- 68 illustrates that comparison for the three jetties. Existing South Jetty deficits range from approximately 410,000 to 700,000 tons of stone to bring the existing structure up to a minimum or small template. For the North Jetty, approximately 240,000 to 570,000 tons of stone would be needed to bring the existing structure up to a minimum or moderate template. Jetty A would need approximately 87,000 tons to bring the existing structure up to a small template. A range of stone volumes is reported here to provide a framework for considering design or structure modifications necessary to respond to increased loading of the structure at some locations.

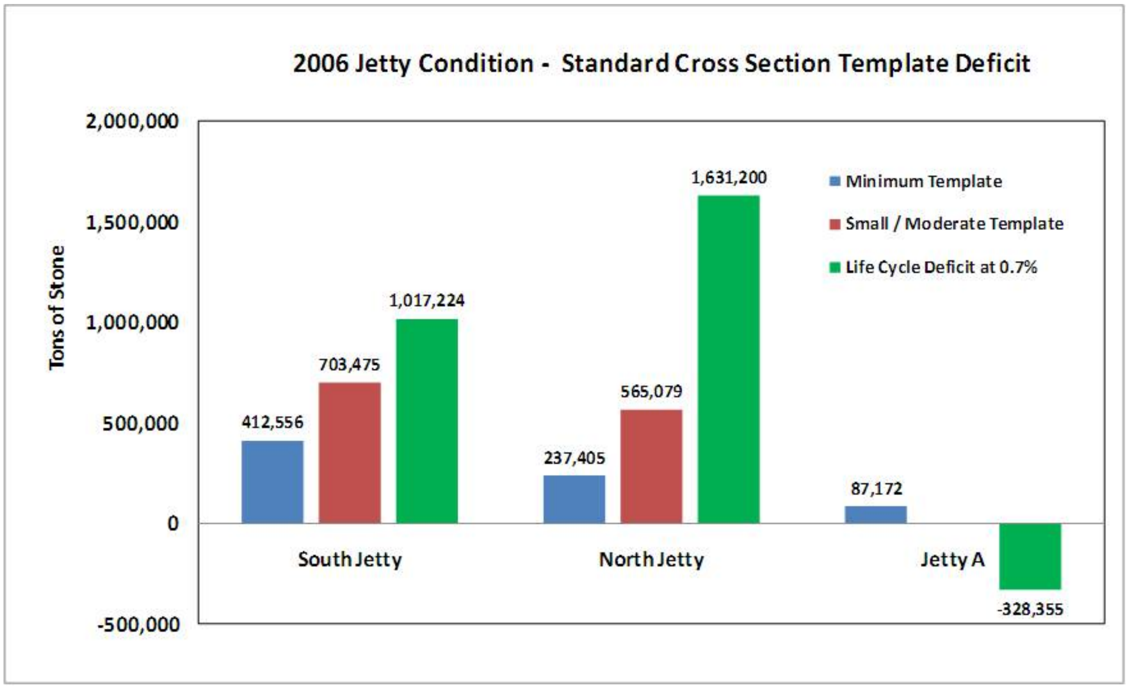


Figure A1- 68. North, South, and Jetty A Standard Cross Section Template Deficit

Crest elevation and jetty length changes are documented in Figure A1- 33 through Figure A1- 35 with respect to a complete project survey conducted in 2000. For the North Jetty, jetty length loss of approximately 2200 ft and significant channelside foundation erosion (up to 60 ft change in depth) impacting approximately the seaward half of the jetty are the most significant. In addition, as shown in Figure A1- 38, the north side of the North Jetty is being increasingly exposed to higher wave and water level conditions due to the erosion of Benson Beach. For the South Jetty, jetty length loss of approximately 6200 ft has worked interactively with ebb tidal shoal changes to increase loading particularly for the seaward half of the structure. The concrete monolith at approximately Station 330 and the channelside spur groins have slowed down the physical morphological changes at that location. Jetty A has lost approximately 900 ft and in addition, a large scour hole at the southern end of the Jetty A head, up to 120 ft depth, has impacted its stability.

Figure A1- 69 illustrates the critical shoals surrounding and supporting the MCR jetties. As previously stated, numerous modifications to these shoals over the project life and continuing today have the potential to impact the stability of the jetties. As the jetties recede, deteriorate, or become breached the adjacent morphology is affected; the inlet and jetties become increasingly exposed to wave and current action. Sediment mobilized from the morphology can increase the MCR O&M dredging requirement.

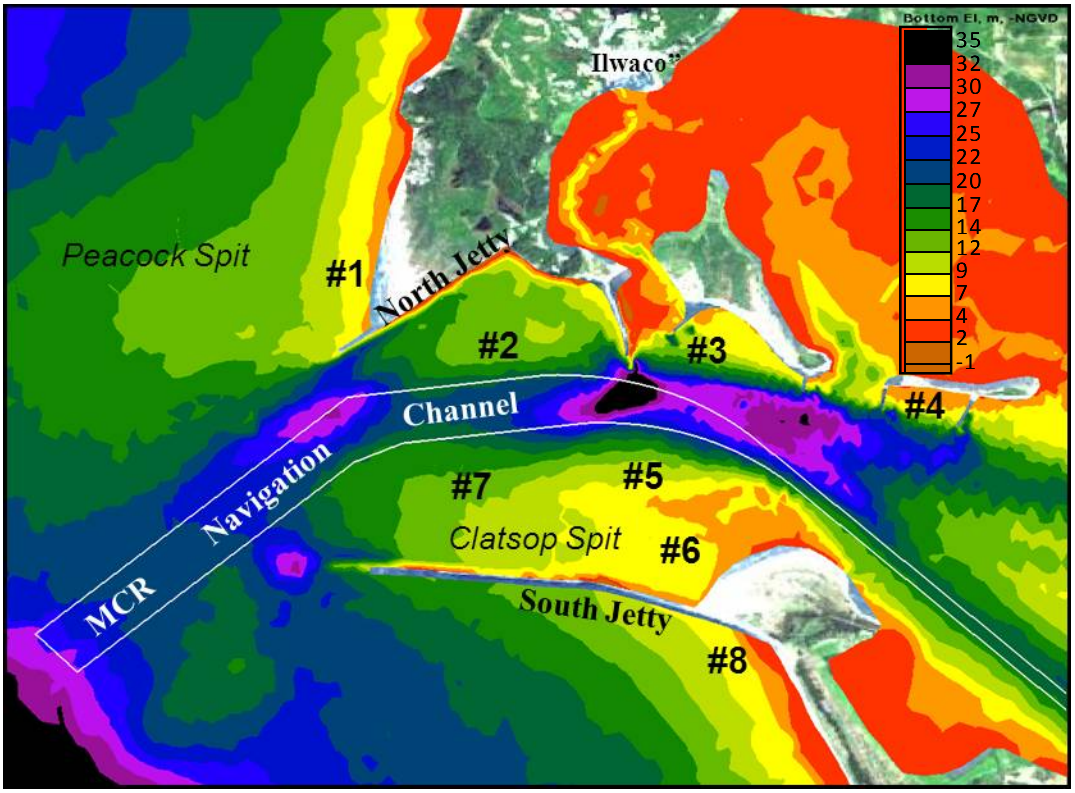


Figure A1- 69. Areas of MCR morphology affected by jetty deterioration

d. Performance of MCR Jetties and Key Structural Elements

The jetties have required periodic and extensive repairs every 20 years to maintain the functional integrity of each jetty. Since initial construction, the North and South jetties have required the placement of 3.62 million tons of stone to maintain the functional integrity of each jetty. Collectively, this represents 43% of the stone used to construct both jetties. The total resources expended to maintain the MCR North and South jetties since "new work" construction is significant because the environment in which the jetties were built is severe and the scale of the jetties is large.

Although considerable resources and effort have been invested to maintain the North and South jetties, the jetties have performed satisfactorily given the environmental setting. Damage sustained by the jetties is a process of both continual and episodic events, much like a linear trend with small steps. Jetty repair actions are not a continual process. They arise infrequently, when the cumulative damages are severe enough as to render the jetty susceptible to complete loss of function. A repair function would resemble an abrupt step-wise trend. Future jetty performance is contingent upon the level of rehabilitation that is now required to re-establish functional integrity.

7. Forcing Environment – General Considerations

a. General

Wave height is the environmental parameter that drives jetty armor layer design. The design of a jetty armor layer is a function of wave height[3] (incident at the jetty). Figure A1- 70 to view how wave height can influence armor unit size (weight). Basic coastal jetty design dictates that the *armor layer* withstands wave action commensurate with the jetty design life-cycle. If a jetty is to have a 50-year life-cycle, the cross section of the jetty (armor layer) should be designed to withstand a wave loading scenario associated with a 50-year event (incident at the jetty). A "50-year event" is an occurrence that is expected to be exceeded, on average, once every 50 years. The annualized probability of a 50-year event is 0.02 (or 1/50). For a coastal jetty, the design event is a combination of various forcing conditions (i.e., offshore wave height, tide level, storm surge, and nearshore bathymetry). A 50-year life-cycle also requires that the jetty foundation should withstand a 50-year cumulative scour potential (corresponding to destabilization of the jetty foundation).

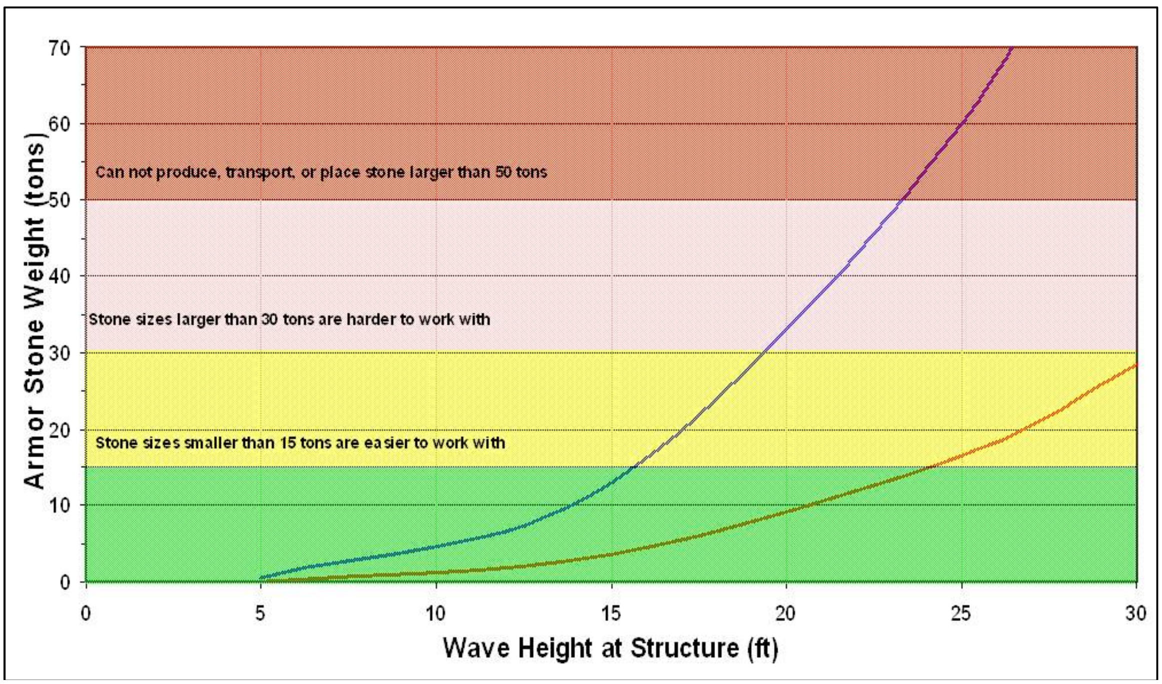


Figure A1- 70. Functional relationship between wave height (H) at jetty and required armor stone size (W), based on the Hudson Equation

(Results are shown for two different scenarios based on a variation in rock density (γ), stability number (Kd), and jetty side slope (θ). The two scenarios effectively define the envelope available for optimizing armor stone size, based on the above design parameters.)

The combination of elevated water levels and storm wave conditions creates an environment of enhanced shoaling and breaking waves that batter the jetties, displacing armor and core stone along areas of the jetties that have been weakened by foundation scour. Portrayal of the physical environment at MCR is essential for understanding the harsh context for which the MCR jetties must function and to develop a reliable description of the forcing environment (waves and tides) that is required to design jetty repairs. The following section describes the general physical environment at MCR and summarizes the forcing environment in terms of the parameters used for jetty (repair) design.

1. Waves Offshore MCR

In the northeast Pacific Ocean, winter-time weather fronts associated with maritime cyclonic storms can extend over the ocean for 1,000 miles and cover a latitude difference of 25 degrees. When these maritime low-pressure systems make land fall on the U.S. Pacific Northwest, the coast can be subjected to hurricane-like conditions: Sustained wind speeds can be greater than 40 knots for fetches greater than 125 miles. The resulting wind stress can produce ocean waves greater than 30 ft high having wave periods (Tp) greater than 16 seconds, and a "set-up" of the mean water level (storm surge of 1-5.5 ft for 1-6 hours duration), depending on storm evolution. Wave heights (Hmo) of up to a maximum of have been recorded at NDBC buoy 46029, located 18 miles offshore the MCR (Figure A1- 71).

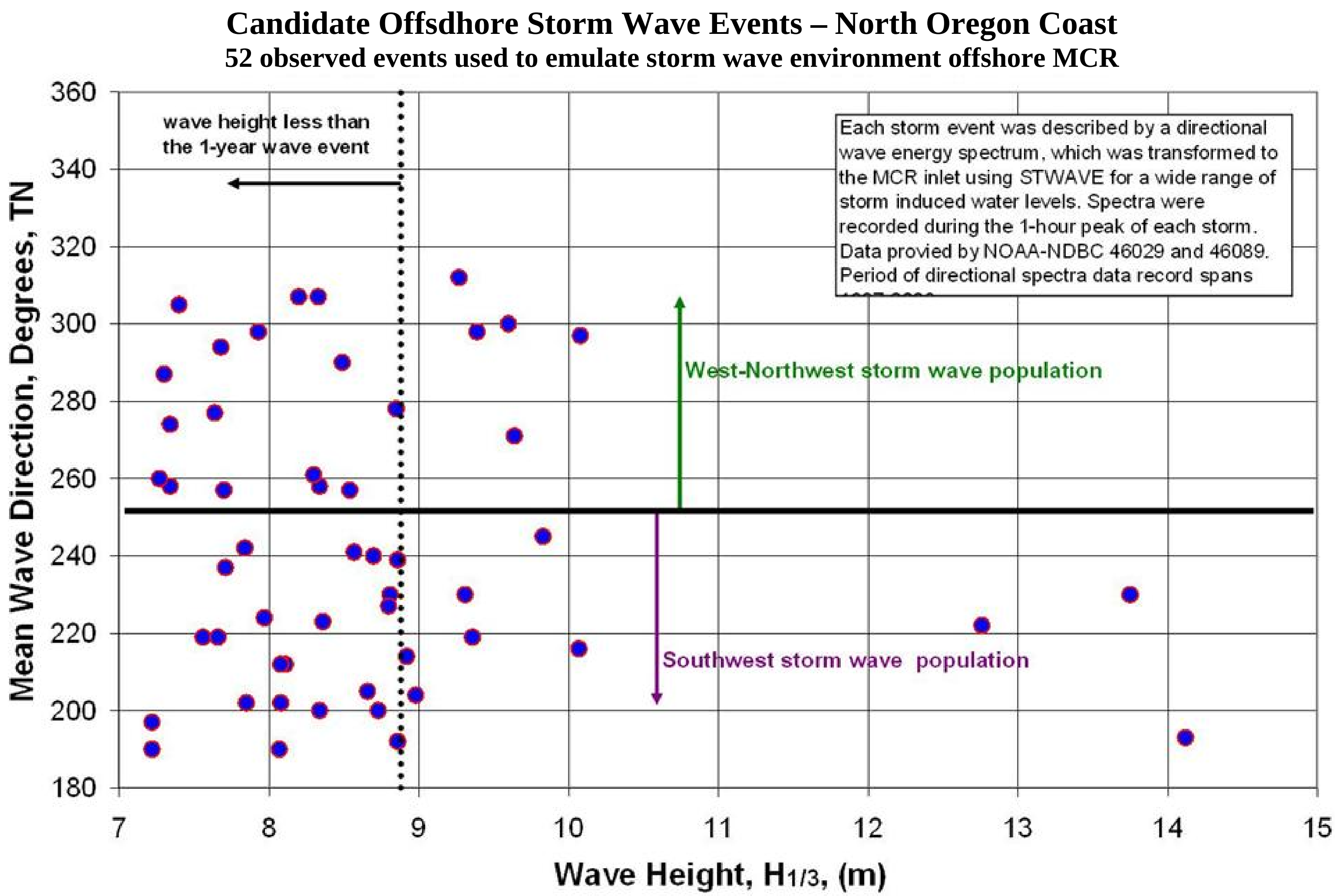


Figure A1- 71. Offshore wave events used to characterize incident wave environment at MCR jetties

The ocean entrance at MCR is characterized by large waves and strong currents and has been considered one of the world's most dangerous coastal inlets [Gonzalez 1984]. The transition from coastal regime to oceanic is abrupt at MCR. Excluding Astoria Canyon, which is about 11 miles (18 km) offshore, the continental shelf break (1,000 ft water depth) lies approximately 18 miles (30 km) offshore from the MCR. The sea state at MCR during storm conditions is characterized by high swell approaching from the northwest to southwest combined with locally generated wind waves from the south to southwest. During October-April, the seasonal average wave height and period is 9 ft (2.7 m) and 12 seconds, respectively. During intense winter storms, waves can exceed 30 ft (9 m). Individual waves having a height of 45-55 ft (trough to crest) were recorded 5 miles south of MCR in water depth of 135 ft [Moritz 2001]. During May-September, average wave height and period is 5 ft (1.5 m) and 9 seconds, respectively. Figure A1-68 illustrates that approximately 70% of all offshore storm waves approaching the MCR are from the west-northwest [Moritz 2007].

2. Waves at MCR Inlet

As waves propagate shoreward toward the MCR, the waves are modified (waves begin to shoal and refract) by the asymmetry of the MCR's underwater morphology. Nearshore currents and tidal currents are also modified by the jetties and the MCR's morphology. These modified currents interact with the shoaling waves to produce a complex and agitated wave environment within the MCR. The asymmetric configuration of the MCR and its morphology is characterized by the significant offshore extent of Peacock Spit on the north side of the North Jetty, southwesterly alignment of the North/South jetties and channel, and the absence of a large shoal on the south side of the MCR. The asymmetry of the MCR causes incoming waves to be focused onto areas which would not otherwise be exposed to direct wave action. An example of this wave-focusing effect is the area along the south side of the North Jetty. Upon initial inspection, it would appear that this area is most susceptible to wave action approaching the MCR from the southwest. However, this is not the case; the opposite is what occurs. The area located between the North Jetty, the navigation channel, and Jetty A is affected by wave action during conditions when the offshore wave direction is from the west-northwest, because of the refractive nature of Peacock Spit. Waves passing over Peacock Spit (approaching from the northwest) are focused to enter the MCR along the south side of the North Jetty. Conversely, large waves approaching the MCR from the southwest are refracted/diffracted (changed in direction) around the South Jetty and over Clatsop Spit, protecting the south side of the North Jetty from large, southerly waves.

3. Time-Varying Changes in Nearshore Wave Climate at MCR

The changes in regional and localized waves at the project site since original construction can be described in two separate categories. The first approach is to look at our understanding of any increasing trends of the regional wave environment associated with variable climate effects. The second approach is to look at the impacts of morphology evolution on the depth-limited characteristics of the waves at the project. Measurements of the deep water wave climate offshore of the MCR project area are available for 1984 to present (NDBC 46029). Analysis of this deep water wave data indicates that height of storm-related waves and frequency of storms may be experiencing an increasing trend. Due to the relatively short data record, it is not known whether this trend is a persistent increase or just a subset of a larger data base of wave heights that experiences a wide range. The data record describes deep water wave conditions. However, the wave heights actually impacting the MCR jetties are shallow water waves, being transformed to shoreward over the nearshore bathymetry. The actual impact (associated with climate variation) on shallow wave heights at the structure will be dampened by the depth-limited wave characteristics of the project site. Wave height is physically reduced as the water gets shallower, oftentimes eliminating any increased increment of wave height by the time it reaches the project. This fact introduces the second element of wave height change over the project life; morphology change at the inlet. If the nearshore bathymetry (submerged shoals) at the project area becomes deeper over time, waves (height) affecting the structure can increase. The opposite is true for morphology accretion.

When the water depth near a structure becomes shallower over time, the depth-limited wave height is reduced. This is why the morphology at the MCR inlet is crucial to the permanence of the jetties: The morphology created by jetty construction protects the jetties from large damaging waves. If the morphology along the jetties recedes excessively, large damaging waves can attack and destabilize the jetties. The wave environment at MCR has evolved in response to the morphology changes induced by jetty construction. Depending on the location at the inlet; the wave environment could be less severe now than at the time of jetty construction. In some cases, the wave environment along a given MCR jetty was reduced or eliminated soon after jetty construction due to rapid accretion of sand shoals. As the accretionary feature was dispersed over time, the wave environment gradually increased to the point of being larger now than at the time of jetty construction. A combined wave and water level modeling approach was applied to account for the evolving nature of the morphology at MCR. The wave modeling effort used numerical modeling (STWAVE) to transform offshore waves to the project site. Jetty life-cycle analysis and design utilized the above wave modeling to estimate waves in the past, present, and future. The depth-limited wave heights at the project increase as the depth along the jetties increase.

4. MCR Tidal Regime and Circulation

Astronomical tides at MCR are mixed semi-diurnal with a diurnal range of 8.5 (2.6m) feet. Twice each day, the MCR is the hydraulic battlefield between two distinct water masses, the freshwater outflow of the Columbia River and the marine inflow from ocean tides. The instantaneous flow rate of estuarine water leaving the MCR during ebb tide can exceed 2 million cfs (70,000 m^3/sec) and the flow rate of marine water entering MCR during flood tide can exceed 1 million cfs (35,000 m^3/sec). Currents within the navigation channel can attain 2.5 meter/sec (5 knots or 8 ft/sec) and are highly variable, in time and space, across the MCR. A large, clockwise-rotating eddy current has been observed to form between the North Jetty, the navigation channel, and Jetty A during ebb tide. A less pronounced counter-clockwise eddy forms in response to flood tide. The North Jetty eddy has varying strength and direction (based on location and timing of tide) ranging from 0.3 to 3.3 feet per second.

In coastal waters immediately adjacent to the MCR, the dynamics of the Columbia River estuary dominates circulation, tending to draw (denser) bottom marine waters into the estuary while discharging low salinity waters (the plume) at the surface. The asymmetry of tidal flow, coastal currents, and wave action in vicinity of MCR is caused by the orientation of bathymetric contours offshore of Peacock and Clatsop spits. The nearshore wave and tidal environment at MCR is greatly affected by Peacock Spit and Clatsop Spit, due to the spits' significant offshore extent (Figure A1- 1 and Figure A1- 2). The orientation of the shoals/spits at MCR has arisen due to interaction of jetties, waves, currents and sand. Figure A1- 72(B) shows a simulated "snap-shot" of the flow pattern at MCR during an ebb tide on 6 October 1997. During ebb tide, much of the primary flow passes through the deeper areas of MCR and impinges on controlling features that boarder the deeps. Figure A1- 72(A) shows the time-averaged flow through MCR during 2-10 October 1997 and highlights the residual circulation (eddies and gyres) that forms within the inlet. Eddies and gyres that form within MCR arise due to the interaction of estuarine and coastal flow with jetties and the morphology. These eddies greatly influence circulation and shoaling within the channel. Detailed simulation of circulation at the MCR was performed using Deflt-3D (Gelfenbaum et al., 2007) and CMS (Kraus et al., 2007). Results of these detailed simulations are described elsewhere in this appendix.

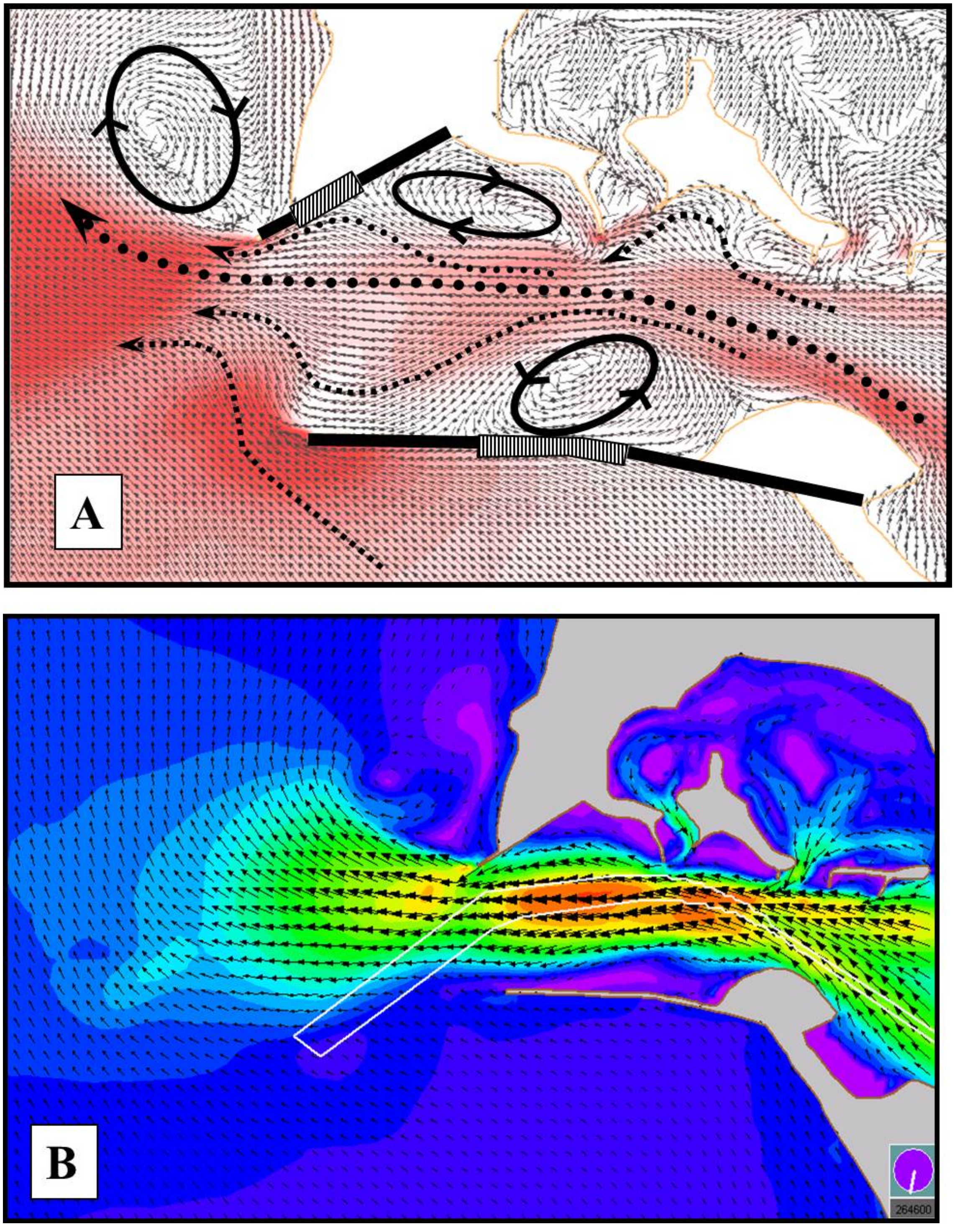


Figure A1- 72. Estimated Average Circulation at Columbia River Mouth & Simulation of Ebb-flow Currents

(A) Estimated average circulation at Columbia River mouth, based on ADCIRC 2-D hydrodynamic computer model, for 1-10 Oct 1997. Eddies and several flowlines shown for clarity. Shaded areas indicate higher current magnitude. (B) Simulation "snapshot" of ebb-flow currents (when tide level is almost at low stand) during 6 Oct 1997, (orange) peak flow is 2.5 m/s

5. Littoral Transport and Ephemeral Morphology at MCR

Historically, the Columbia River has been a major source of sediment to the northwest coast. On the ocean side of the MCR, the inlet is flanked by broad sandy beaches. To the immediate south lies Clatsop spit where the beach is backed by substantial dunes. To the north lie Peacock Spit and a rocky headland (Cape Disappointment), which anchors the shore. The sandy sediment on the southwest Washington and northwest Oregon coastal beaches originated from the Columbia River. Development of navigation at the MCR (jetty construction) has significantly altered the dynamics of the littoral zone and sediment budget near the inlet. The stability of the MCR channel is related to the jetties and the morphology of Peacock Spit and Clatsop Spit (Moritz et al., 2003). Through phased jetty construction from 1885 to 1939 and the associated response of the MCR morphology, the project features at the MCR and the resultant morphology are now mutually dependent, both in terms of structural integrity and project feature functional performance.

On the ocean side of the estuary, marine sand from the coast is transported to the MCR by the north and southbound littoral currents and flood-tidal currents. Previous studies indicate that some of the sand-sized sediments within the lower Columbia River estuary have been transported into the estuary from adjacent nearshore and shelf regions of the Washington and Oregon coasts [Lockett 1962 and Roy et al., 1983]. The Columbia River estuary is being filled not only by river transported sediment, but also by marine sediment entering the MCR by tidally-induced movements of bottom water entering the estuary from the ocean. The littoral dynamics immediately north and south of MCR (within 2-4 miles) are drastically different than at "open coast" areas away from the entrance. Depending on the regional wind field, which varies seasonally and during storms, the "coastal current" north and south from MCR can attain speeds of 1 m/s. The combination of large waves and strong tidal currents can transport large volumes of sediment at MCR. During the course of several tidal cycles (1-2 days), the seabed on MCR tidal shoals can vary by 1-3 ft. As presently authorized by Congress, the MCR navigation channel requires annual O&M dredging of 3-4 million cubic yards (mcy). The dredged material is sand (0.15-0.23 mm) and is placed in open water disposal sites.

b. Definition of Offshore Wave Climate and Water Levels

1. Design Wave Climate - Offshore

An analysis of the wave record at the NOAA-NDBC buoys (during 1984-2008) is the basis for defining the offshore wave environment at MCR [Moritz 2007]. The wave data used in this analysis was extrapolated from an existing, verified record of hourly wave data from the NOAA NDBC buoys #46029 (located 20 NM west of the mouth of the Columbia River (MCR) entrance) and the #46089 (located 60 NM WNW of Tillamook, OR). Data from these buoys was used to create as complete a data record as possible for the period of 1984-2008. Storms in this dataset were initially separated into individual 'blocks' based on a threshold of 4.0 meters. Each 'block' identifies a separate storm event and is defined as the consecutive number of data records for which the wave height exceeded 4.0 meters. In this manner, the individual storm events are kept separate and independent from other storm events. Storm wave events were grouped by *water* year, as opposed to calendar year. Water year is defined as the period from 1 OCT to 30 SEPT of any given year. 1 OCT 2000 to 30 SEPT 2001 is considered water year 2000. This step was taken for consistency with the SRB life-cycle modeling. A given 'year' is synonymous with water year.

A graphical summary of the analysis for all observed storms producing a peak significant offshore wave height >= 4 meters is shown in Figure A1- 73 and Figure A1- 174. Results are based on a partial-duration frequency analysis for a 17-yr period of record using data that was recorded at 1-hour intervals. Data gaps reduced the 24-year duration of observation to a 17-year period of record. Results were extrapolated to a 100-yr frequency of occurrence using a fitted Weibull distribution (k-0.75) and are presented here in terms of an annualized return interval (RI). The expected value for 10-year offshore wave height = 41 ± 6 ft. The offshore wave height expected to be exceeded approximately 5 times within a given year (RI = 0.2) is 22 ft.

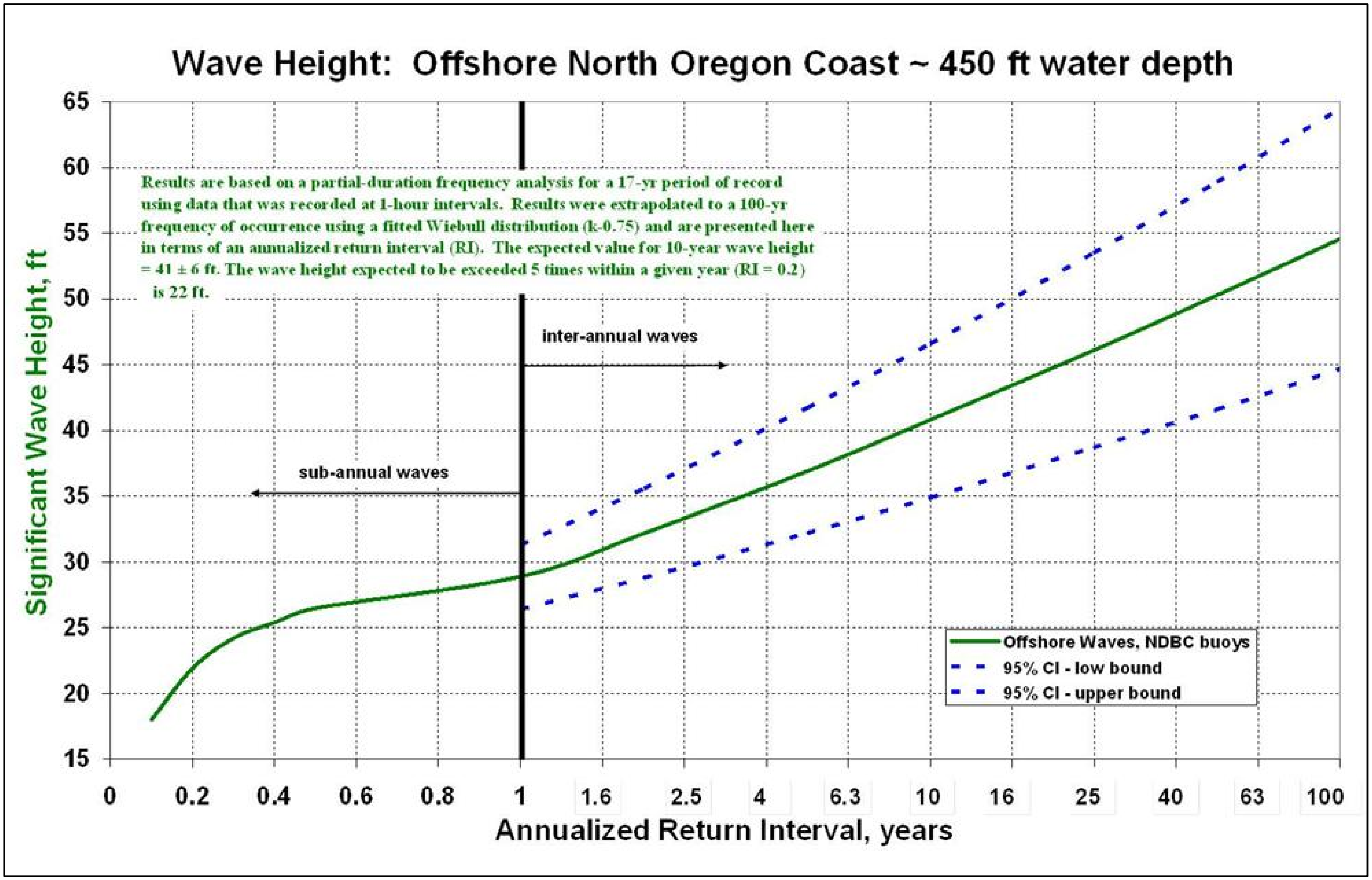


Figure A1- 73. MCR Offshore wave environment expressed in terms of annualized return interval

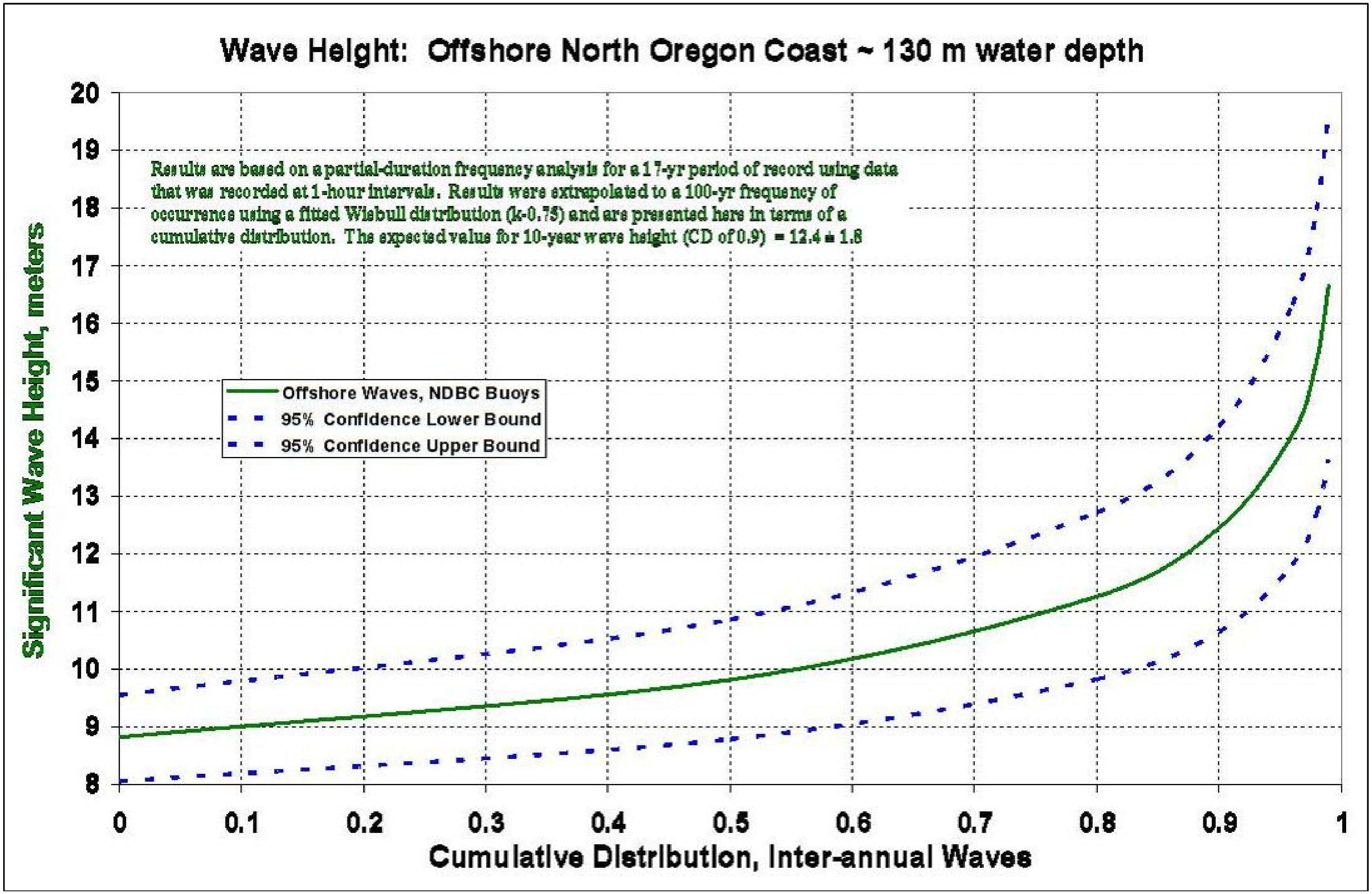


Figure A1- 74. Cumulative distribution for MCR Offshore wave environment

Recall that offshore waves are modified as they travel into shallow water and the water level can have an important effect on nearshore wave modification. This means that the 10-year wave height incident at the MCR jetties will *not* be the same as the offshore 10-year wave. The wave height *at* a jetty is predicated by the offshore (deepwater) wave climate, nearshore bathymetry, and water level. As offshore waves travel close to shore, wave height is limited by the water depth: A higher water level will allow bigger waves to travel closer to shore (or a jetty). This means that water levels (tide + “storm surge”) can have a significant effect on the design wave used for jetty design. Note that offshore gravity wave (swells and seas) conditions are *not* affected by water level variations; the water depth offshore is too deep to have an effect on offshore waves.

A procedure for offshore wave event and water level selection was combined with wave modeling to define the incident wave environment affecting each jetty at MCR. The results from this procedure were used to define the design attributes for jetty repair and rehabilitation, and to drive SRB life-cycle simulations (see Appendix A2).

2. Water Levels at the MCR Coastal Margin

A high water level along the coastal margin allows larger waves to attack a jetty, and topple armor stones if the armor layer is not designed and constructed accordingly. Water levels along the Oregon Coast are primarily a function of astronomical tide influences (Figure A1- 75). “Other factors” that can influence water levels are atmospheric pressure, wind set-up, and wave set-up (Figure A1- 76shows a wave rose for offshore of MCR). Wave set-up can be modulated by infragravity transients, which are low frequency variations of the water surface (1-4 minute period) induced by groups of storm waves (Figure A1- 77). Collectively, these “other factors” are called storm surge; when the observed water level exceeds the predicted tidal water level during storms. The total storm-induced water level (SWL, used for calculation of nearshore wave height) was estimated by adding “storm surge” to predicted tidal water level:

Total storm-induced water level = Water surface elevation due to tides + storm surge

*where S*torm surge = Static component of storm surge + infragravity transients

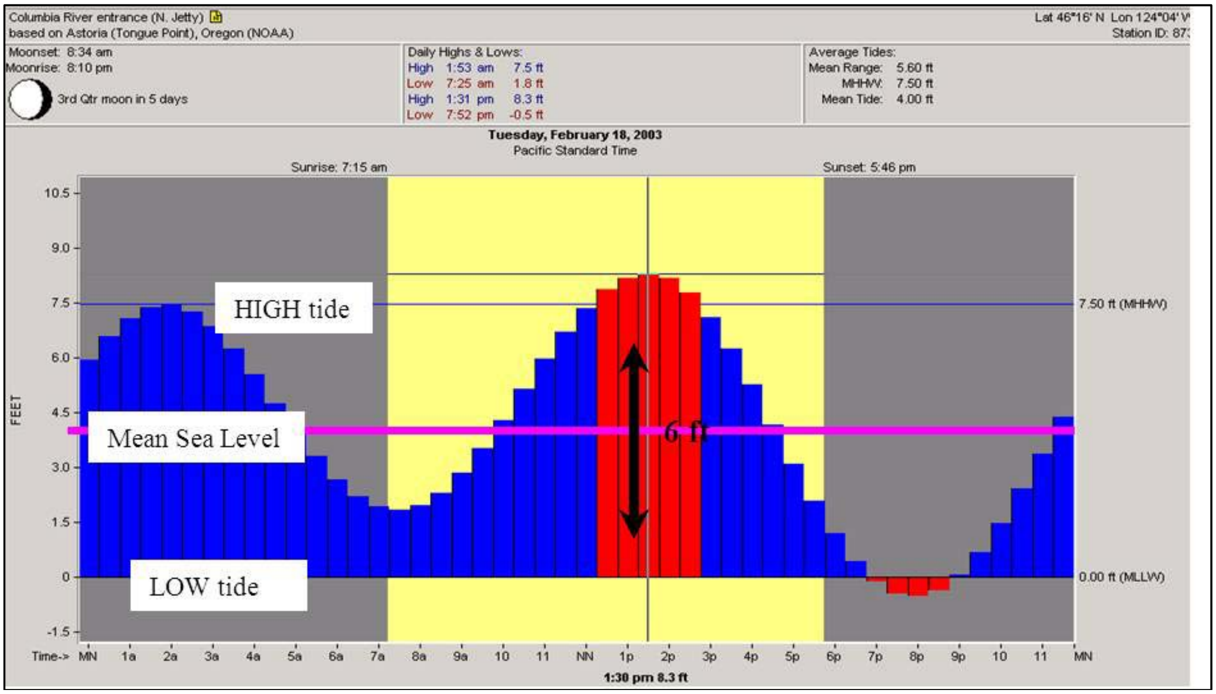


Figure A1- 75. TIDE on NW PAC Coast is Semi-Diurnal

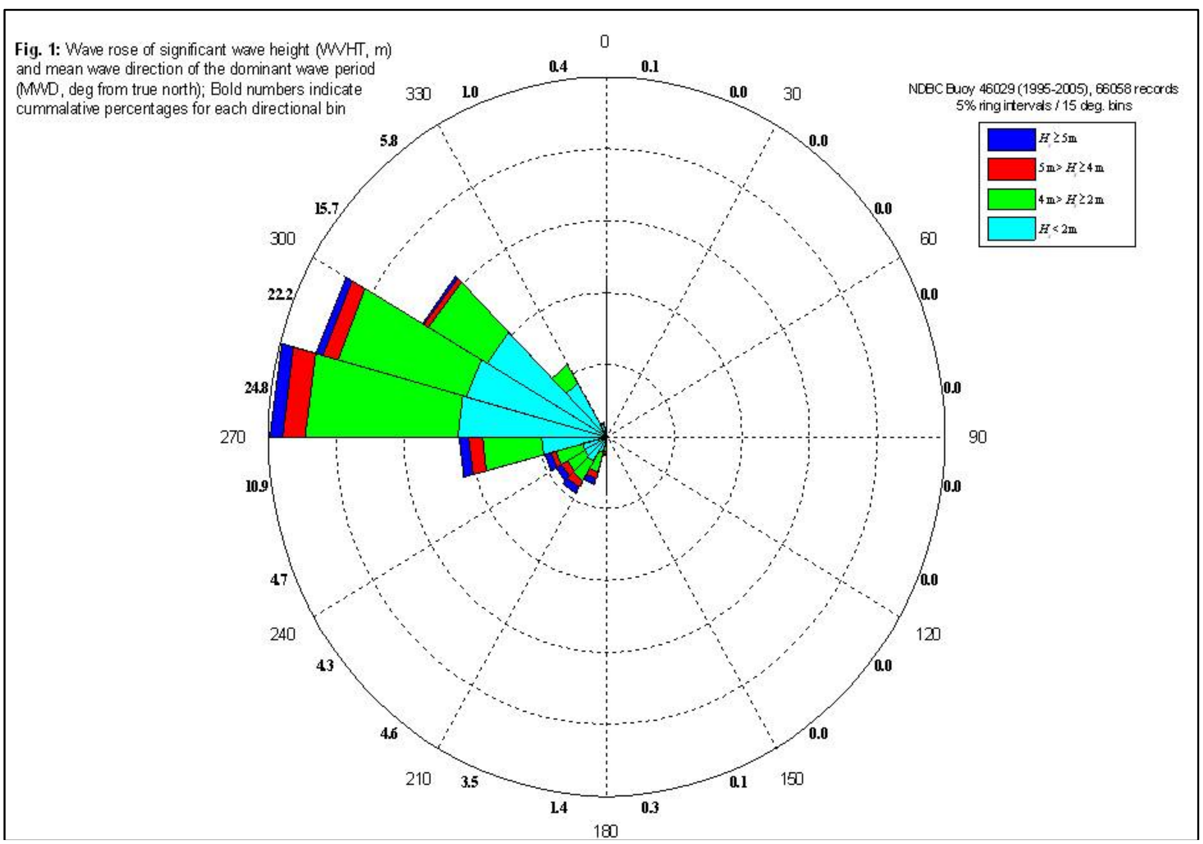


Figure A1- 76. Offshore Wave Rose at MCR

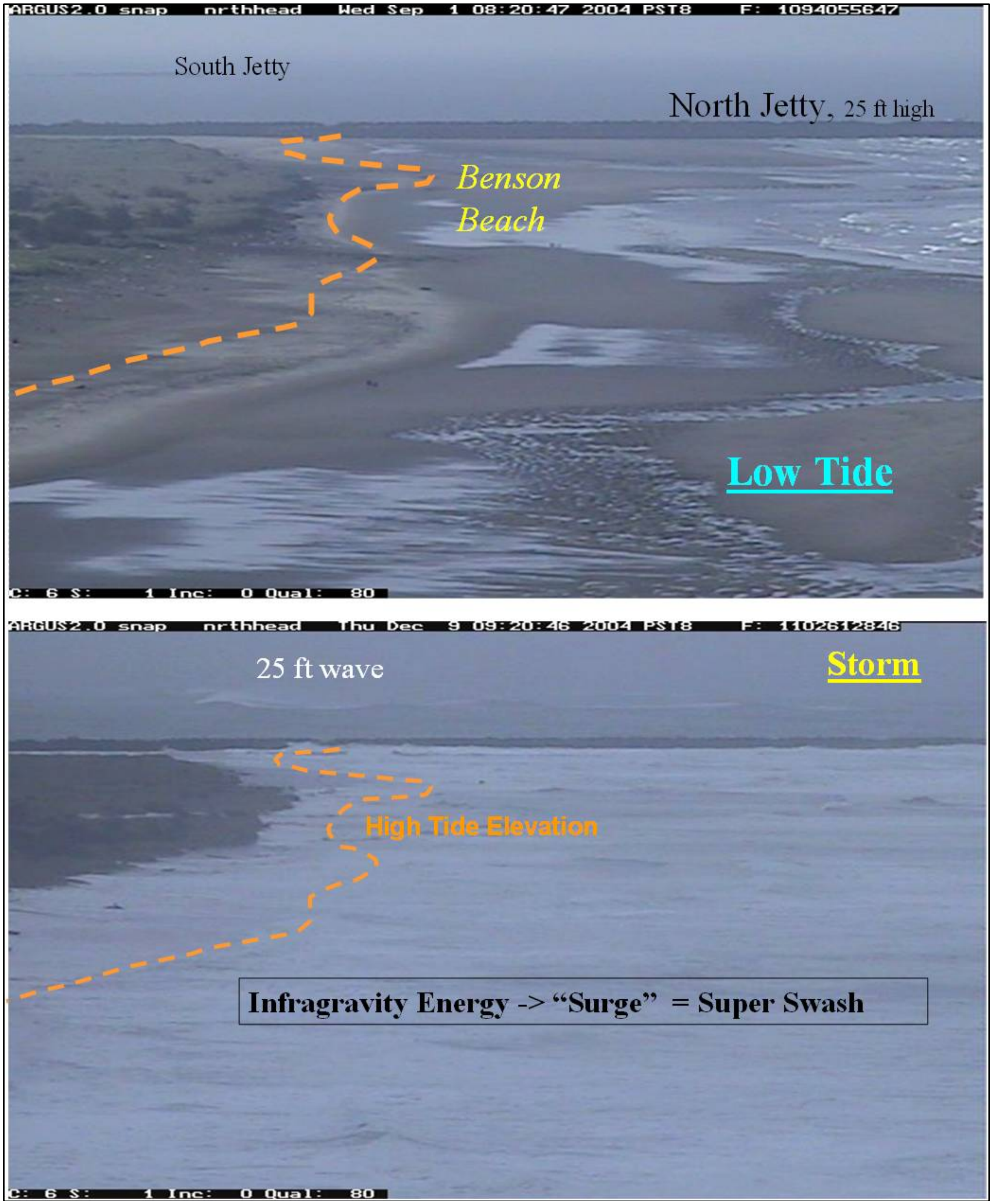


Figure A1- 77. Effects of Storm Water Level on Jetty Root Stability

Image of MCR North Jetty as viewed from the north facing south.. (A) LOW tide @ -5.5 ft NGVD during summer. (B) HIGH tide pus surge @ 14 ft NGVD during winter storm. During elevated water level, large waves attack vulnerable areas of the jetty root. Images from ABMS camera at North head light house.

Figure A1- 78 summarizes the water level components associated with storm events [Moritz 2007]. The time-varying excursion of the water surface elevation (WSE) at the MCR due to TIDE is shown in terms of an annualized percent exceedance for Astoria 1987-2007, applied to the MCR using a 0.87 modulation factor. The hourly high tide level exceeded 10% of the time during a given year = 3.4 ft NGVD (6.9 ft MLLW). The 1% annual high tide is 4.6 ft NGVD (8.1 ft MLLW). 0 MLLW= -3.5 ft NGVD. The estimate for static storm surge is based on a partial-duration frequency analysis for a 20-yr period of record using data that was recorded at Toke Point, WA (1-hr interval). Results were extrapolated to a 100-yr frequency of occurrence and are presented in Figure A1- 78 in terms of a cumulative distribution. The 10-year (0.9) static storm surge = 4.7 ft. Storm-induced Infragravity transient results are based on an estimated cumulative distribution. The 10-year (0.9) estimate for 50 ft water depth = 5 ft. Each component for water level was defined in terms a probability density function (PDF), which was used to for generating a randomized total water level when simulating the life-cycle of MCR jetties within the SRB model (Appendix A2).

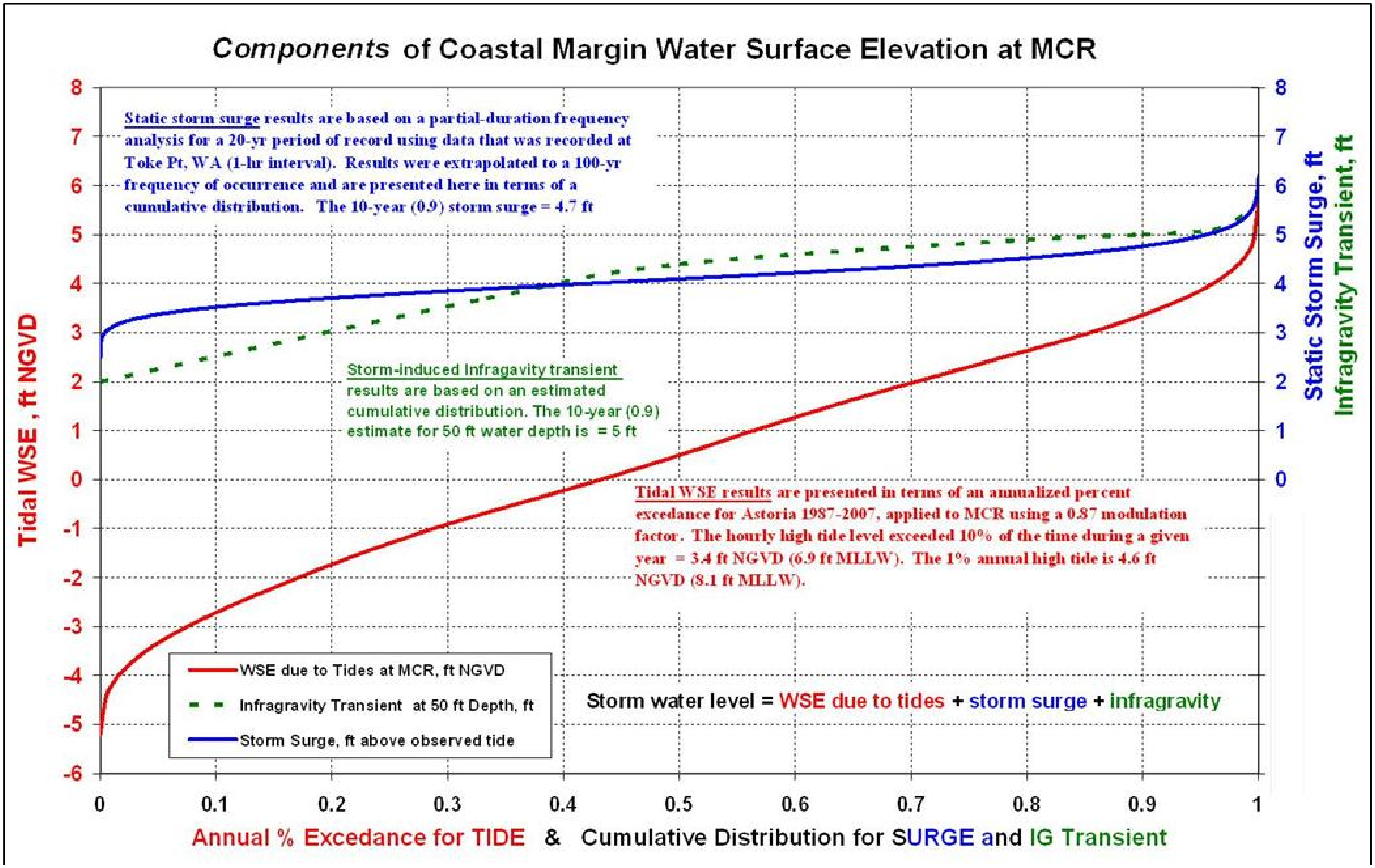


Figure A1- 78. Components of Water Level at MCR

3. Potential for Sea Level Rise

The effect sea level rise was included for assessments of *future* jetty performance at MCR. Future sea level rise estimated within the SRB model as outlined in EC-165-2-211 [USACE 2011]. The EC prescribes a method for defining three future projection curves which are used to bound the estimate for sea level rise over time. The sea level projections (curves) are site specific and are derived based on the historical sea level trend blended with the eustatic effect. EC Curve #1 defines the lowest expected bound for sea level rise, EC Curve #2 defines a "prudent" expected trend, and EC Curve #3 defines the highest expected bound. The sea level projections that were used within the SRB model were based on the NOS station at Astoria, Oregon. Within the SRB model, each jetty life-cycle realization (extending 50 years beyond the base year 2012) was assigned a randomly generated sea level rise trend, which is bounded by EC Curve #1 (-0.2 ft) and EC Curve #3 (1.8 ft; see Figure A1- 79). A total nearshore water level is estimated for each storm by adding the estimated sea level rise (for a given year, i) to the nearshore storm-induce water level, described above. Sea level rise effects were not included within the historical assessment of jetty performance (hindcast).

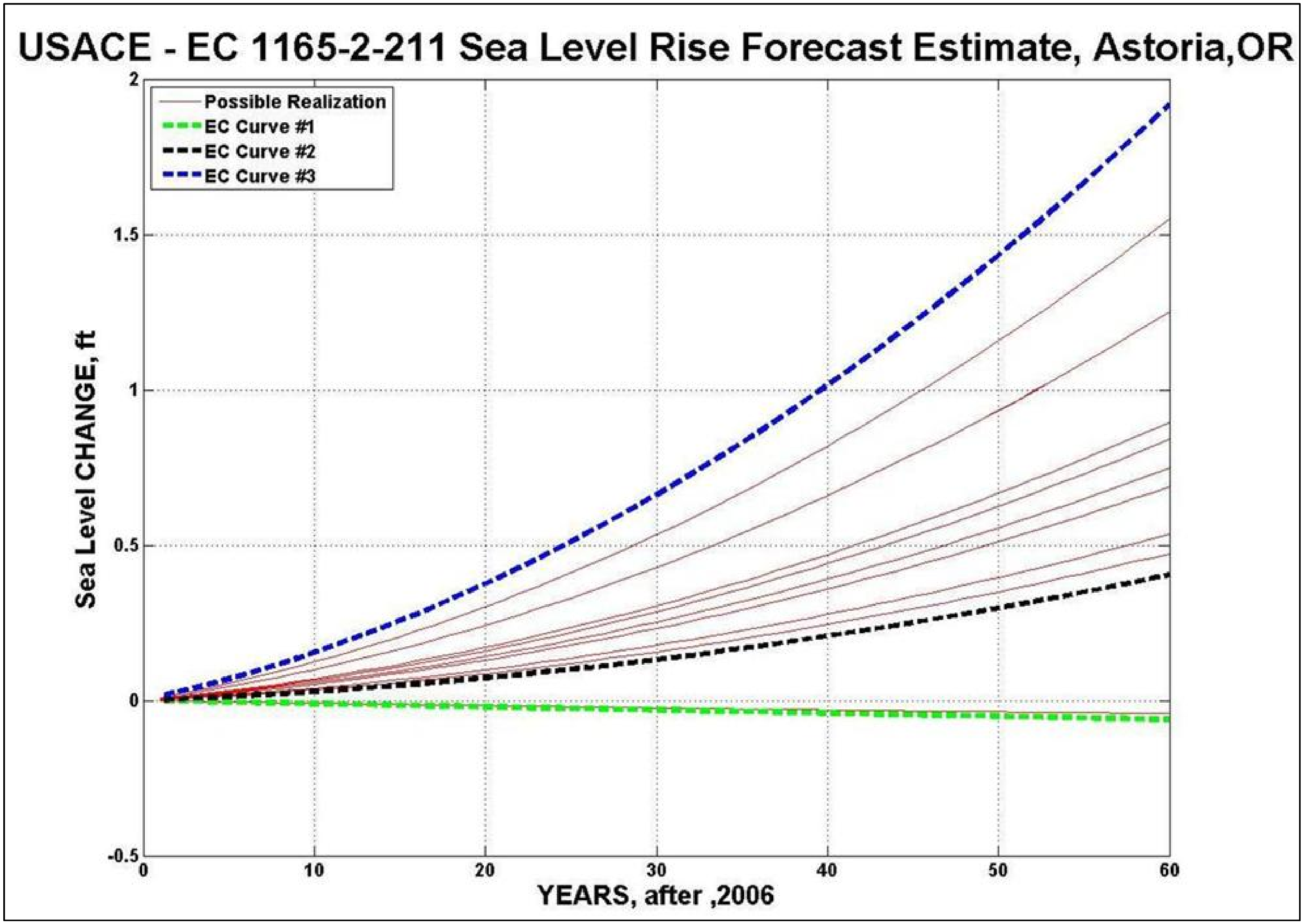


Figure A1- 79. Example of Sea Level Rise Realizations used in Life Cycle Analysis

c. Definition of Wave Climate at the Jetties

The storm wave "climate" affecting each MCR jetty was estimated by synthesizing the offshore storm wave environment in terms of a series of observed wave events. Each offshore wave event was described in terms of a directional wave spectrum. A phased-average spectral wave model was used to transform the candidate offshore wave events to various locations along each jetty, for a range of water levels.

1. Selection of Offshore Wave Events

For this analysis, the candidate storm events were defined when the wave heights within each storm 'block' exceed a threshold (7.0 meters). The largest 84 storms on record were identified for the period spanning 1984 to 2008. A peak over threshold analysis determined that storms having wave height ≧ 7 meters occur 1-11 times per year, having a MLE (Maximum Likelihood Estimate) of 4.5 times per year. A peak over threshold analysis focuses the extremal analysis on only those events which cross the defined threshold. The re-occurrence for offshore wave height (Hsig) > 7 meters was emulated using a GEVD (Generalized Extreme Value Distribution) PDF. Years in which no extreme storm events were recorded were omitted from the PDF estimate. The reason for this is that some years did not include a complete data record for the year. An extreme storm still may have occurred that year, but was not recorded.

Out of a total of 84 candidate storms, a total of 52 peak wave height events were recorded in terms of reliable directional spectra (input used for modeling the transformation of offshore waves to the nearshore). Each spectrum was tagged to a specific modal wave height (Hmo), wave period (Tp), and wave direction (Dp). Figure A1- 71 summarizes the 52 selected storms. All events with a return period greater than 1-year were utilized. The buoy data was synthesized to produce a data-base of candidate storm wave events, used to emulate the annual offshore storm wave climate. Each candidate storm event was portrayed by an observed "real world" offshore directional wave spectrum, using the NDBC spectral amplitude and Fourier coefficients. Each directional wave spectrum (52 events) was described by a wave frequency range spanning 0.03 to 0.35 Hz (using a frequency increment of 0.01). Directional resolution of each wave spectrum was defined by 5-degree increments spanning 185 to 355 degrees AZ (TN). STWAVE [Smith et al 2001] was used to simulate the propagation of each candidate wave event, from the offshore observation point (NDBC buoy) to specific points along each jetty.

To account for the effect that water level can have on nearshore wave height, total nearshore water level was developed from a superposition of variably-correlated random components featuring tide, static storm surge, and infra-gravity transient. STWAVE simulations were performed for each offshore wave event using two nearshore storm-induced water levels: An extreme low (0.4 m MLLW), a median (8.5 ft), and extreme high water level (4.8 m MLLW) were used. The low water level (used for wave modeling) was based on: 10% annual exceedance for astronomical tide WSE = -2.7 ft NGVD + a value of 0 ft for static storm surge = 0 ft + a sub-annual exceedance for infragravity transient = 0.5 ft. The median water level is based on 50% annual exceedance of astronomical tide which is 4.5 ft NGVD, a sub-1 year value of static storm surge (2.5 ft) and a sub-one year value for infragravity surge (2 ft). The high water level (used for wave modeling) was based on: 90% annual exceedance for astronomical tide WSE = 3.4 ft NGVD + a 10-year value for static storm surge = 4.8 ft + a 2-year value for infragravity transient = 4 ft.

2. STWAVE - Wave Transformation Modeling

The wave environment incident *at* the MCR north and south jetties was estimated using a numerical model, STWAVE [Smith et al., 2001]. STWAVE (STeady-State spectral WAVE) is a computer model used to simulate the two-dimensional propagation of a wave field as it travels through winds and current, and encounters variable bathymetry. STWAVE simulates depth-induced wave refraction and shoaling, current-induced refraction and shoaling, depth- and steepness-induced wave breaking, wind-wave growth, wave-wave interaction, and white capping that redistribute and dissipate energy in a growing wave field [Smith et al., 2001]. STWAVE use the wave action conservation equation, solved in the frequency domain using phase averaging to simulate wave propagation. This means that STWAVE neglects changes in wave phase and superposition of waves having different phases is not performed; results for wave height (hmo at a specific x,y location) are phase averaged. Phase-averaging limits these models from directly solving for wave diffraction and reflection caused by bathymetric features and surface piercing structures. However, approximation methods have been incorporated into STWAVE to indirectly account for wave diffraction and reflection. STWAVE has been applied at various inlets in the Pacific northwest with excellent agreement between model results and prototype data. Refer to Smith et al. (2003) for additional details.

Applying STWAVE requires several steps: A) create the model's computational "domain" by adapting the bathymetry of interest to form a numerical grid, B) obtain directional wave spectra to "force" the offshore boundary of the STWAVE model, C) run the STWAVE model; the offshore wave data is transformed through the model domain to estimate the nearshore wave conditions throughout the domain and at specified points of interest, and D) post-process the STWAVE output, if needed.

3. Bathymetry

The bathymetry data used in any wave modeling effort is the primary factor that controls the accuracy and legitimacy of model output. Imposing the correct and best bathymetry is a necessary condition to achieve reliable wave model results. Strict attention to detail and much effort was expended to develop a bathymetry data set for use in the subject STWAVE model. Bathymetry for the area surrounding the MCR was compiled from different sets of survey data, based on the most recent and detailed surveys available. A composite bathymetry data set was produced from data collected using three different survey methods during 2003-2007 (as mentioned in Section 6(b)).

1. Conventional single beam fathometry was used to survey bathymetry within and outside the main inlet of the MCR. The conventional bathymetry survey was controlled using DGPS and NOAA tidal corrector.
2. Multi-beam fathometry was used to survey the submerged areas of the jetties. The multi-beam survey was controlled using RTK-DGPS.
3. Controlled aerial topographic mapping was used to survey the exposed (subareal) areas of the jetties. The aerial photography that was used for topographic mapping of the jetties was controlled using ground reference points with the aircraft camera being tracked using RTK-DGPS with an inertial measurement unit.

The average resolution for bathymetry surveys conducted within and outside the inlet was 70 m, having horizontal and vertical accuracy of ± 0.5 m and ± 0.3 m, respectively.

The bathymetry data was adapted to an STWAVE grid to form a highly resolved computational domain of 33 km x 37 km (offshore distance x alongshore distance). The cell size used to generate the STWAVE grid domain was 20 meters (making the STWAVE grid dimensions = 1650 cells x 1850 cells). The overall area for which STWAVE was applied, is shown in Figure A1- 70 and Figure A1- 80. The vertical datum of STWAVE bathymetry was based on NGVD.

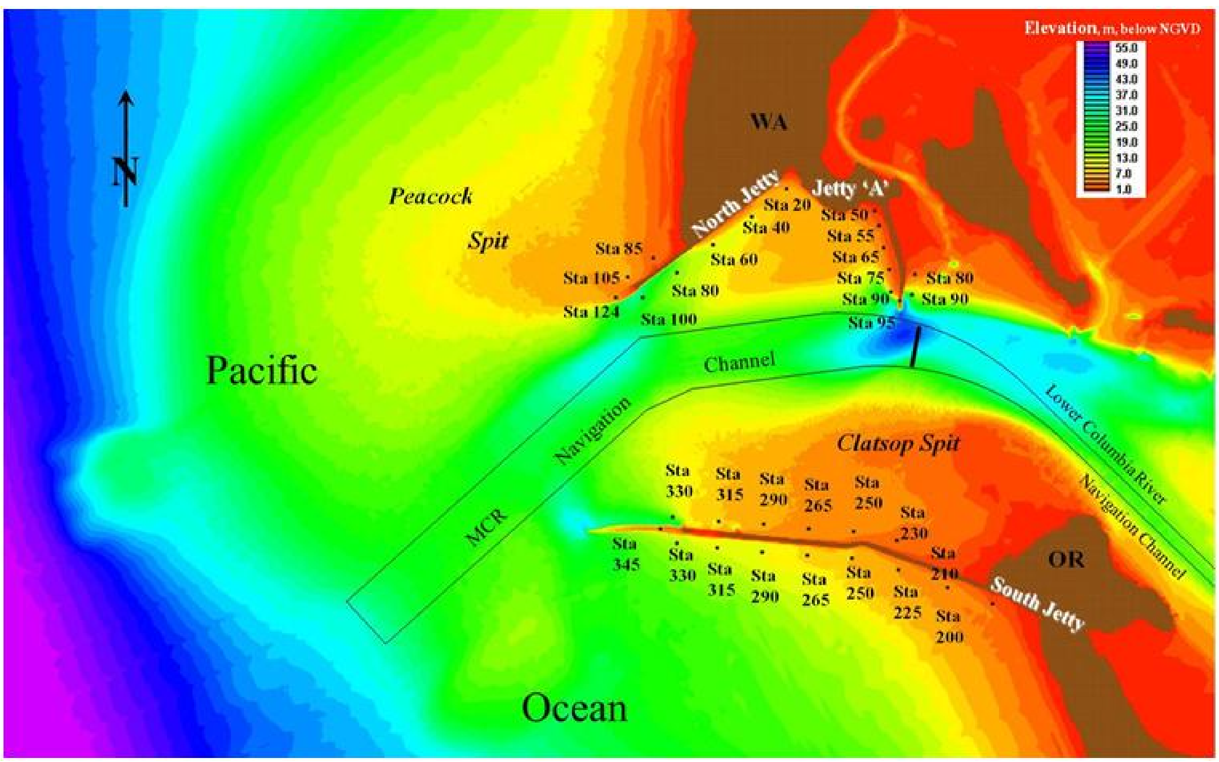


Figure A1- 80. Close-up View of MCR Bathymetry as Described in STWAVE Model

Area shown is 10 km (north-south) x 15 km (east-west). Distance between north and south jetties is 3 km. Survey data is a composite from 2003-2007. Figures A2- - show STWAVE results obtained for each of the 52 wave conditions. Figures A-10 & A-11 specify the wave height, at each of the "points" shown along the jetties, for the 52 storms modeled using STWAVE.

The markers shown in Figure A1- 80 (along the jetties) were used as "observation points" to record wave height output from each STWAVE run. Each observation point is 300-400 ft away from the jetty. Fifty-two (52) different STWAVE runs were made, each using a different offshore wave (boundary) condition and two water levels, as described above. The effect of current was not included in the STWAVE modeling. The presence of a strong ebb current (2 m/sec) can cause opposing waves with short period (less than 9 seconds) to increase in height, through steepening. However, large storm waves (design waves used for jetty design) have periods greater than 14 seconds, are depth limited at the MCR jetties, and are not susceptible to significant steepening in the presence of an ebb current of 2 m/sec. Ebb currents occur near the time of low point tide, which means that water depth is reduced, restricting depth-limited waves more than during a high-tide water elevation.

4. Offshore Wave Field - STWAVE Boundary Conditions

Fifty-two wave fields were selected to represent the range of storm wave conditions offshore of the MCR (Figure A1- 71). The wave fields were used to "force" the offshore boundary condition for the STWAVE model. The range in characteristics of wave energy (wave period, height and direction) that affects the MCR was included in the candidate wave fields. The intensity of modeled offshore wave conditions ranged from a 50-year wave (2% offshore wave event) to an event that occurs approximately 5 times, on average, every winter. Each selected wave condition represents a distinctive type of wave field as described by its directional spectrum (example shown in Figure A1- 81). Some of the candidate wave fields describe conditions that have been generated primarily by large storms far offshore, creating "swells" that come from a specific direction with high energy and low frequency. Other wave fields represent conditions that are dominated by locally generated "seas," waves with a larger range of frequency and direction. Most are a combination of these two sources, with varying degrees of influence from each. This diversity of storm characteristics in the different wave scenarios ensures that all wave events likely to occur at the MCR have been considered.

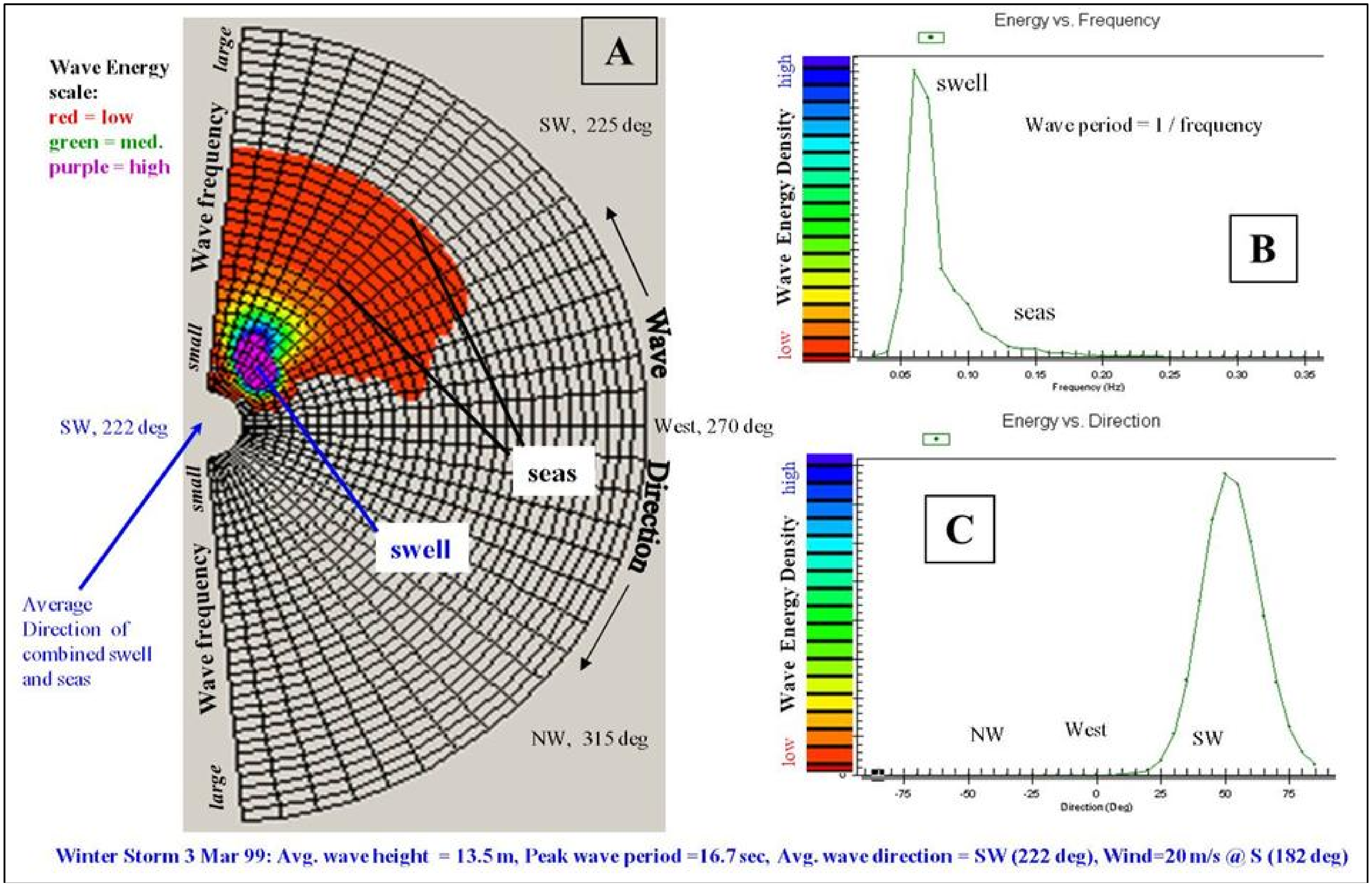


Figure A1- 81. Offshore energy spectrum for waves composed of swell and seas (NDBC 46029)

Graphic (A) shows the wave energy distribution in terms of wave direction and frequency. Graphic (B) is a x-section thru the areas of maximum energy, along the frequency axis in (A), to show where the most energy is in terms of frequency. Graphic (C) is an x-section thru the areas of maximum energy, along the direction axis in (A), to show where the most energy is in terms of wave direction. The wave field is dominated by swell within a narrow frequency range (wave period = 15-20 seconds) from the Southwest.

5. STWAVE Results

STWAVE transformed each offshore wave field (boundary condition) through the model domain, to generate nearshore wave conditions based on the bathymetry and water level that was imposed within the model. The computed nearshore wave environment is a function of the offshore wave boundary condition and bathymetry within the model domain. It must be emphasized that the wave conditions inshore (say at a water depth of 60 ft) are not the same as offshore (200 ft) due to wave shoaling, wave-wave interaction, wind and wave interaction, and wave breaking. The 10-year wave height incident at a specific jetty location may conform to a sub-annual offshore wave event. This is the case in reality and it is also simulated by STWAVE. In some cases, the wave height along specific areas of the MCR jetties is depth limited, especially for low storm event water levels. Wave height provided by STWAVE is Hmo (wave height at the peak of the spectral density), whereas the wave height normally used in design of coastal infrastructure is Hs (average of the highest 1/3 wave heights). Several post-processing steps were applied to reconcile Hmo to Hs. At each of the STWAVE observation points (32), the local wave conditions (zero-eth moment wave height, H_{mo}, peak wave period, T_p, wave direction and wave breaking index) were extracted from the STWAVE output. The wave breaking index determines if a wave is breaking based on the following wave steepness computation:

$$H_{mo_{max}} = 0.1L\tanh(kd) \qquad [1]$$

where L is the wavelength, k is the wave number and d is the water depth at that location and accounts for water level variations.

Additional processing of the data yielded the significant wave height, H_s, and the depth limited breaking wave height, H_b. The significant wave height is the average of the largest 1/3 waves observed at a location. The depth limited breaking wave height is a function of the water depth, typically presented as $H_b = \gamma * d$, where γ can vary, but is 0.78 in this analysis. A value for γ of 0.78 is typically used for long, mild slope beaches. The final wave heights selected from this analysis, H_{final}, were chosen from H_{mo}, H_s and H_b. This was a two-step process. First, if the wave was determined to be breaking using the STWAVE criteria, then $H_{final} = H_{mo}$ for that wave case and location. Second, if the wave was not breaking, then H_s was computed from H_{mo} using equation 2:

$$e^{0.00136\left(\frac{d}{9.8/Tp^2}\right)^{-0.834}} \qquad [2]$$

H_s was further examined to ensure that it did not exceed H_b at that location. In this situation, H_{final} = minimum $[H_s, H_b]$. The H_{final} wave heights were ranked in ascending order and probability of non-exceedance plots were produced for each side of each jetty, for a total of six probability plots.

Example results of nearshore computed wave height estimates are shown Figure A1- 82(A) and (B). Note the protected areas on Clatsop Spit, in the lee of the South Jetty during southerly storm wave events. The opposite is true for waves approaching from the NNW. The windward areas along the South Jetty are subject to larger incident waves. The situation along the North Jetty (south side) is more complex due to the local bathymetry of the inlet. Peacock Spit protects the northern half of MCR from significant nearshore wave activity by causing waves to break before making landfall, during large offshore wave events. During events when offshore wave action is less severe, Peacock Spit causes waves to shoal and grow as they approach landfall. Depending upon the wave direction and period (and location at the MCR), there can be times when a "lesser" offshore wave condition can produce larger nearshore waves than a severe offshore wave condition. This is the reason for a detailed wave transformation model (like STWAVE) using a variety of offshore wave conditions when trying to define design wave conditions nearshore (incident to the jetties).

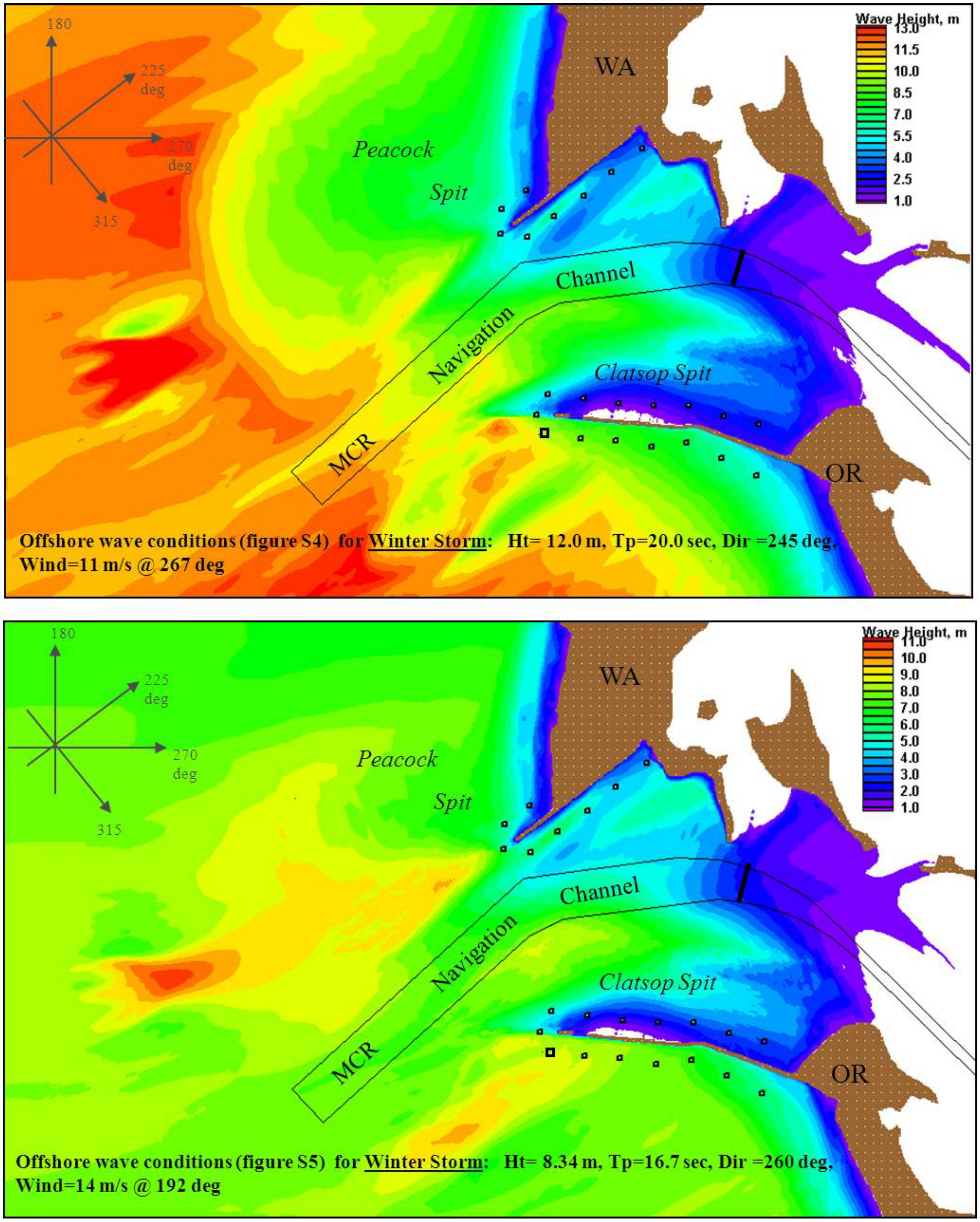


Figure A1- 82. STWAVE Model Simulation of Nearshore Wave Height at MCR for 2 of the 52 Wave Events

Note depth limitation (by breaking) of waves offshore Peacock Spit and south of south jetty. North side of south jetty is protected large swells

d. Summary of Wave Environment Estimated for MCR Jetties

STWAVE-based estimates for wave height were made for each of the 32 observation points located along the North and South jetties for each of the 52 offshore wave conditions and three water levels. Rather than presenting meaningless and confounding tabular results, the results for each observation point were rank-ordered and presented in terms of a cumulative distribution (Figure A1- 83 through Figure A1- 88). The cumulative distribution allows one to view the data in terms of a percent exceedance reference. Design values for nearshore wave height can be selected, in the same manner as offshore waves can be selected. Recall that the 52 offshore wave boundary conditions included a range between a 25-year event and sub-annual (<1-year) event, and that the expected life-cycle for interim repairs is 10-25 years. The design wave heights along each jetty (to be used for calculating armor stone sizes for future repairs) were selected based on the 0.7 to 0.9 value of exceedance (cumulative distribution). Rehabilitation elements affected by incident wave height were designed using a CD (Cumulative Distribution) of 1.0. Results are shown in Table A1- 4.

e. Life-Cycle Simulation of Annualized Wave and Water Level Environment

Stochastic Risk-based (SRB) life-cycle modeling was performed for each jetty, as described in Appendix A2. The SRB model utilized STWAVE results as summarized here. For each storm event within a given simulation year, the SRB model uses appropriate PDFs to generate random estimates for offshore wave height, period, and direction. A best match realization is selected from the data-base of candidate storms. The nearshore transformations of offshore candidate storms to the jetties were performed a priori for extreme high, median, and low total water levels. The SRB model applies appropriate water level components PDFs to generate a randomized total nearshore water level which is associated with the realized storm event. The event-based water level is used to interpolate from within the range of STWAVE solutions for extreme water levels associated with candidate storm. This series of steps produces the combined wave and water level environment along the jetty for a given storm event. The calculated storm wave environment along the jetty is modified based upon the present morphological stage within the jetty life-cycle being simulated. The wave event is used to estimate jetty damage by accessing the appropriate damage function and reliability is calculated. This process is repeated for each storm event within a given year. Recall, that there can be 1 to 11 storm events randomly occurring per year. The above stochastic approach accounts for variation of: A) annual storm climate (numbers of storms per year), B) individual storm wave parameters (height, direction, period), C) the superposition of water level components (tide, storm surge, and infra-gravity transients), and D) the evolving morphological stage of the inlet which was estimated using historical bathymetry data.

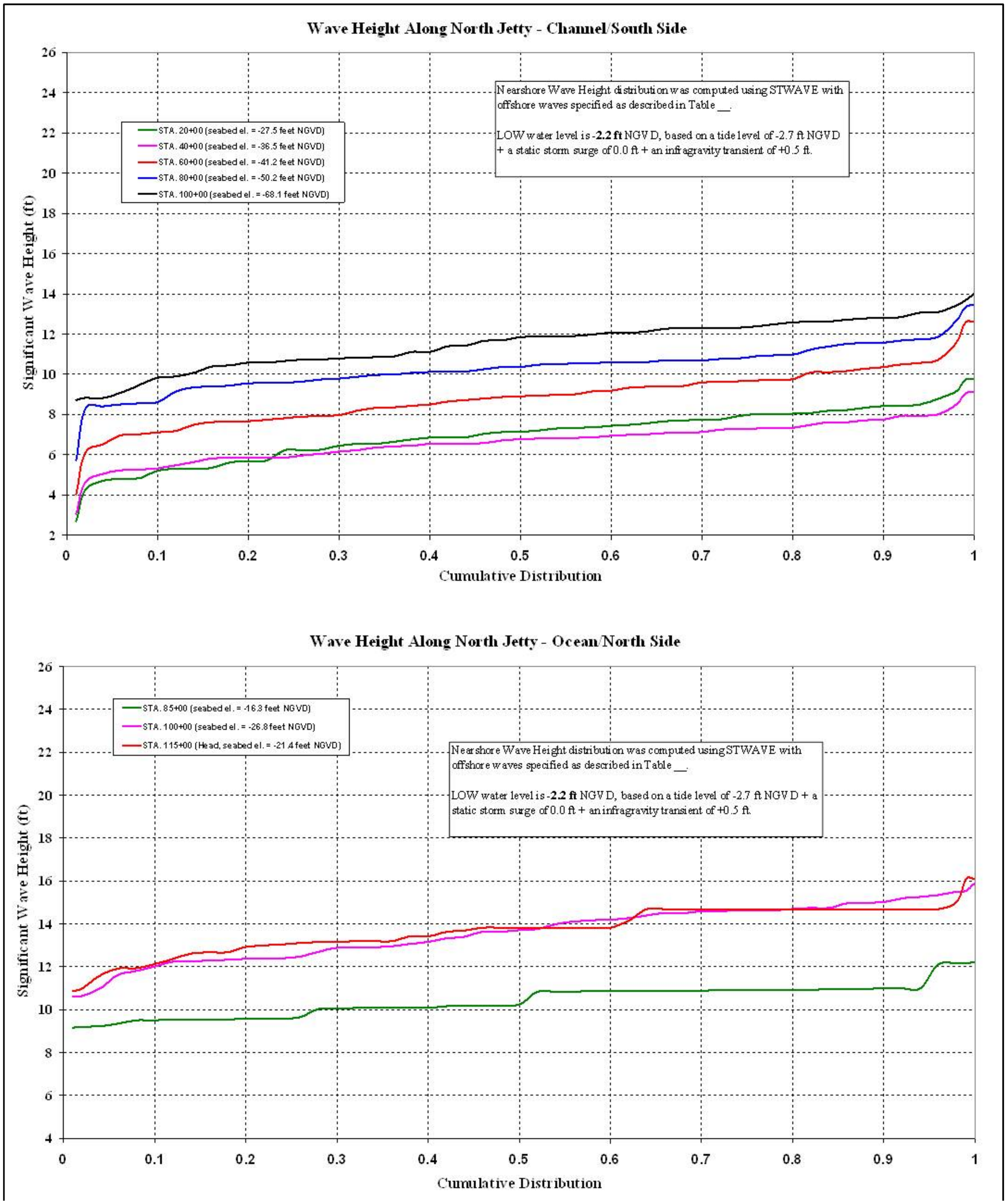


Figure A1- 83. Cumulative Distribution for Wave Height at MCR NORTH Jetty for LOW Water Level (WSE @ -2.2 ft NGVD

(A) is south side of jetty. (B) is north side of jetty. Values were estimated using the STWAVE model to transform offshore wave conditions for 52 storm wave events.

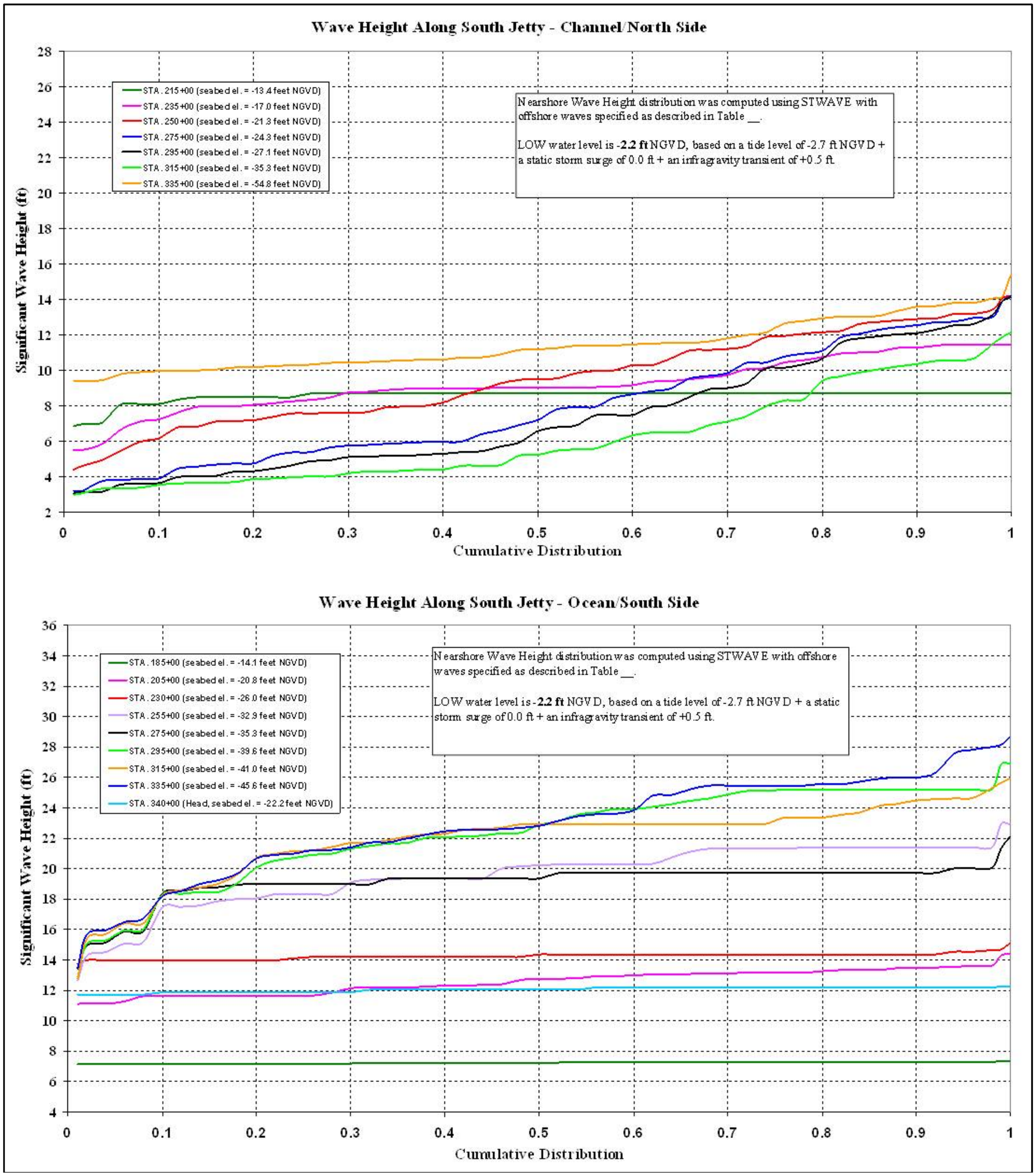


Figure A1- 84. Cumulative Distribution for Wave Height at MCR SOUTH Jetty for LOW Water Level (WSE @ -2.2 ft NGVD)

(A) is south side of jetty. (B) is north side of jetty. Values were estimated using the STWAVE model to transform offshore wave conditions for 52 storm wave events.

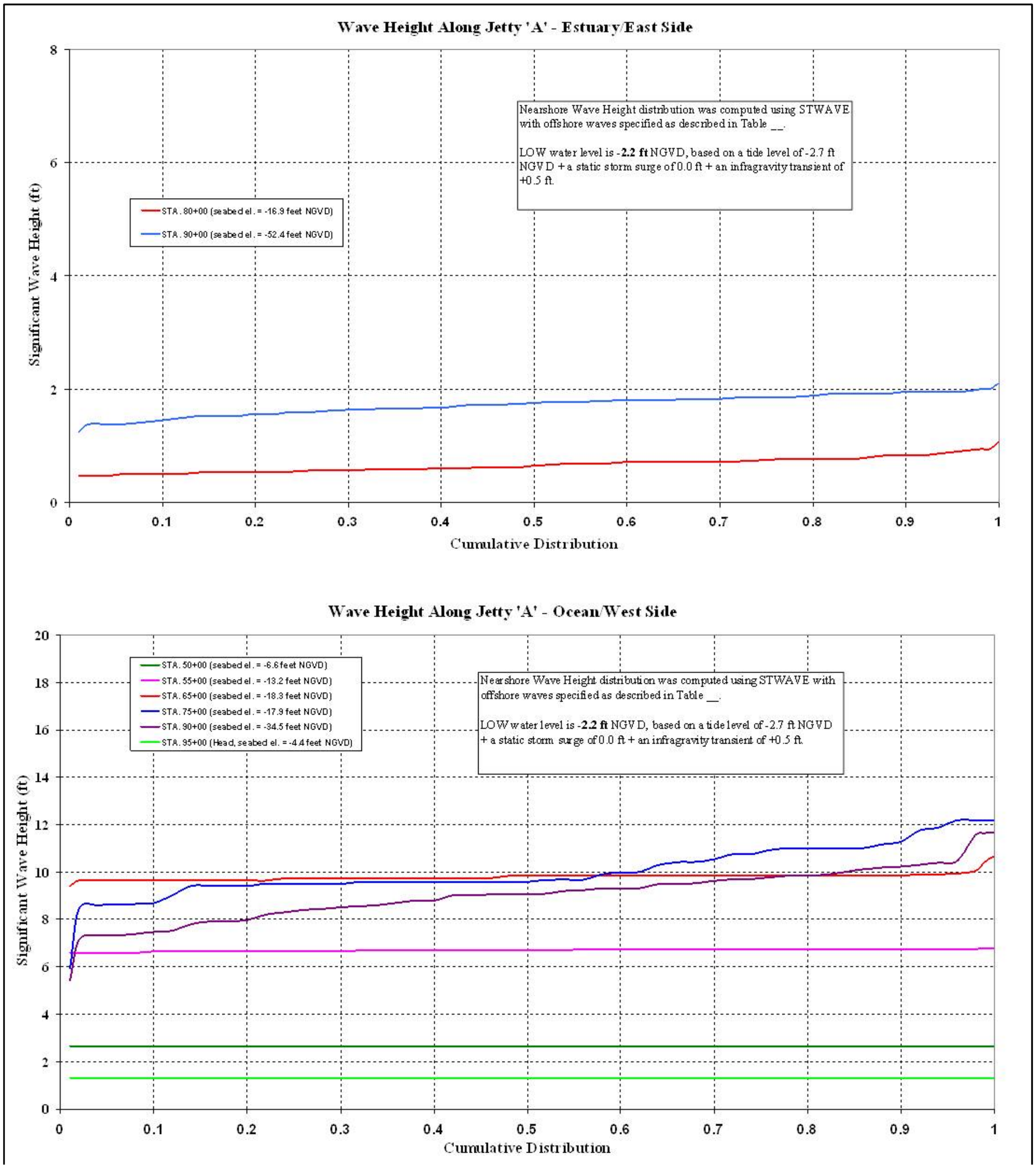


Figure A1- 85. Cumulative Distribution for Wave Height at MCR JETTY "A" for LOW Water Level (WSE @ -2.2 ft NGVD)

(A) is south side of jetty. (B) is north side of jetty. Values were estimated using the STWAVE model to transform offshore wave conditions for 52 storm wave events.

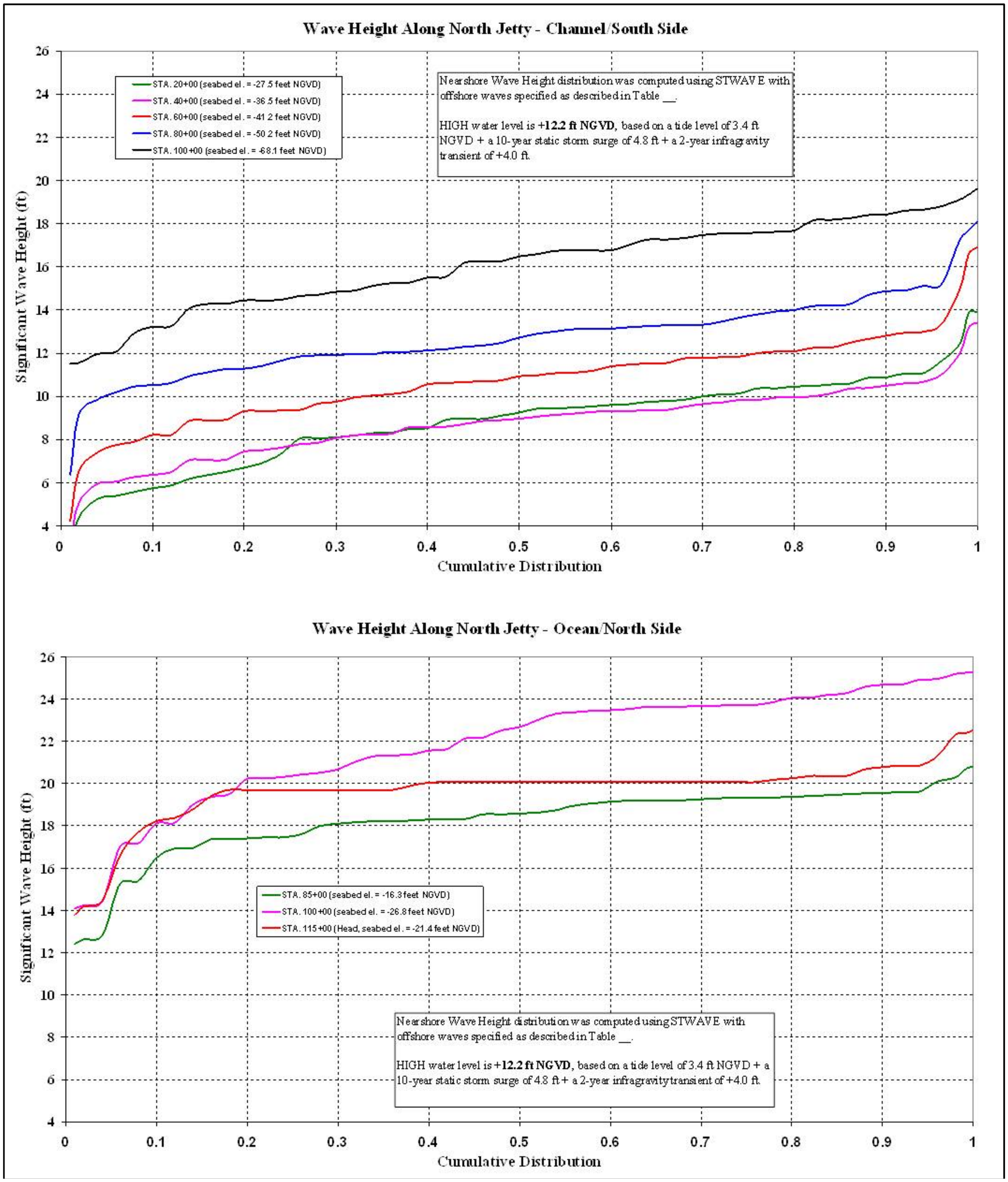


Figure A1- 86. Cumulative Distribution for Wave Height at MCR NORTH Jetty for HIGH Water Level (WSE @ 12.4 ft NGVD)

(A) is south side of jetty. (B) is north side of jetty. Values were estimated using the STWAVE model to transform offshore wave conditions for 52 storm wave events.

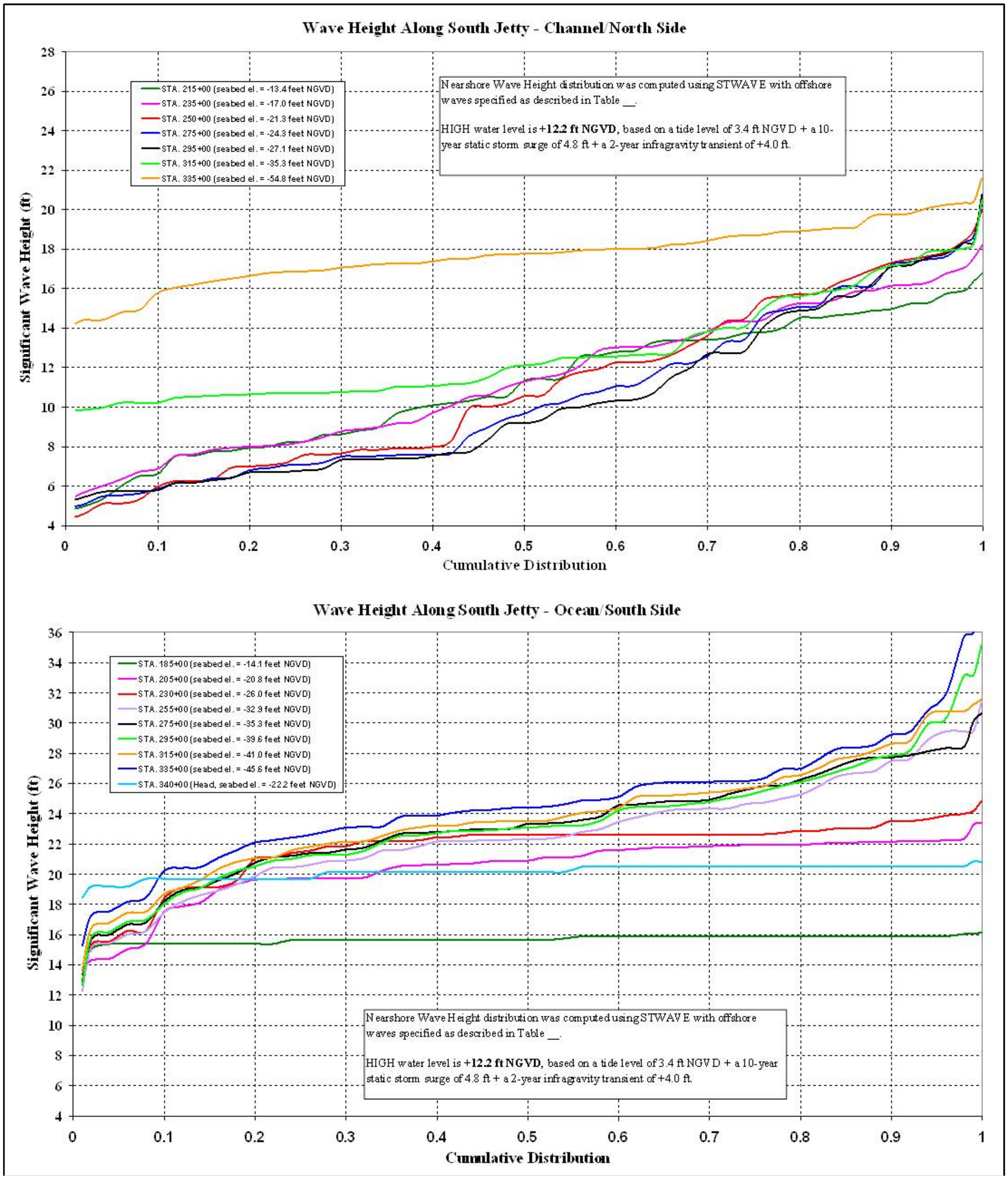


Figure A1- 87. Cumulative Distribution for Wave Height at MCR SOUTH Jetty for HIGH Water Level (WSE @ 12.4 ft NGVD)

(A) is south side of jetty. (B) is north side of jetty. Values were estimated using the STWAVE model to transform offshore wave conditions for 52 storm wave events.

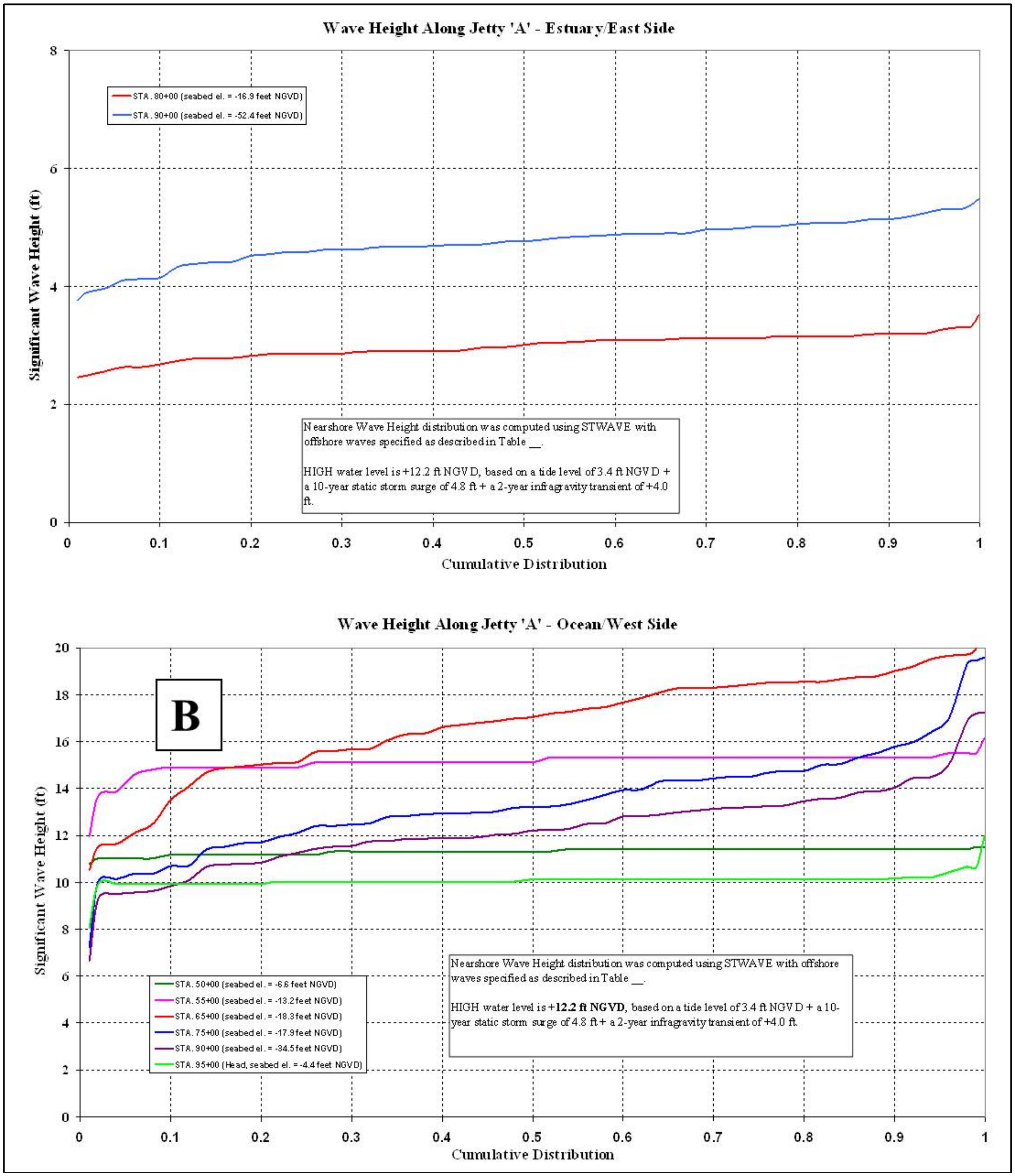


Figure A1- 88. Cumulative Distribution for Wave Height at MCR JETTY A for HIGH Water Level (WSE @ 12.4 ft NGVD)

(A) is south side of jetty. (B) is north side of jetty. Values were estimated using the STWAVE model to transform offshore wave conditions for 52 storm wave events.

Table A1- 4. Wave Height Incident at MCR Jetties Based on STWAVE Simulations

Figure A1- 83 through Figure A1- **88** for cumulative distribution of 0.9 and 1.0. First value is for LOW water level (-2.2 ft NGVD). Second value is for HIGH water level (+12.2 ft NGVD). CD = 0.9 would be upper limit design wave height for jetty repair. CD = 1.0 would be upper limit design wave height for jetty rehabilitation.

NORTH Jetty jetty station	Bottom Elevation ft, NGVD	**Incident Wave Height at Jetty, $H_{1/3}$, feet** **0.9 CD value**	**1.0 CD value**
Sta 20+00: Channel Side	-27.5	8.3 - 10.9	9.8 - 13.9
Sta 40+00: Channel Side	-36.5	7.8 - 10.5	9.1 - 13.4
Sta 60+00: Channel Side	-41.2	10.4 - 12.8	12.6 - 16.9
Sta 80+00: Channel Side	-50.2	11.6 - 14.9	13.5 - 18.1
Sta 100+00: Channel Side	-68.1	12.8 - 18.4	14.0 - 19.6
Sta 115+00: Ocean Side	-21.4	14.9 - 20.8	15.9 - 22.5
Sta 100+00: Ocean Side	-26.8	15 - 24.7	15.9 - 25.3
Sta 85+00: Ocean Side	-16.3	11 - 19.5	12.2 - 20.8
SOUTH Jetty jetty station	Bottom Elevation ft, NGVD	**0.9 CD value**	**1.0 CD value**
Sta 185+00: Ocean Side	-14.1	7.3 - 15.8	7.4 - 16.4
Sta 205+00: Ocean Side	-20.8	13.5 - 22.1	14.4 - 23.4
Sta 230+00: Ocean Side	-26.0	14.4 - 23.5	15.1 - 24.8
Sta 255+00: Ocean Side	-32.9	21.2 - 27.5	22.9 - 31.4
Sta 275+00: Ocean Side	-35.3	19.7 - 27.8	22.1 - 31.4
Sta 295+00: Ocean Side	-39.6	25.1 - 27.9	26.9 - 30.6
Sta 315+00: Ocean Side	-41.0	24.5 - 28.6	25.9 - 35.2
Sta 335+00: Ocean Side	-45.6	25.9 - 29.2	28.6 - 36.0
Sta 335+00: Channel Side	-54.8	13.6 - 19.7	15.4 - 21.5
Sta 315+00: Channel Side	-35.3	10.4 - 17.2	12.1 - 20.8
Sta 295+00: Channel Side	-27.1	12.1 - 16.2	14.1 - 20.8
Sta 275+00: Channel Side	-24.3	12.6 - 16.2	14.1 - 20.8
Sta 250+00: Channel Side	-21.3	12.9 - 16.2	14.1 - 20.8
Sta 235+00: Channel Side	-17.0	11.3 - 16.2	11.5 - 18.2
Sta 215+00: Channel Side	-13.4	8.7 - 15.0	8.7 - 16.7
JETTY "A" jetty station	Bottom Elevation ft, NGVD	**0.9 CD value**	**1.0 CD value**
Sta 50+00: Ocean Side	-6.6	2.7 - 11.4	2.7 - 11.5
Sta 55+00: Ocean Side	-13.2	6.8 - 15.4	6.8 - 16.4
Sta 60+00: Ocean Side	-18.3	9.8 - 19.0	10.7 - 20.5
Sta 70+00: Ocean Side	-17.9	11.3 - 15.8	12.2 - 19.5
Sta 85+00: Ocean Side	-34.5	10.2 - 14.1	11.7 - 17.2
Sta 95+00: Ocean Side	-4.4	1.3 - 10.2	1.1 - 11.9
Sta 95+00: Channel Side	-52.4	2 - 5.1	2.1 - 5.5
Sta 80+00: Channel Side	-16.9	1 - 3.3	1.1 - 3.5

8. Engineering Considerations

a. General

The engineering analysis of the rehabilitation plans covered two primary areas: (1) jetty cross section repair, and (2) engineering features which addressed larger process deterioration of the structures. Tools used for design analysis in this study included historical performance at the MCR, other case studies, 2-dimensional physical modeling, and hydrodynamic numerical modeling. The South Jetty and Jetty A were evaluated for cross section repair options, spur groins to reduce jetty scour, and jetty head reconstruction as shown in Figure A1- 89 and Figure A1- 90. The North Jetty was evaluated for cross section repair options, spur groins to reduce jetty scour, stabilization of backfill area along the jetty root and jetty head reconstruction as shown in Figure A1- 90.

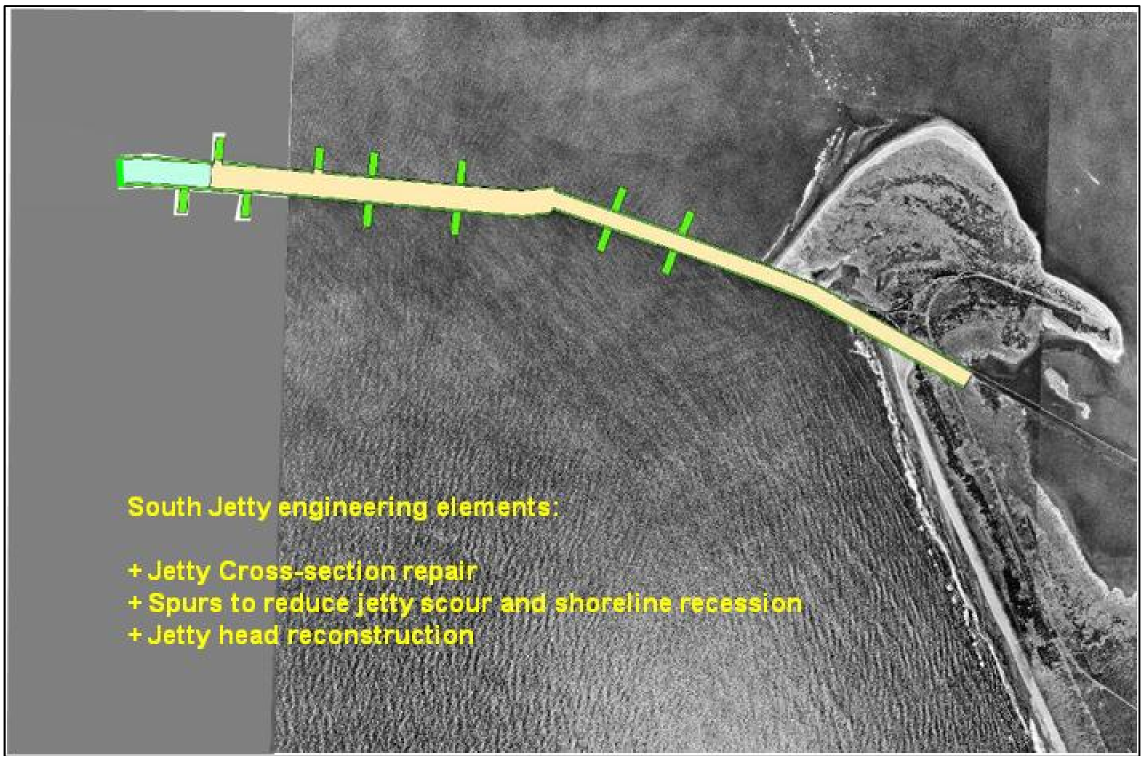


Figure A1- 89. South Jetty Life Cycle Engineering Elements

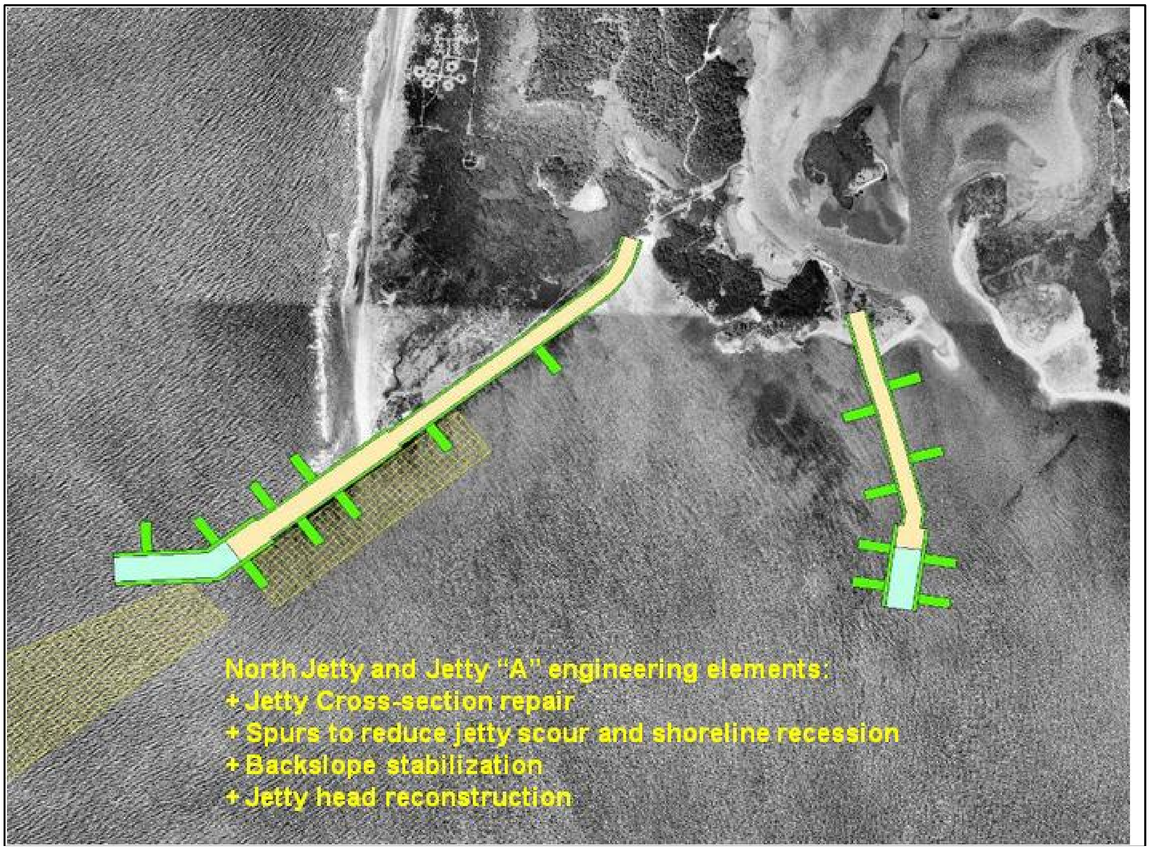


Figure A1- 90. North Jetty and Jetty A Engineering Elements

Jetty structure reliability can be separated into above and below water areas controlled essentially by wave-driven and erosion-driven processes. An effective and long term rehabilitation effort needs to address both sets of damage processes.

b. General Failure Modes for Jetties

Structural performance modes for a rubblemound jetty can be characterized in terms of its ability to: A) remain stable during wave attack (dynamic stability), and B) maintain a stable footprint/slope configuration on the seabed foundation (static stability). These performance modes are described below and shown conceptually, as failure modes, in Figure A1- 91.

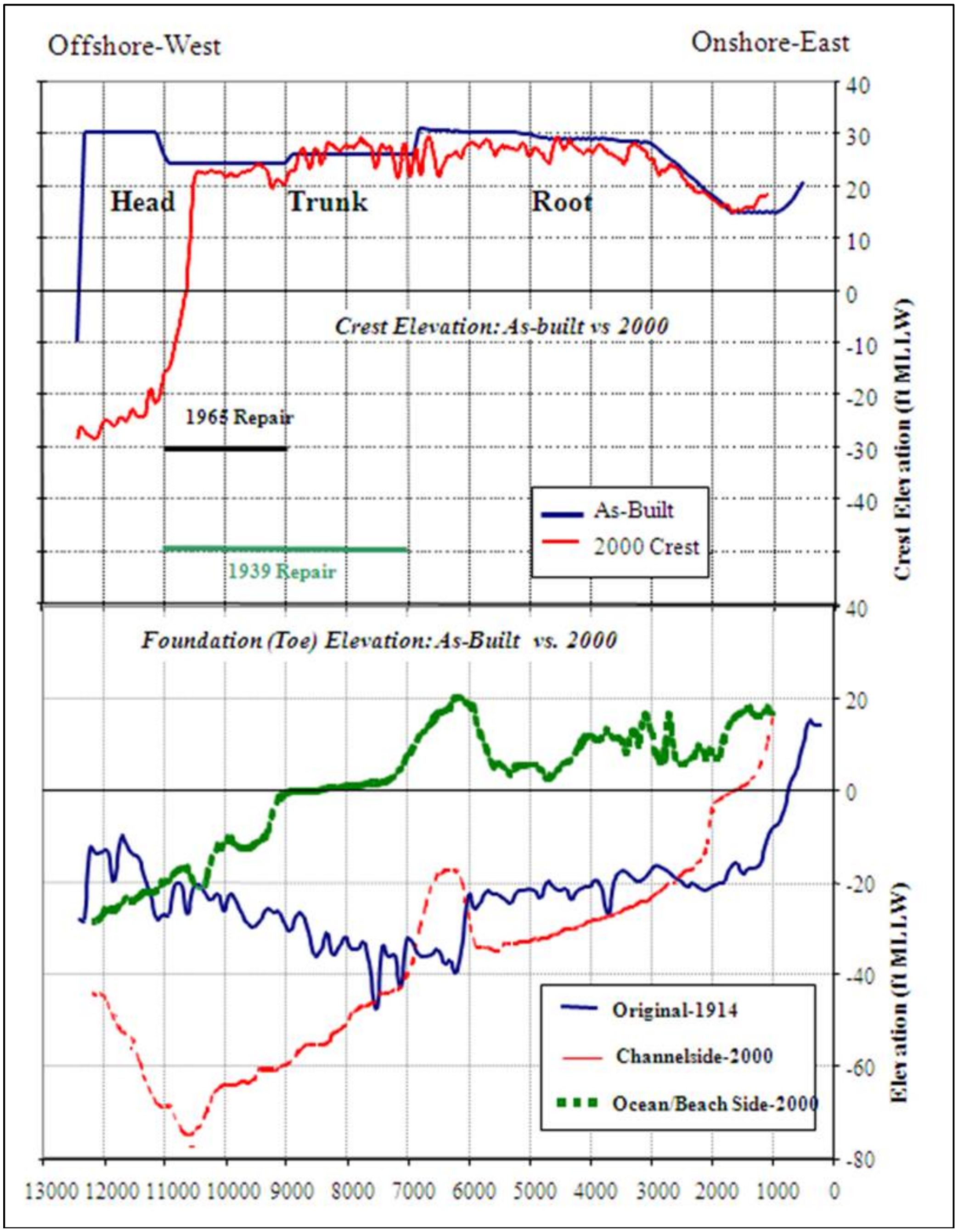


Figure A1- 91. Structural Performance Modes for Jetties at MCR

Dynamic Stability. This affects the upper part of a jetty cross-section as a result of wave action, generally from -5 ft MLLW up to the jetty crest, on the ocean side and channel side of a jetty. On the side of the jetty directly exposed to ocean waves, dynamic stability is manifest by the direct impact of waves on the jetty and the resultant displacement of individual armor units. On the lee side of the jetty, dynamic stability addresses the effect of waves overtopping the jetty crest and displacing armor units down slope, off of the jetty cross-section.

Static Stability. This affects the lower part of the jetty cross-section, generally below -5 ft MLLW, on the ocean side and channel side of the jetty. Static stability addresses the susceptibility of the jetty toe to wave-current scour, and resistance of the jetty slope to sliding down grade along a slip-plane. Damage due to static stability issues propagates up-slope to affect the upper region of the jetty cross-section.

c. Delineation of Structure Design Reaches

Utilizing the design climate for each structure, the existing condition of each structure, as well as the identified potential process impacts along each jetty length, key design reaches are outlined as shown in Figure A1- 92 and Figure A1- 93 and Table A1- 5 for the North Jetty. South Jetty is illustrated in Figure A1- 94 and Figure A1- 95 and Table A1- 6. Jetty A is shown in Figure A1- 96 and Figure A1- 97 and Table A1- 7. The design parameters provided in Table A1- 5 through Table A1- 7 are for existing conditions only. These parameters will change in the future based on progressive morphological changes and damage to the jetties. Basic categories of design concern can be grouped in the following categories:

- Frontslope wave attack
- Backslope overtopping wave attack
- Foundation loss
- Adjacent shoreline recession
- Backside foundation loss.

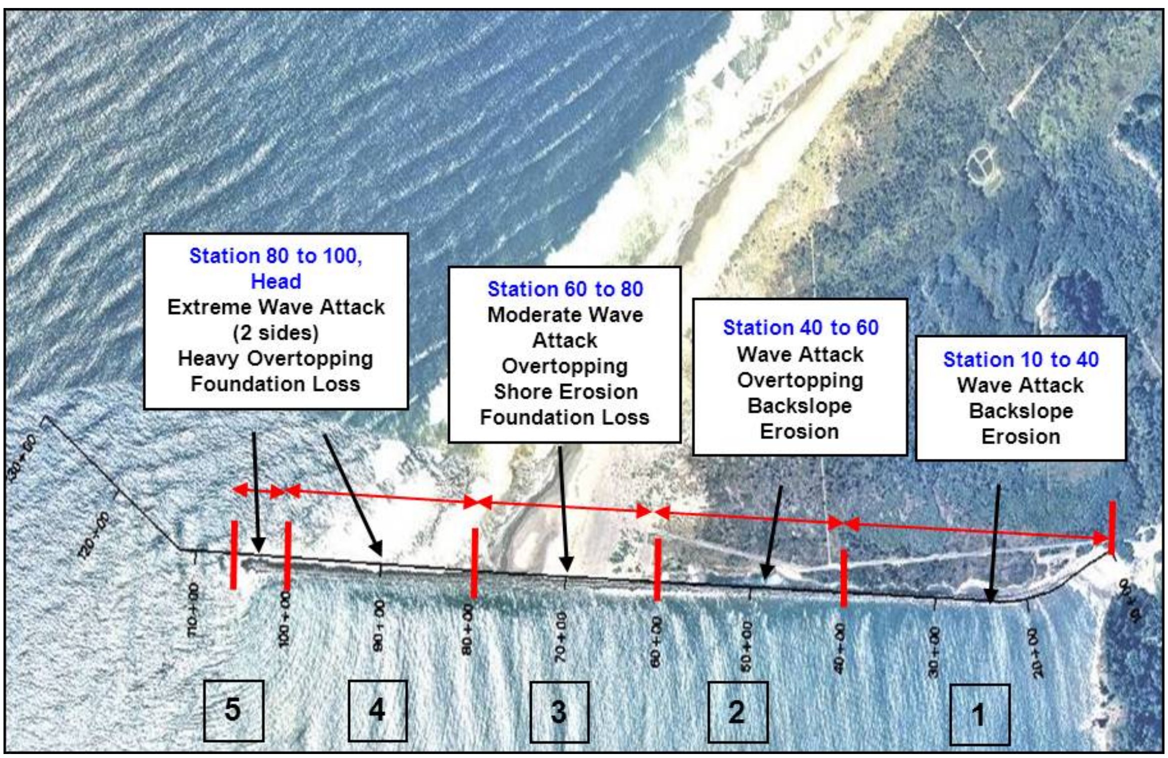


Figure A1- 92. North Jetty Design Reaches

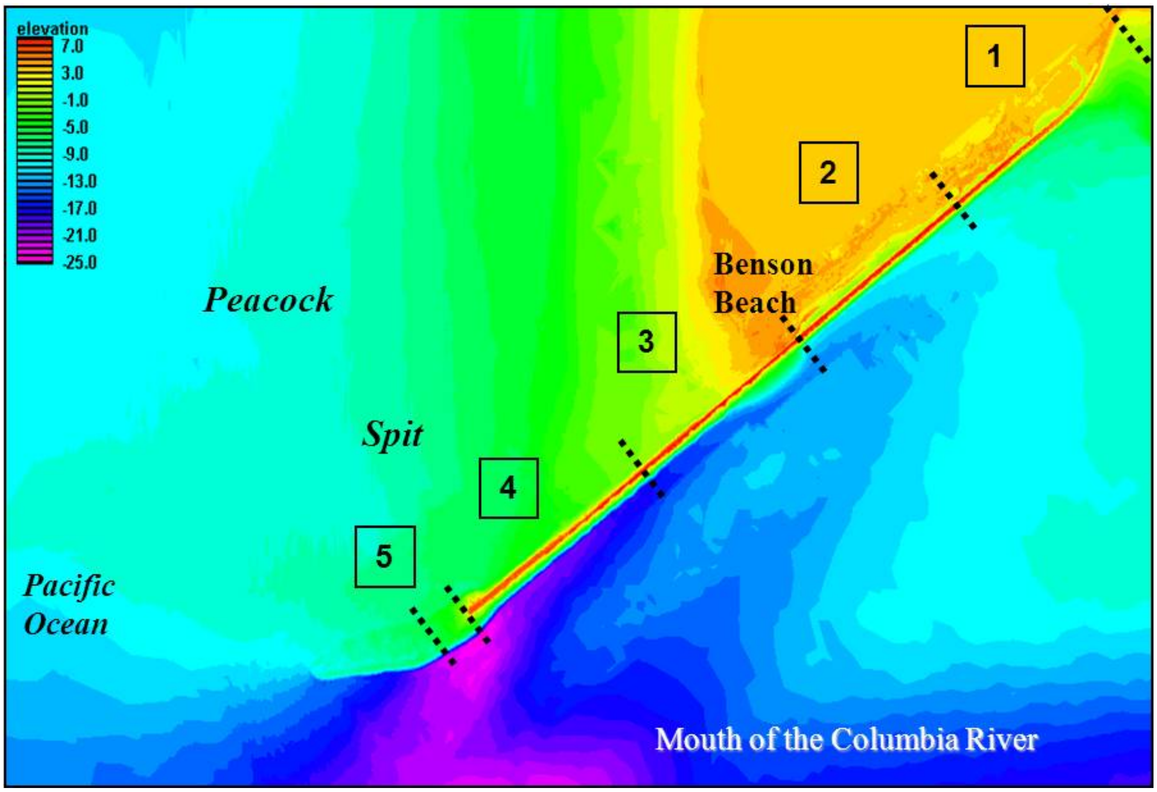


Figure A1- 93. North Jetty Bathymetry and Design Reaches

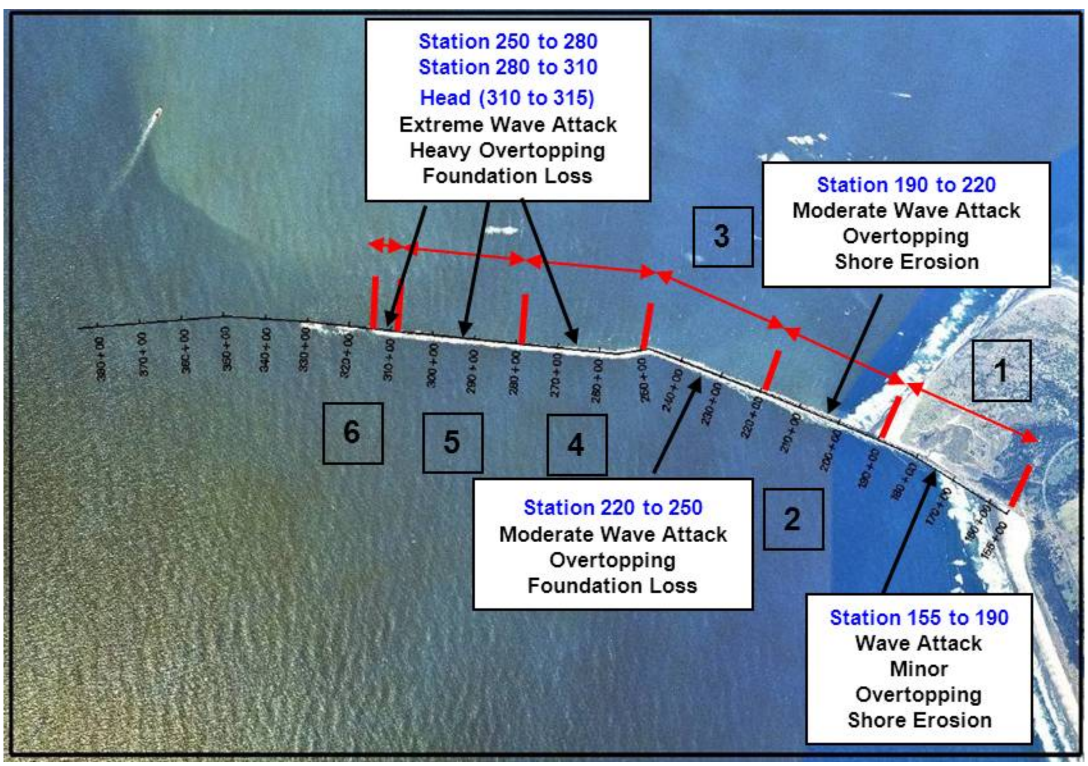


Figure A1- 94. South Jetty Design Reaches

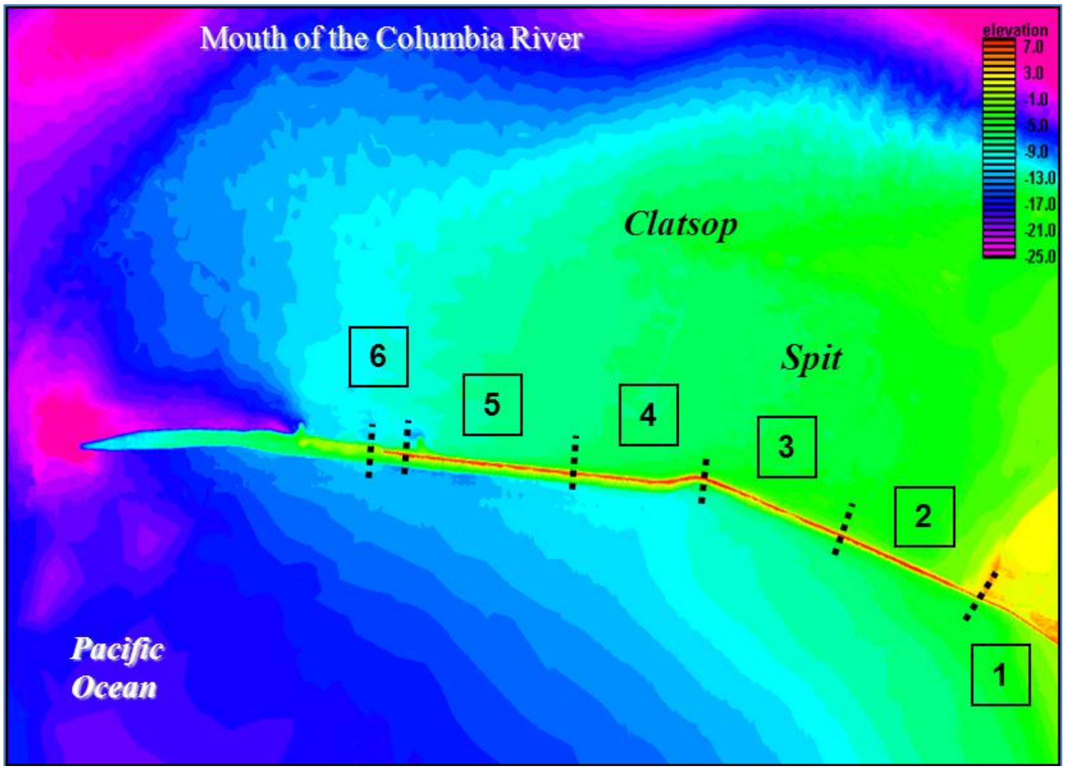


Figure A1- 95. South Jetty Bathymetry and Design Reaches

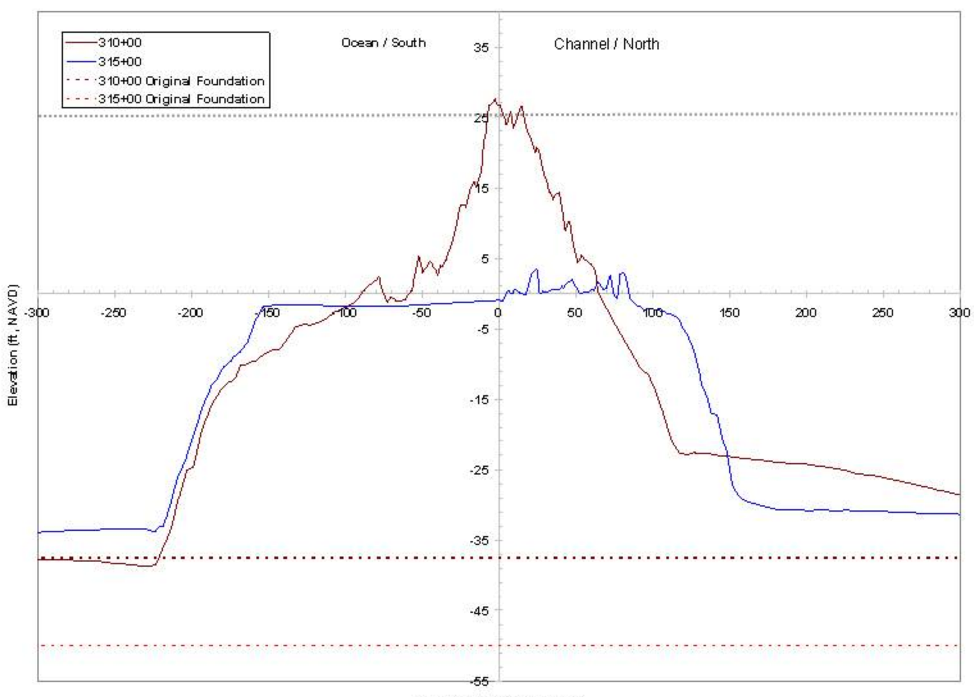


Figure A1- 96. South Jetty – Reach 6

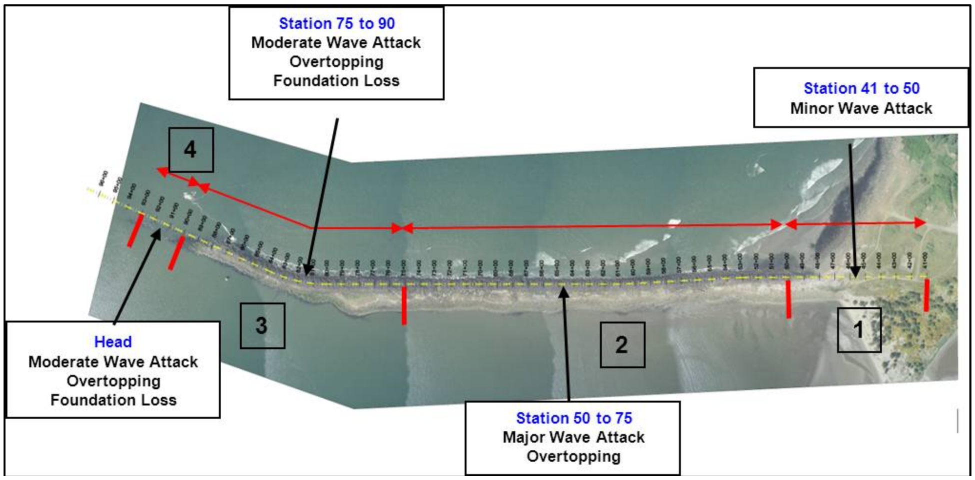


Figure A1- 97. Jetty A Design Reaches

Table A1- 5. North Jetty Design Input Parameters

Station	Crest Elevation	Crest Width	Design Wave Height Ocean	Design Wave Height Channel	Depth at Toe Ocean	Depth at Toe Channel	Design Issue
	(ft, MLLW)	(ft)	(ft)	(ft)	(ft, MLLW)	(ft, MLLW)	
10 to 40	15 to 25	10 to 30	0	10 to 14	+4 to +15	-10 to -20	Minor frontslope wave attack (1) Backside foundation
40 to 60	20 to 27	10 to 30	0	14 to 17	+3 to +11	-9 to -13	Moderate frontslope wave attack (1) Overtopping (1) Backside foundation
60 to 80	20 to 25	20 to 35	5 to 21	17 to 18	-1 to +15	-15 to -55	Moderate frontslope wave attack (2) Overtopping (2) Foundation loss (1) Shore erosion
80 to 100	17 to 25	10 to 40	21 to 25	18 to 20	-2 to -15	-55 to -65	Extreme frontslope wave attack (2) Heavy overtopping (2) Foundation loss (1)
Head	19 to 20	15 to 40	26	20	-10 to -17	-65 to -75	Extreme frontslope wave attack (3) Heavy overtopping (3) Foundation loss (3)

Note: These design input parameters are valid only for the existing condition.

1. North Jetty Design Reaches

The North Jetty is divided into 5 reaches. Half of the jetty is backed by accreted land on the north side. The seaward half of the jetty, while it does not have land behind it, is backed by the substantial underwater shoal in the form of Peacock Spit. The North Jetty as well as its significant submerged jetty head functions to hold back this significant shoal from the navigation channel. These features can be clearly seen in Figure A1- 93. Benson Beach is located on the north side of the jetty at the transition between above and below water features of the spit. Also visible on Figure A1- 93 are the deepening contours on the channelside of the jetty. Figure A1- 98 illustrates crest and foundation changes over time along the North Jetty. Figure A1- 99 through Figure A1- 107 show pictures of the different reaches of the North Jetty and Figure A1- 108 through Figure A1- 111 illustrate the respective cross sections.

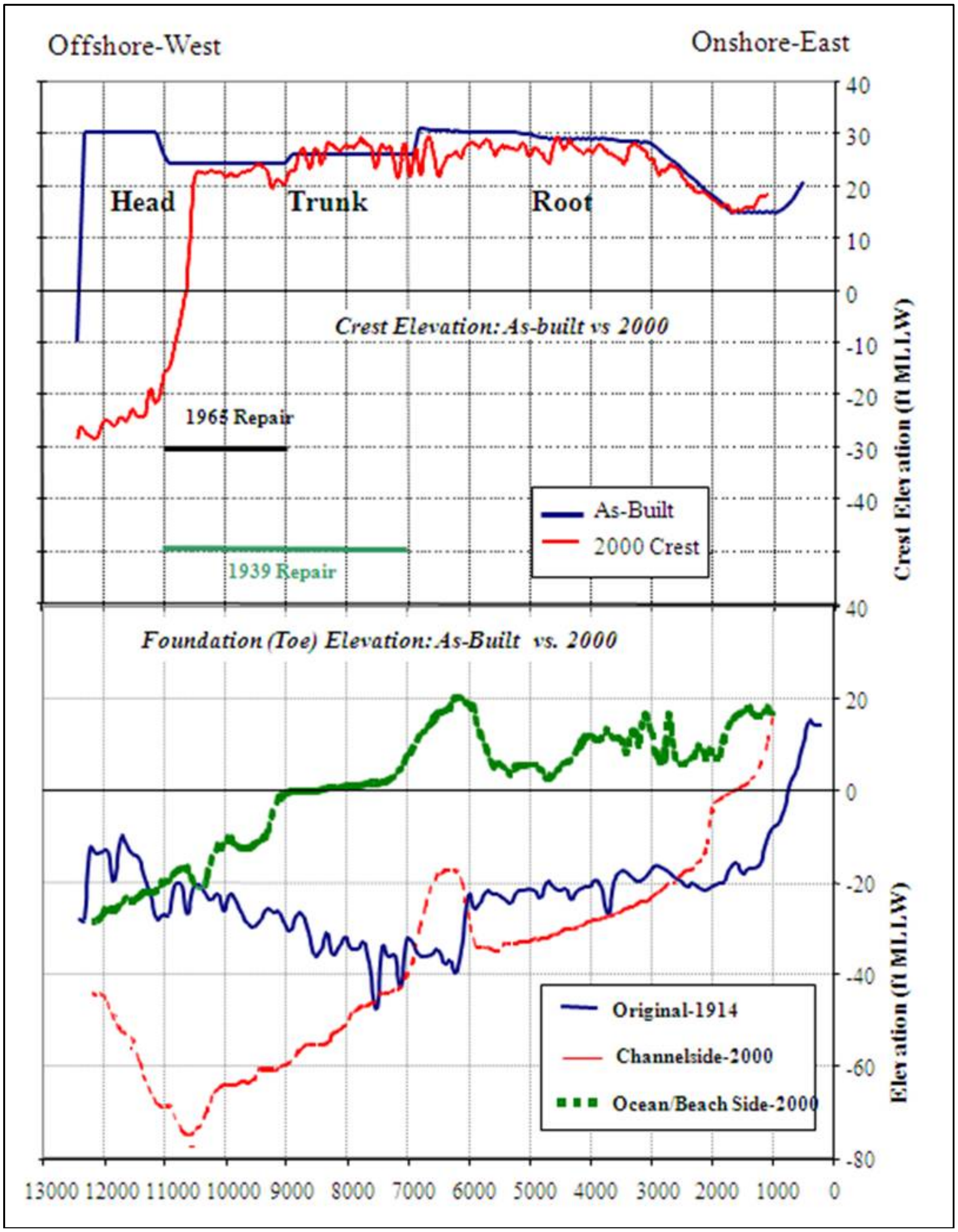


Figure A1- 98. North Jetty Crest and Foundation Changes Over Time

Figure A1- 99. North Jetty Root – Looking West

Figure A1- 100. North Jetty Root and Trunk – Looking East

Figure A1- 101. North Jetty Root – Looking East

Figure A1- 102. North Jetty Trunk - Looking East

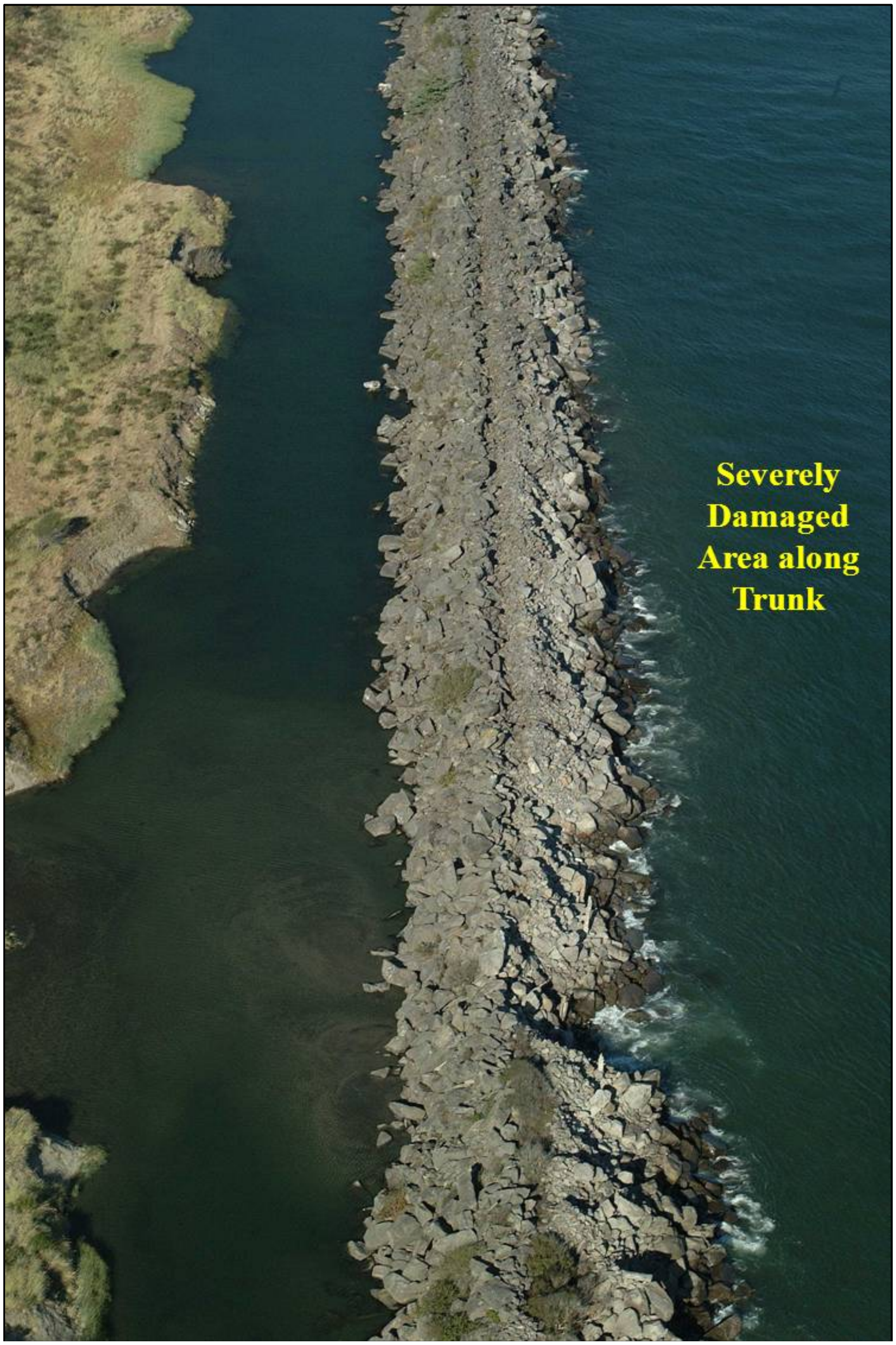


Figure A1- 103. North Jetty Trunk Damage Prior to Interim Repair

Figure A1- 104.   North Jetty Damage Areas

Figure A1- 105.   North Jetty Damage Areas

Figure A1- 106. North Jetty Seaward Trunk Damage

Figure A1- 107. North Jetty Head

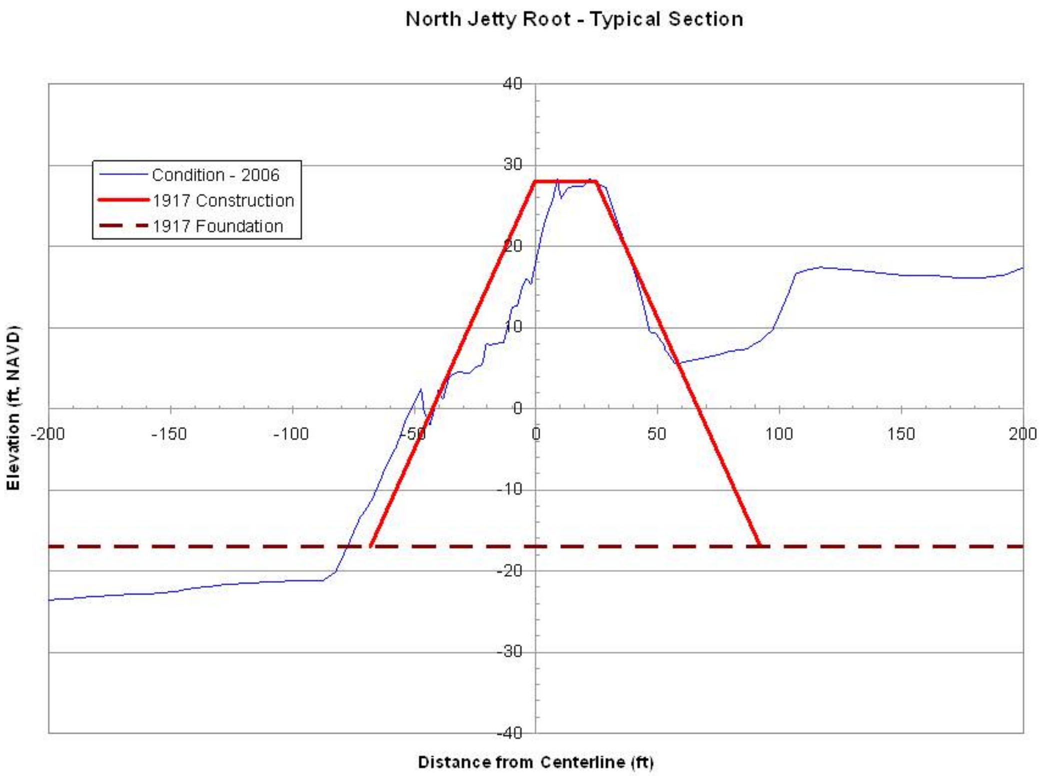


Figure A1- 108. North Jetty Cross Section Template - Root

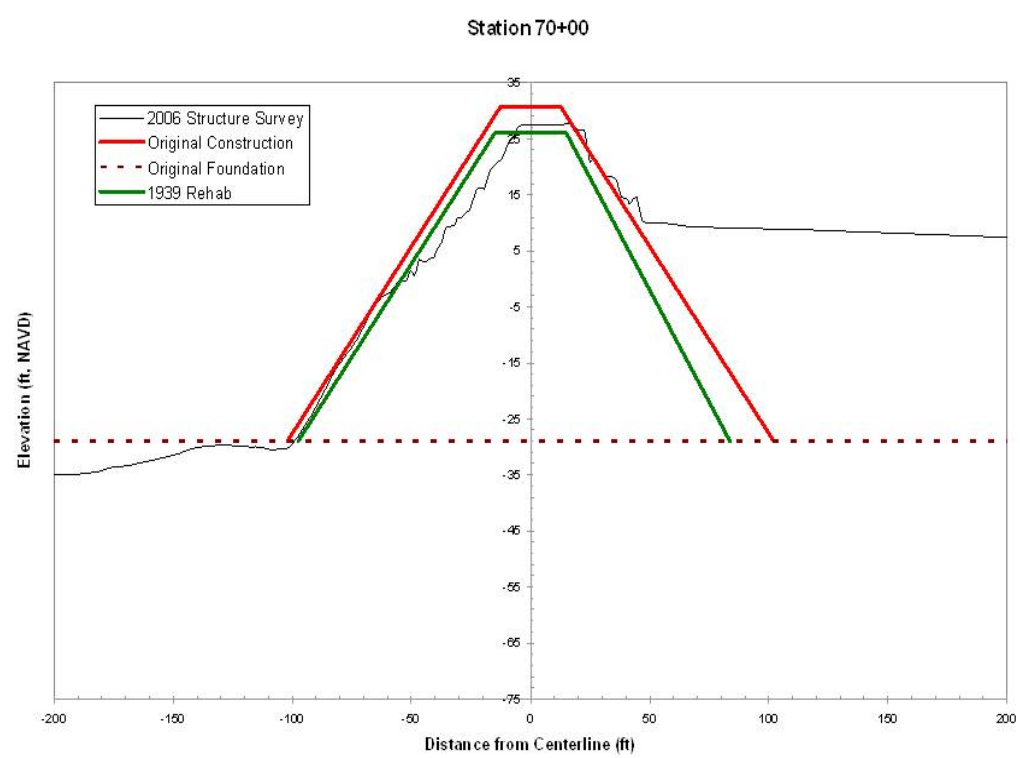


Figure A1- 109. North Jetty Cross Section Templates - Trunk

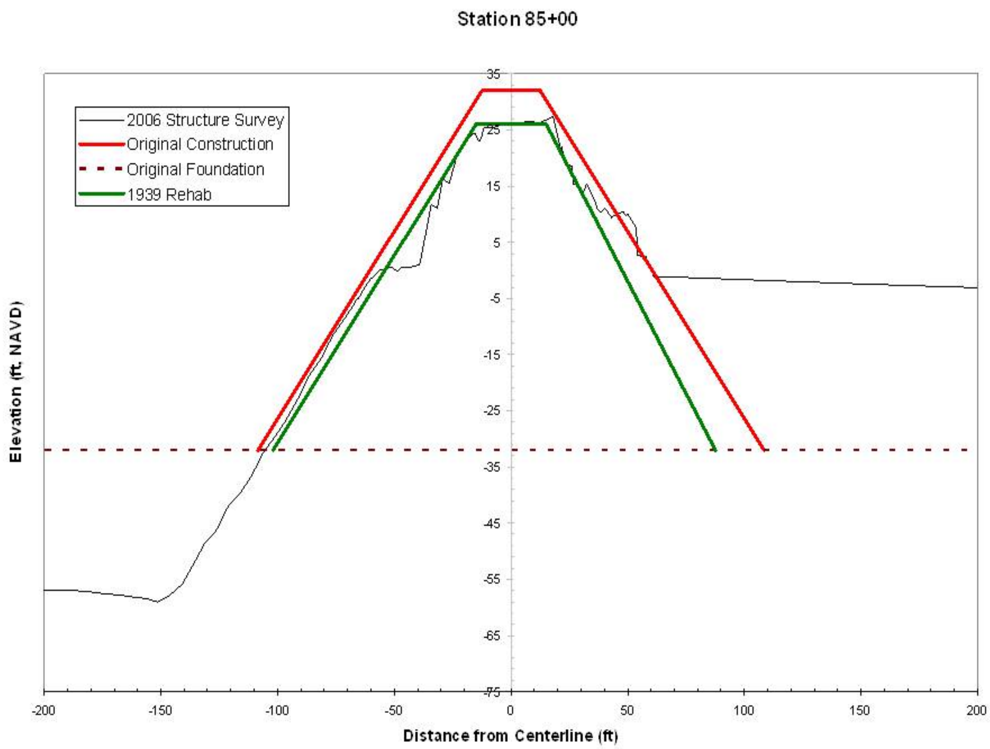


Figure A1- 110. North Jetty Cross Section Templates - Trunk

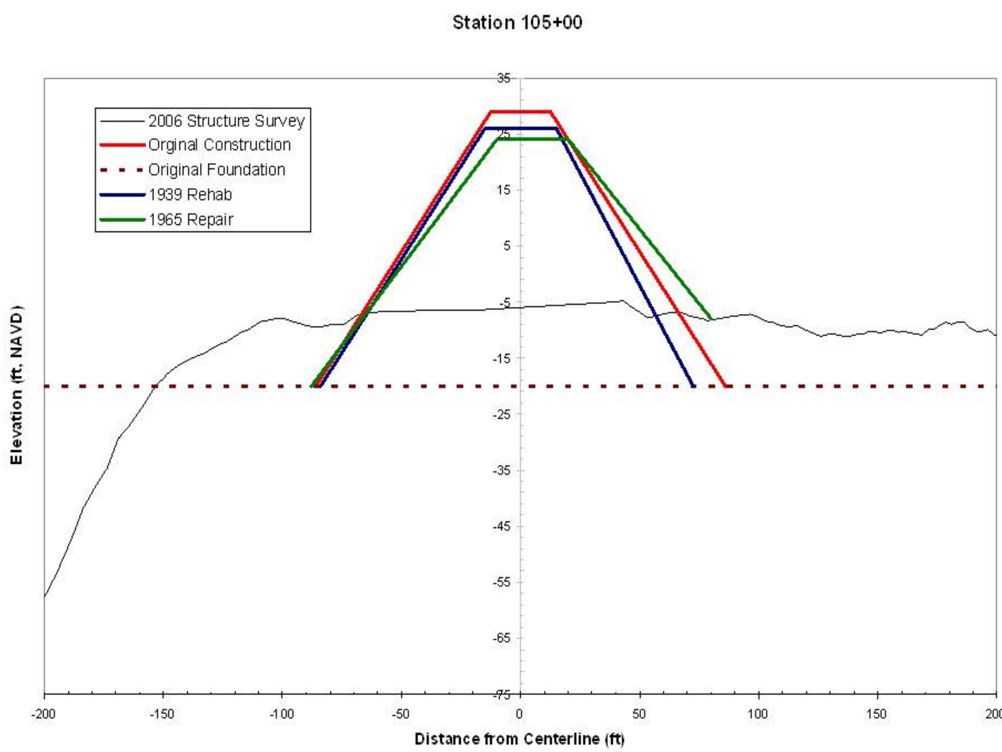


Figure A1- 111. North Jetty Cross Section Templates - Head

The most landward design reach for the North Jetty extends from Station 10 to Station 40 (Figure A1- 112). Depths noted in the table include depths at the toe of the jetty as well as depths at 400 ft away from the jetty, which is representative of the design wave height measurements. Foundation depths along this reach range from -10 to -20 on the channelside and +4 to +15 on the land side. The maximum channelside wave height is projected to be approximately 14 ft and the oceanside of the jetty is protected from wave attack. An eroded area on the backside of the jetty root has developed over time produced by a combination of overland flow channeled toward the jetty as well as tidal flow through the deteriorated jetty structure. This portion of the jetty has never been repaired since its original construction in 1917 (92 years) and it currently exists in a much deteriorated condition. Crest elevations range from +15 to +25 ft with crest widths of 10 to 30 ft wide. The jetty in this reach is in a jumbled state with little rock to rock interlocking as evidenced by the tidal flow allowed through the structure. Primary design issues for this reach are just basic need for structure repair as well as backside undermining of foundation.

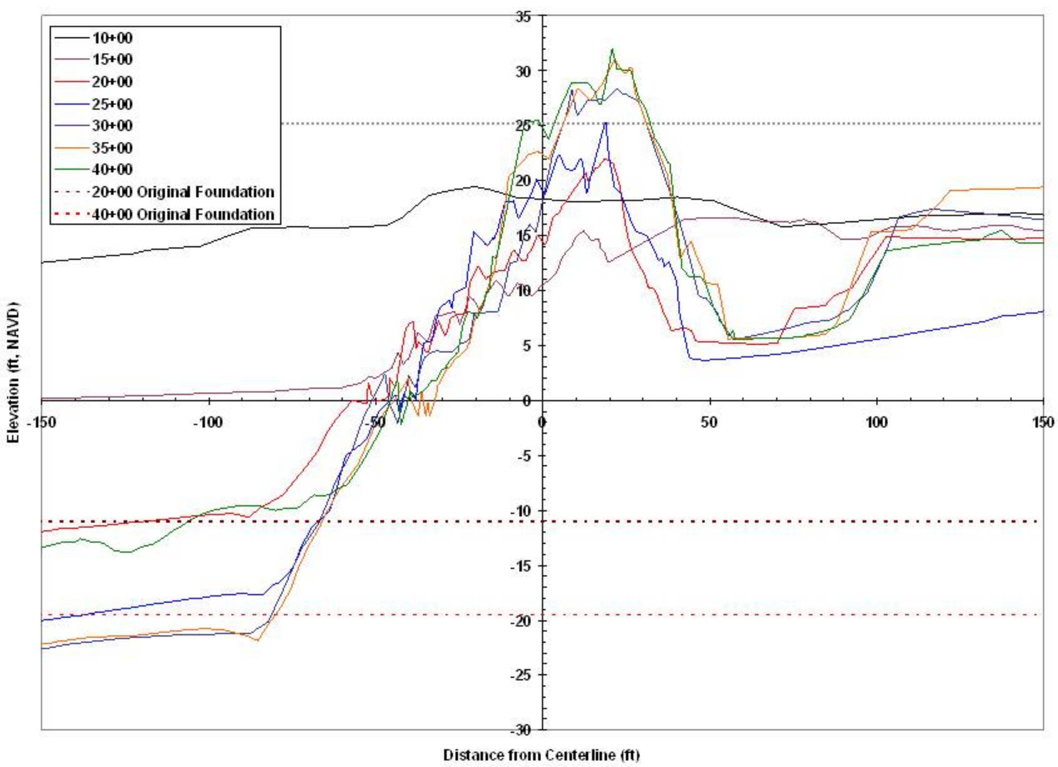


Figure A1- 112. North Jetty – Reach 1

The second design reach extends from Station 40 to Station 60 and, except for 500 ft repaired in the 2005 Interim Repair effort, also has never been repaired since 1917 (Figure A1- 113). Foundation depths range from -9 to -13 ft, MLLW on the channelside and +3 to +11 on the land side. Design wave heights are expected to range from 14 to 17 ft on the channelside. The ocean or north side is protected by land. This reach is also impacted by the hydraulic flow through the jetty to the eroded area behind the jetty. Some wave overtopping may occur in this reach, however, it is not expected to be significant. Primary design issues for this reach are just basic need for structure repair as well as backside undermining of foundation.

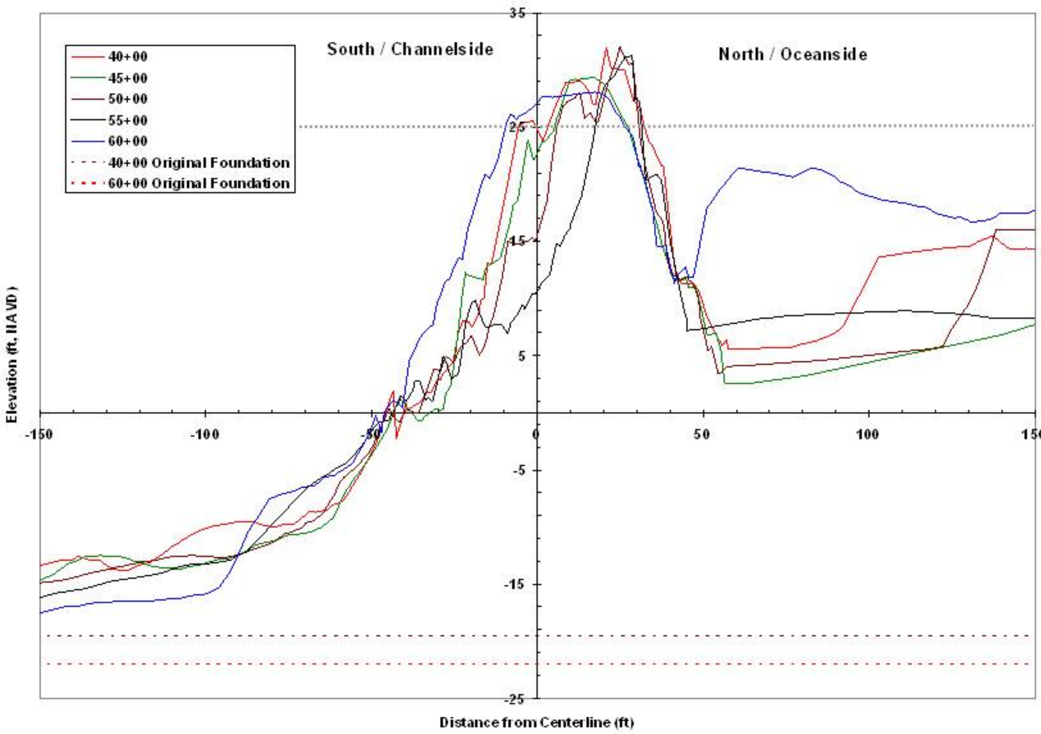


Figure A1- 113. North Jetty – Reach 2

The third design reach extends from Station 60 to Station 80 (Figure A1- 114). Channelside foundation depths increase along this reach (-15 ft to -55 ft, MLLW) impacting the static stability of the entire cross section. On the north side, foundation depths range from -1 to +15 ft, MLLW. This reach extends into the portion of the structure which is exposed to both channelside as well as oceanside wave attack, though the oceanside attack is significantly reduced by the presence of Peacock Spit. Oceanside design wave heights are expected to range from 5 to 21 ft and channelside design wave heights are expected to range from 17 to 18 ft. An additional concern in this reach is the progressive recession of the shoreline which results in increased exposure of the deteriorated jetty root structure as well as increasing the likelihood of hydraulic flow path connection of the ocean wave/surge processes with the tidal flow area which parallels the jetty root. This reach of jetty was recently addressed in the 2005 Interim Repair action which provided some additional short-term stability to the reach. Crest elevations and crest widths achieved during that repair action were +25 ft and 30 ft wide.

Design issues for this reach include moderate wave attack and overtopping, foundation loss and instability, and shoreline recession on the north side.

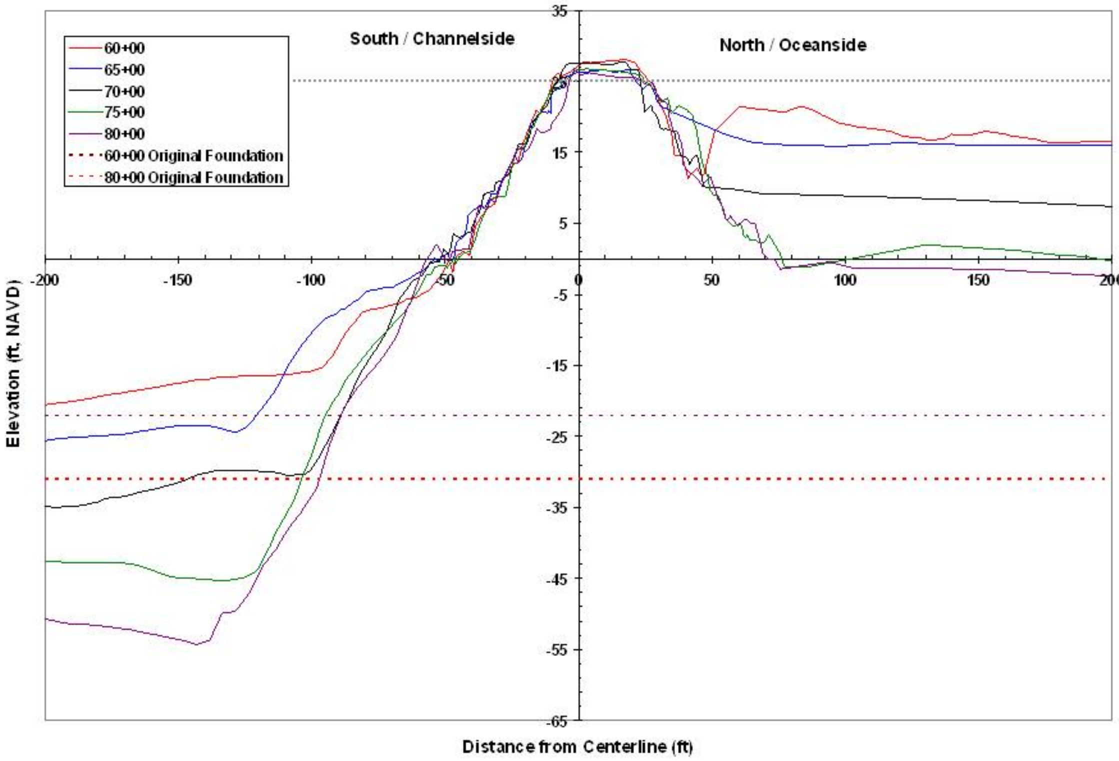


Figure A1- 114. North Jetty – Reach 3

The fourth design reach extends from Station 80 to 100 and represents the most vulnerable reach of the North Jetty at this time, primarily due to its high level of exposure to wave attack from both the oceanside and the channelside (Figure A1- 115). Design wave heights are expected to range from 21 to 25 ft on the oceanside and 18 to 20 ft on the channelside. Both sides of the jetty are exposed to frontslope wave attack as well as significant overtopping forces. Partial repairs were conducted to Station 85 during the Interim Repair effort although this work was not the full Interim Repair section. The last repair conducted in this reach was in 1964, 45 years ago. Crest elevations range from 17 to 25 ft and crest widths range from 10 to 40. Foundation depths along the channelside are significant ranging from -65 ft to -75 ft, MLLW. Scour and upslope stabilization of the cross section are concerns. Primary design issues for this reach include extreme wave attack and overtopping from 2 directions as well as foundation loss.

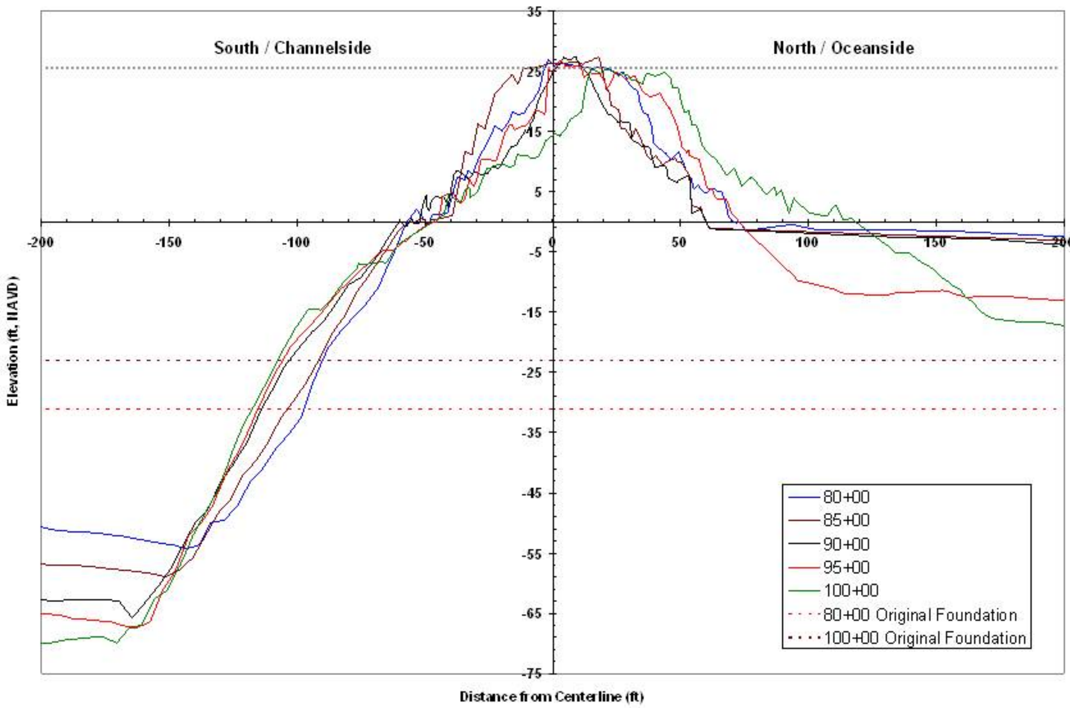


Figure A1- 115. North Jetty – Reach 4

The final design reach on the North Jetty extends from Station 100 to the reconstructed head position, expected to be constructed around Station 103 (Figure A1- 116). Wave exposure on this jetty feature is extreme since it is exposed to 3 different directions of frontslope wave attack and overtopping. Design wave heights are estimated to range from 20 to 26 ft. Foundation depths on the channelside are severe (around -70 ft) and the design of the jetty head stabilization is tailored to be constructed on top of the relic stone base of the existing jetty. Primary design issues for this reach include extreme wave attack and overtopping from 3 directions as well as foundation loss.

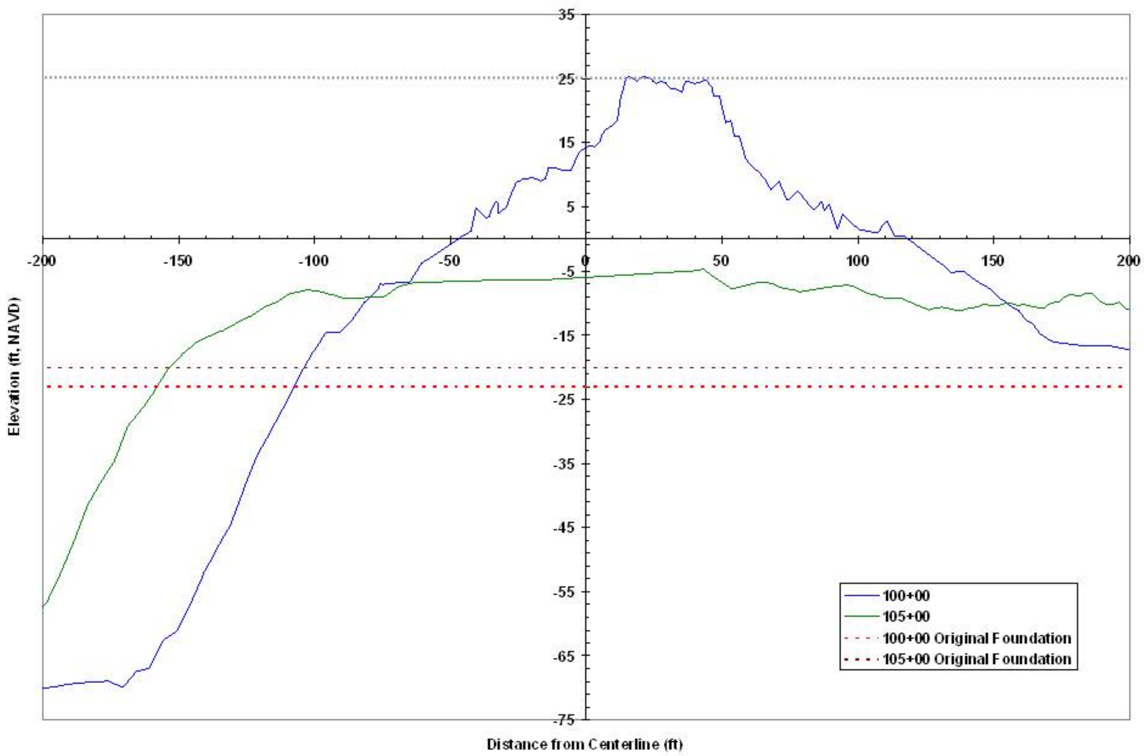


Figure A1- 116. North Jetty – Reach 5

2. South Jetty Design Reaches

The South Jetty is divided into six reaches and is shown in Figure A1- 117 and Figure A1- 118 and Table A1- 6. The design parameters provided in Table A1- 6 are valid only for the existing condition. These parameters will change in the future due to morphological changes and future damage to the South Jetty. Only the first reach of the South Jetty is backed by above water accreted land. The remainder of the structure is exposed to environmental forces from both sides of the structure. The significant underwater shoal on the north side of the South Jetty provides protection both in terms of foundation stabilization as well as reduced wave height exposure. Although the South Jetty extends out into fairly deep water depths, the portion being proposed for this rehabilitation effort is located shoreward of the greatest water depths. Figure A1- 119 illustrates crest and foundation changes over time along the South Jetty. Figure A1- 120 through Figure A1- 129 show pictures of the different reaches of the South Jetty and figures Figure A1- 130 through Figure A1- 133 illustrate the respective cross sections.

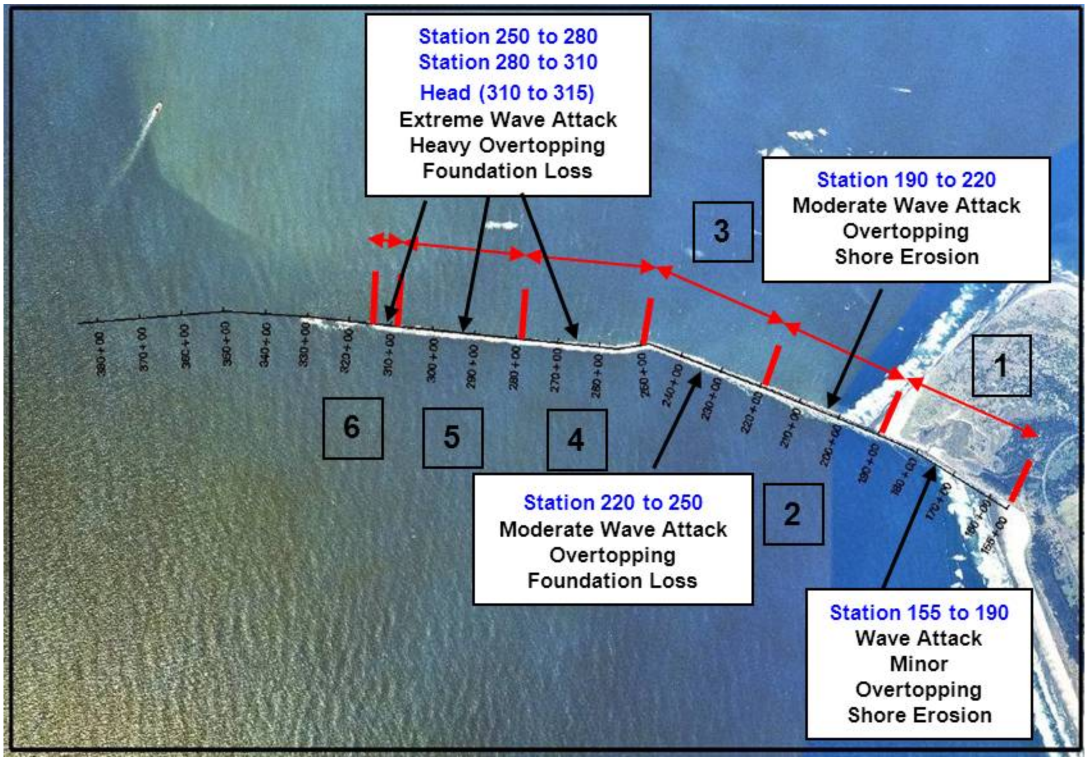


Figure A1- 117. South Jetty Design Reaches

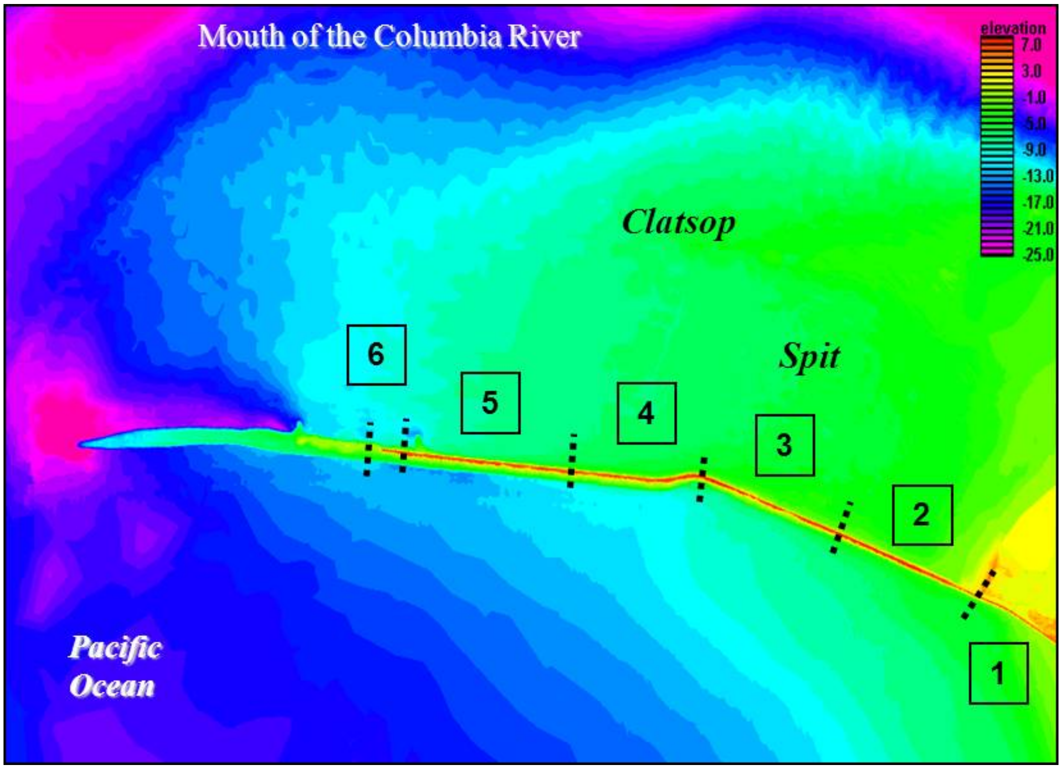


Figure A1- 118. South Jetty Bathymetry and Design Reaches

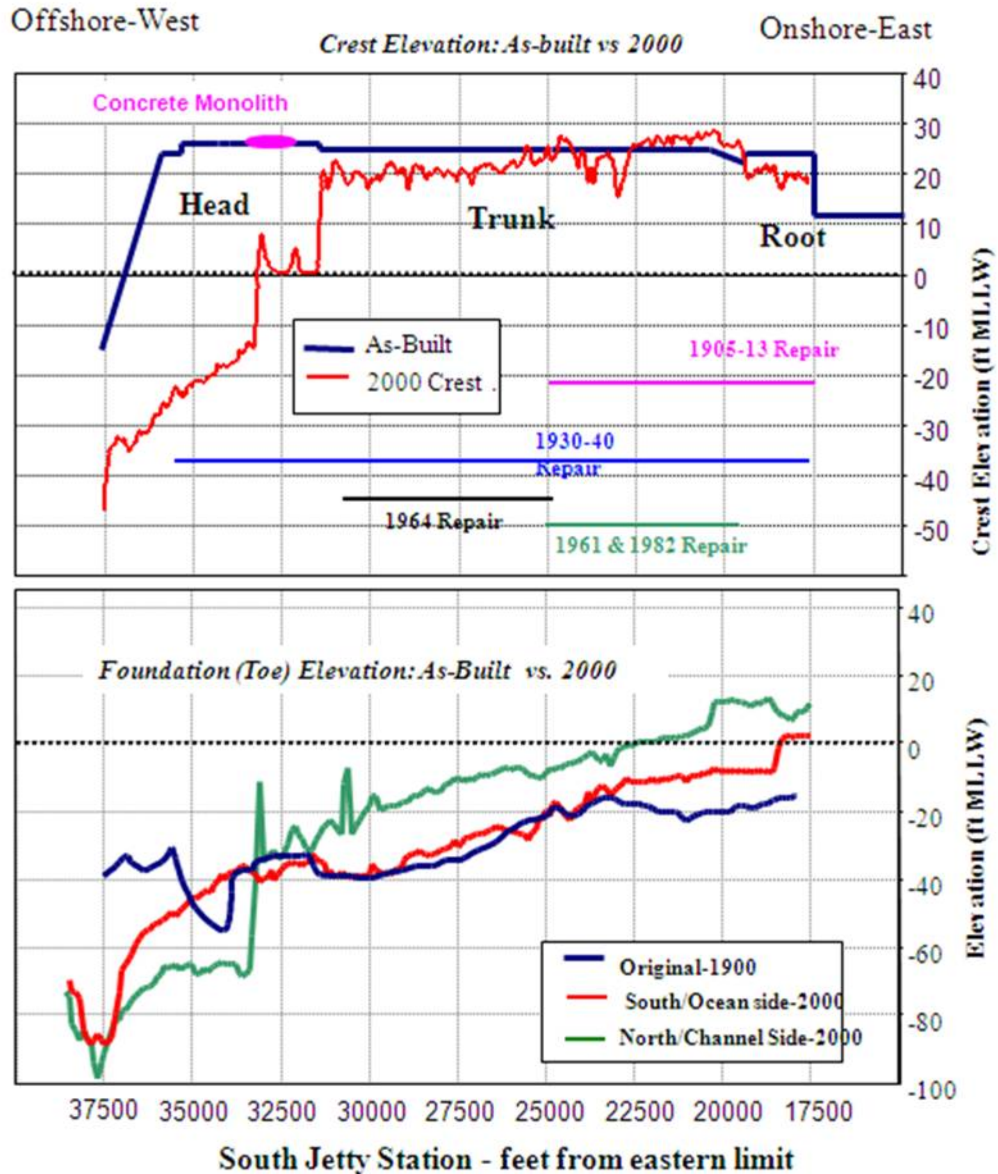


Figure A1- 119. South Jetty Crest and Foundation Changes Over Time

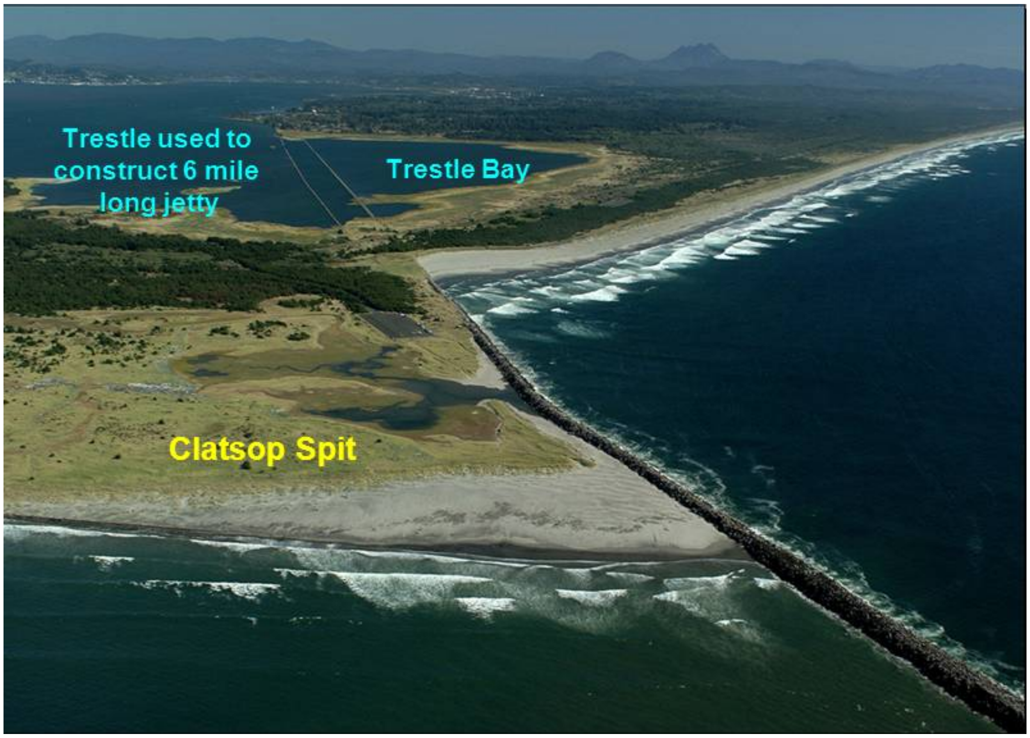


Figure A1- 120. South Jetty Root and Trestle Bay

Figure A1- 121. South Jetty Root

Figure A1- 122. South Jetty Inner Trunk

Figure A1- 123. South Jetty Trunk Damage

Figure A1- 124. South Jetty Trunk Damage

Figure A1- 125. Wave Attack on South Jetty

Figure A1- 126. South Jetty Trunk Damage

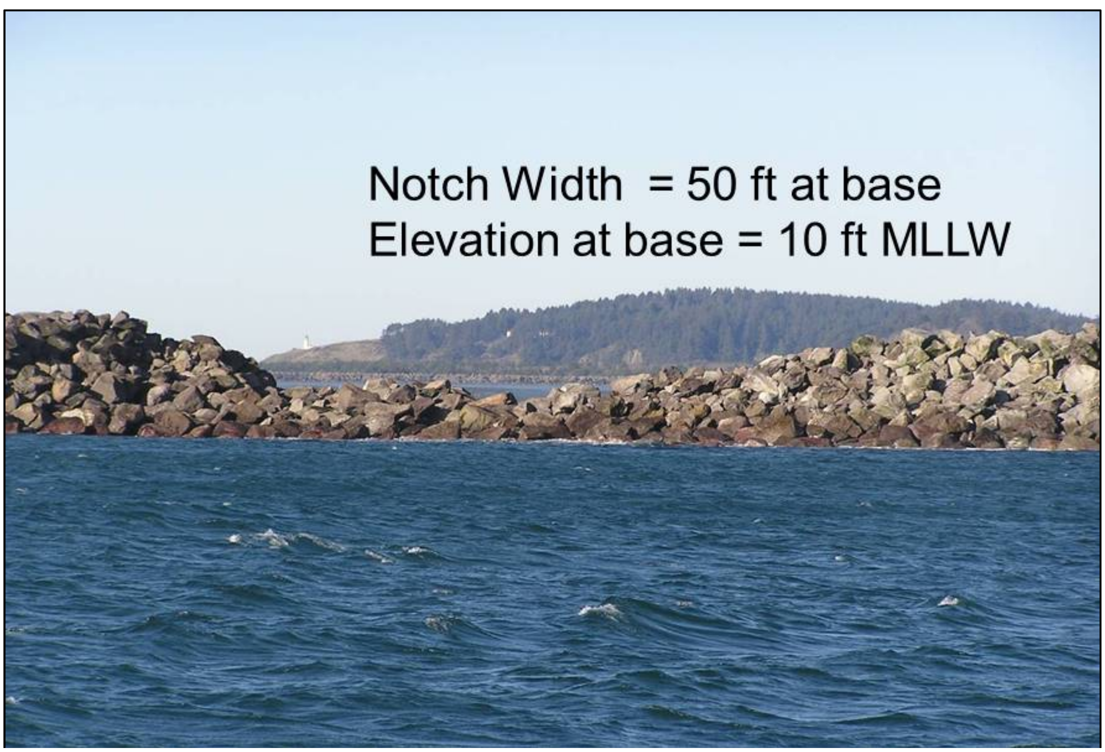


Figure A1- 127. Damage Area known as Shark Bite – Outer SJ Trunk

Figure A1- 128. South Jetty Seaward Trunk and Head

Figure A1- 129. South Jetty Deteriorated Head and Concrete Terminal

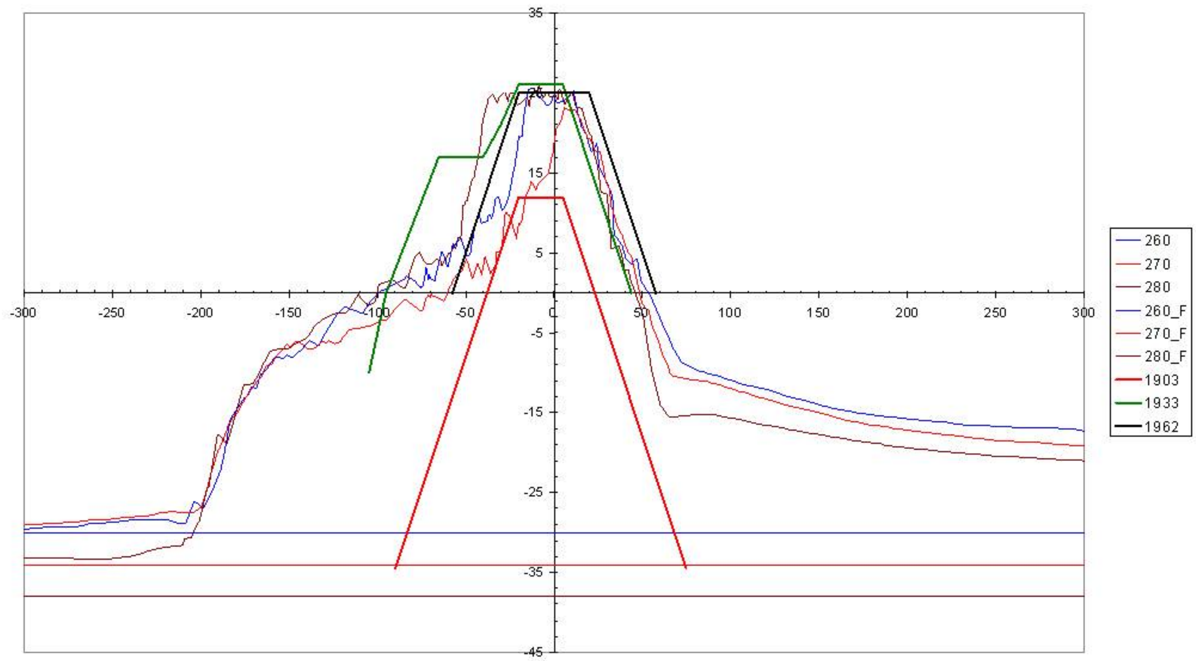


Figure A1- 130. South Jetty Cross Section Templates - Root

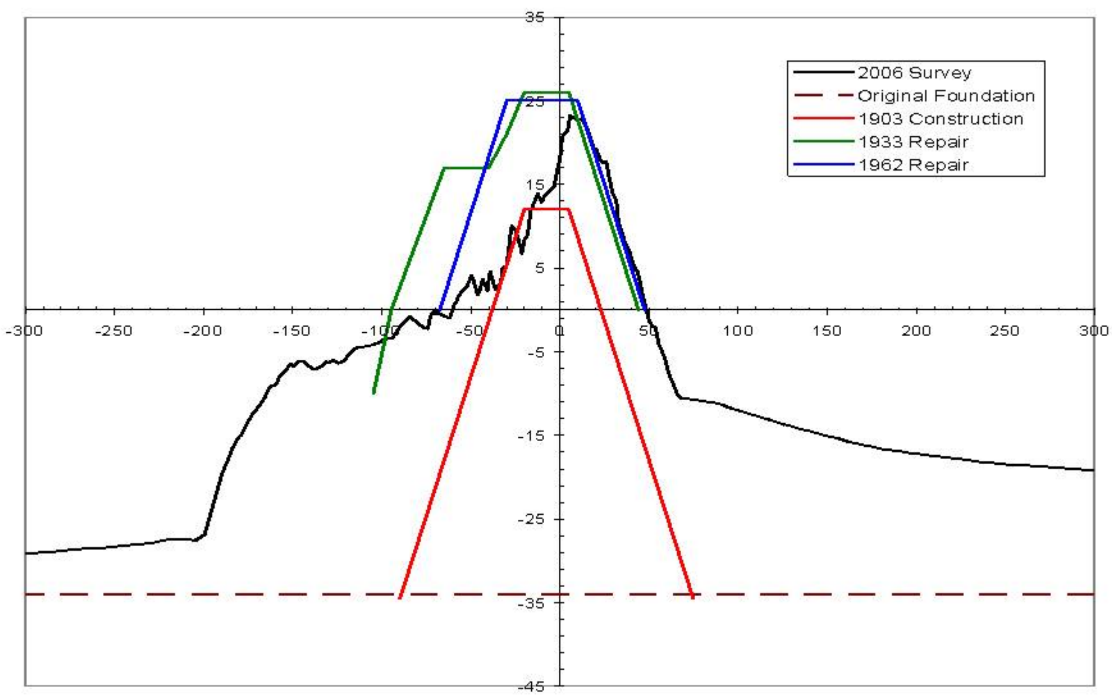


Figure A1- 131. South Jetty Cross Section Templates - Trunk

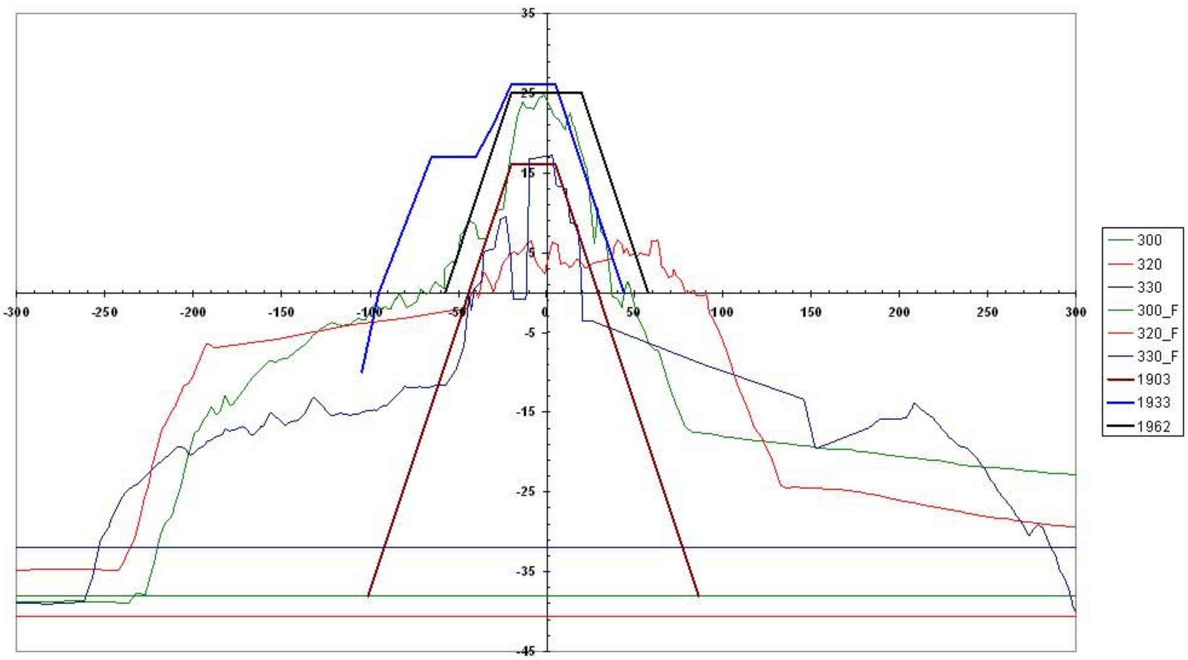


Figure A1- 132. South Jetty Cross Section Templates –Seaward Trunk

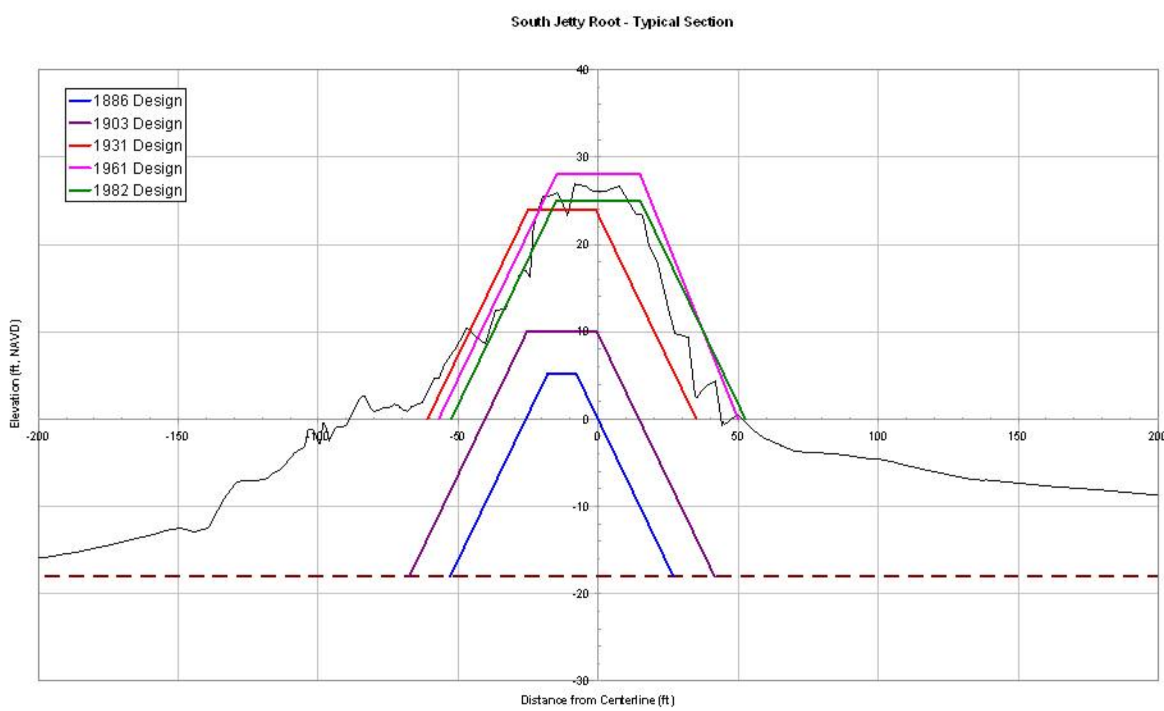


Figure A1- 133. South Jetty Cross Section Templates - Head

The first reach of the South Jetty extends from Station 155 to Station 190 with the northern side of this reach backed by accreted land (Figure A1- 134). A portion of this reach of the

South Jetty has never been repaired since original construction in 1886, 123 years. Foundation depths on the south side of the jetty range from -2 to -15. The shoreline adjacent to the south side of the jetty root has been experiencing successive erosion eastward toward the old jetty root structure. Figure A1- 120 ad Figure A1- 121 show the proximity of the shoreline to Trestle Bay which is on the eastern side of the spit. Action is being taken separate from the rehabilitation study to add sediment to this reach of shoreline. Design wave heights incident to the south side of the structure range from 10 to 16 ft. The crest elevation and crest width along this reach range from 13 to 20 ft and 4 to 20 ft, respectively. Primary design issues for this reach are just basic need for structure repair as well as shoreline erosion eastward.

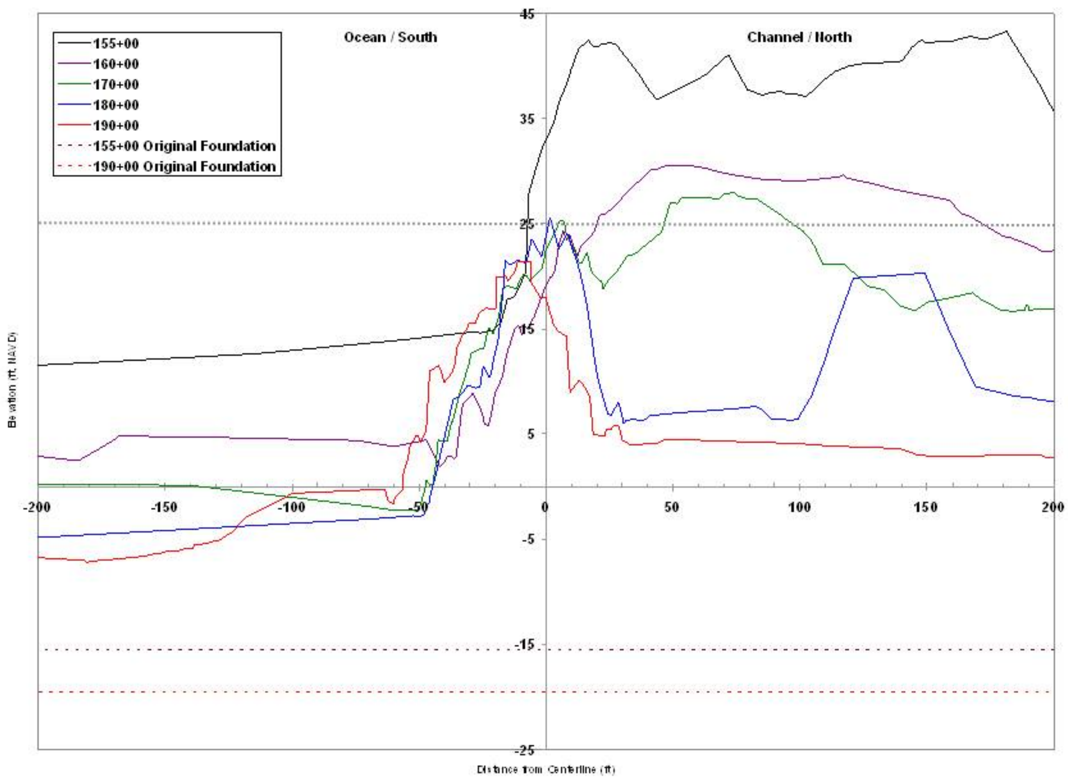


Figure A1- 134. South Jetty – Reach 1

Table A1- 6. South Jetty Design Input Parameters

Station	Crest Elevation	Crest Width	Design Wave Height		Depth at Toe		Design Issue
			Ocean	Channel	Ocean	Channel	
	(ft, MLLW)	(ft)	(ft)	(ft)	(ft, MLLW)	(ft, MLLW)	
155 to 190	13 to 20	4 to 20	10 to 16	0	-2 to +15	+4 to +37	Minor frontslope wave attack (1) Minor overtopping (1) Shore erosion
190 to 220	14 to 25	4 to 37	16 to 25	16 to 18	-2 to -10	-4 to +4	Moderate frontslope wave attack (1) Overtopping (1) Shore erosion
220 to 250	20 to 25	20 to 30	25 to 32	18 to 20	-10 to -22	-5 to -8	Moderate fronslope wave attack (1) Overtopping (1) Foundation loss (1)
250 to 280	20 to 25	25 to 40	32 to 35	20 to 21	-23 to -32	-8 to -15	Extreme frontslope wave attack (2) Heavy overtopping (2) Foundation loss (2)
280 to 310	15 to 25	14 to 40	35 to 36	20 to 21	-32 to -39	-15 to -22	Extreme frontslope wave attack (2) Heavy overtopping (2) Foundation loss (2)
Head	7 to 20	6 to 30	36	21	-33 to -39	-23 to -30	Extreme frontslope wave attack (3) Heavy overtopping (3) Foundation loss (3)

The second reach of the South Jetty extends from Station 190 to Station 220 (Figure A1- 135). This reach is exposed to moderate wave attack from the south side (16 to 25 ft) and minor wave attack from the north side (16 to 18 ft). On the north side or channelside of the structure, the subaerial part of Clatsop Spit is receding eastward exposing more of the older jetty. Foundation depths along this reach vary from -10 to -2 on the seaside and -4 to +4 on the channelside. Existing crest elevation and crest width along this reach vary from 14 to 25 ft and 4 to 37 ft, respectively. Primary design issues along this reach include the shore erosion on the north side and basic need for repair.

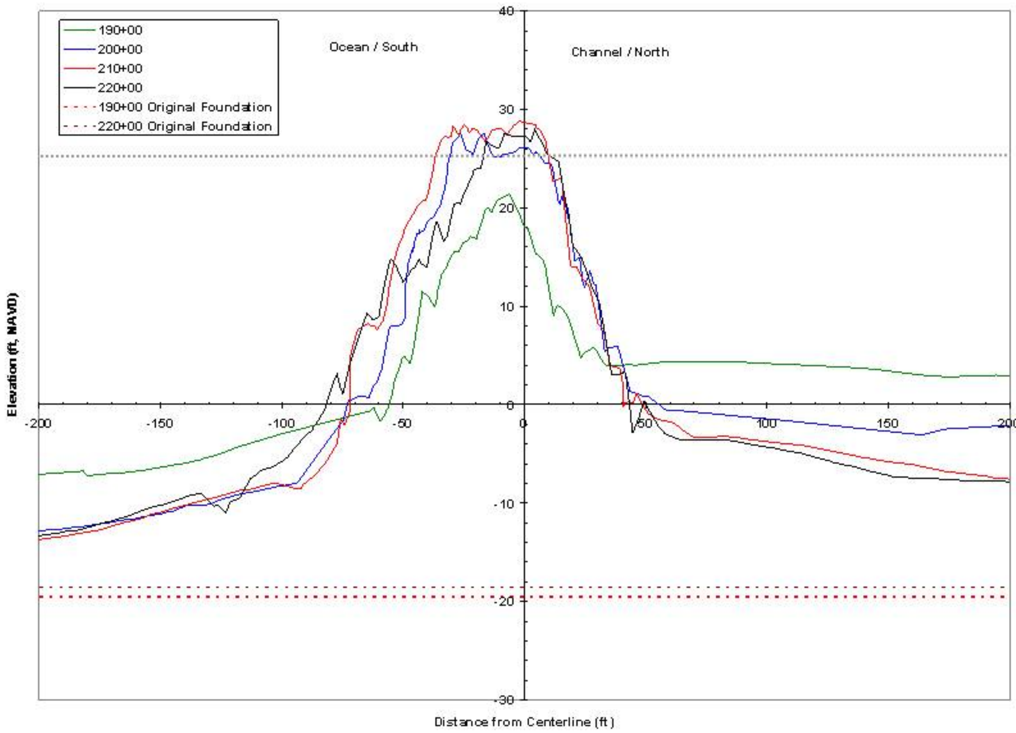


Figure A1- 135. South Jetty – Reach 2

The third reach of the South Jetty extends from Station 220 to Station 250 (Figure A1- 136). The majority of this reach (224 to 245) was addressed with an Interim Repair in 2006. This reach is exposed to design waves of 25 to 32 ft from the oceanside and 18 to 20 ft from the channelside. Existing crest elevations and crest widths are controlled by the most recent Interim Repair effort, 20 to 25 ft elevation and 20 to 30 ft crest widths. This reach of jetty has been repaired 3 times during its lifetime, two of those times to prevent a complete breach of the jetty. Foundation elevations range from -22 to -10 on the oceanside and -8 to -5 on the channelside. Primary design issues for this reach include maintaining the underwater shoal on the channelside of the structure and providing stability against wave attack and overtopping.

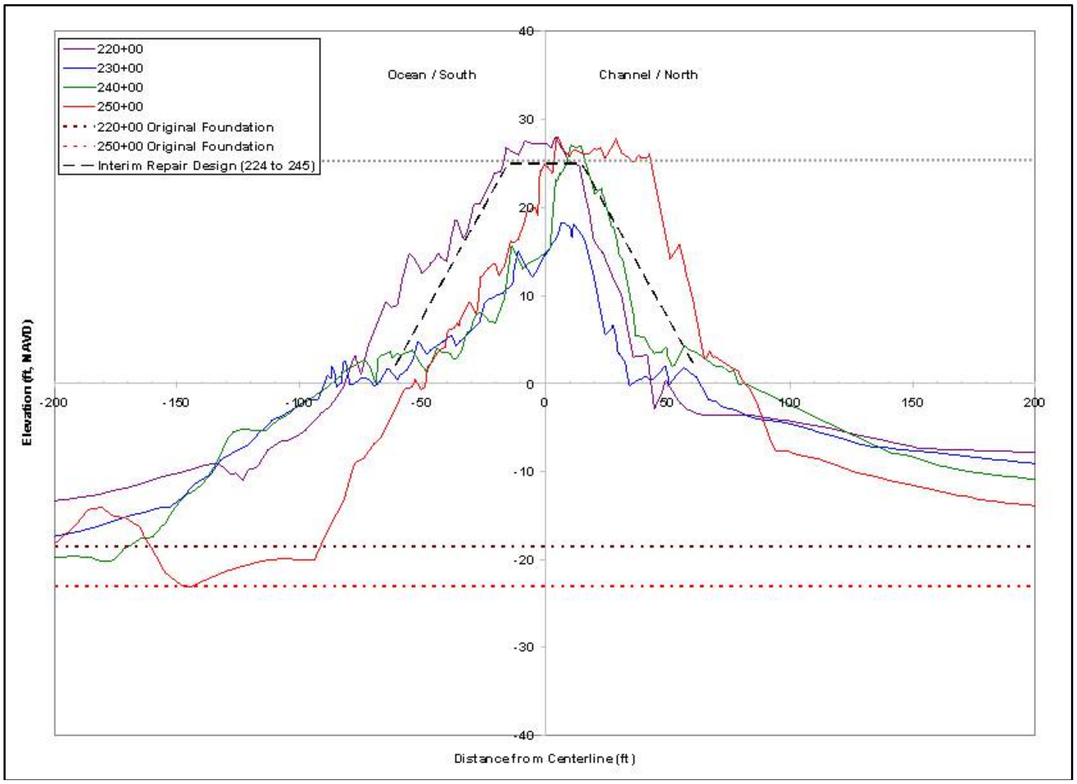


Figure A1- 136. South Jetty – Reach 3

The fourth reach extends from Station 250 to Station 280, a majority of which was addressed in a 2007 Interim Repair effort to prevent a breach of the jetty (Figure A1- 137). Design waves of 32 to 35 ft attack the oceanside of the jetty while 20 to 21 ft waves attack the channelside. Foundation depths range from -23 to -32 on the oceanside and -15 to -8 on the channelside and have exhibited increasing trends on both sides. Subsequent to the 2007 Interim Repair, the crest elevation varies from approximately 20 to 25 ft with crest widths ranging from 25 to 40 ft. Primary design issues for this reach include maintaining the underwater shoal on the channelside of the structure and providing stability against wave attack and overtopping.

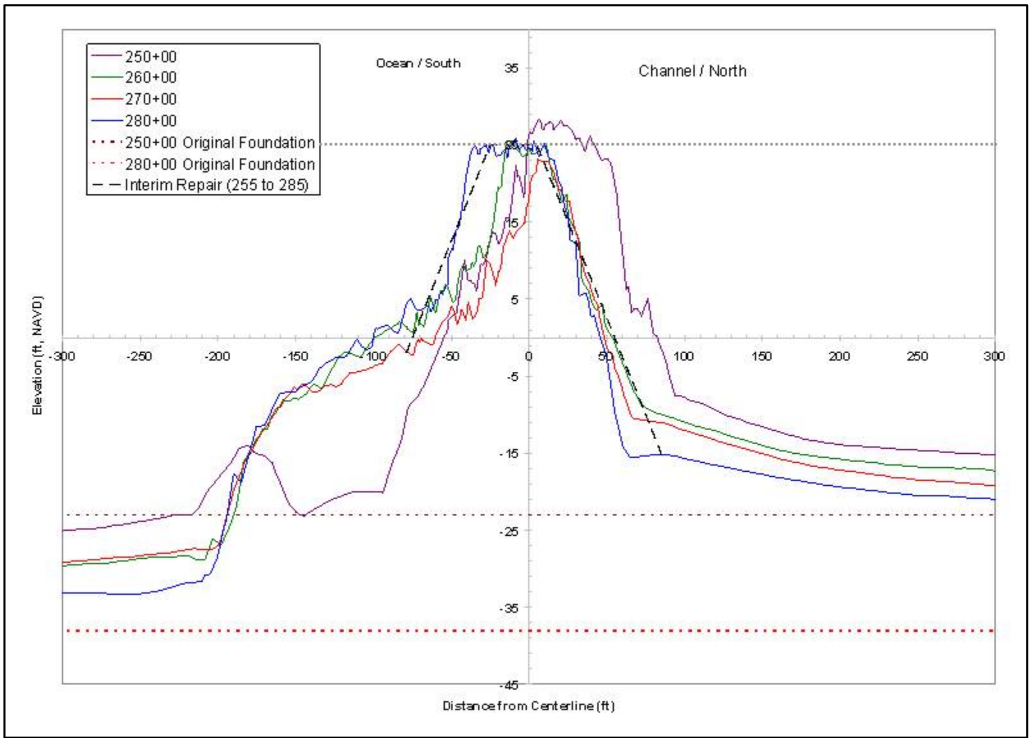


Figure A1- 137. South Jetty – Reach 4

The fifth reach of the South Jetty extends from Station 280 to 310 (Figure A1- 138). This reach has been repaired twice since the original construction in 1913. Foundation depths range from -39 to -32 on the oceanside and -22 to -15 on the channelside and are increasing. Design wave heights are estimated at 35 to 36 ft for the oceanside and 20 to 21 ft for the channelside. The presence of the underwater shoal on the channelside of the South Jetty serves to reduce the wave heights impacting this length of structure. Existing crest elevations and crest widths for this reach range from 15 to 25 ft and 14 to 40 ft, respectively. Primary issues for this reach including the high degree of wave attack from both sides of the structure and the gradually increasing foundation depths.

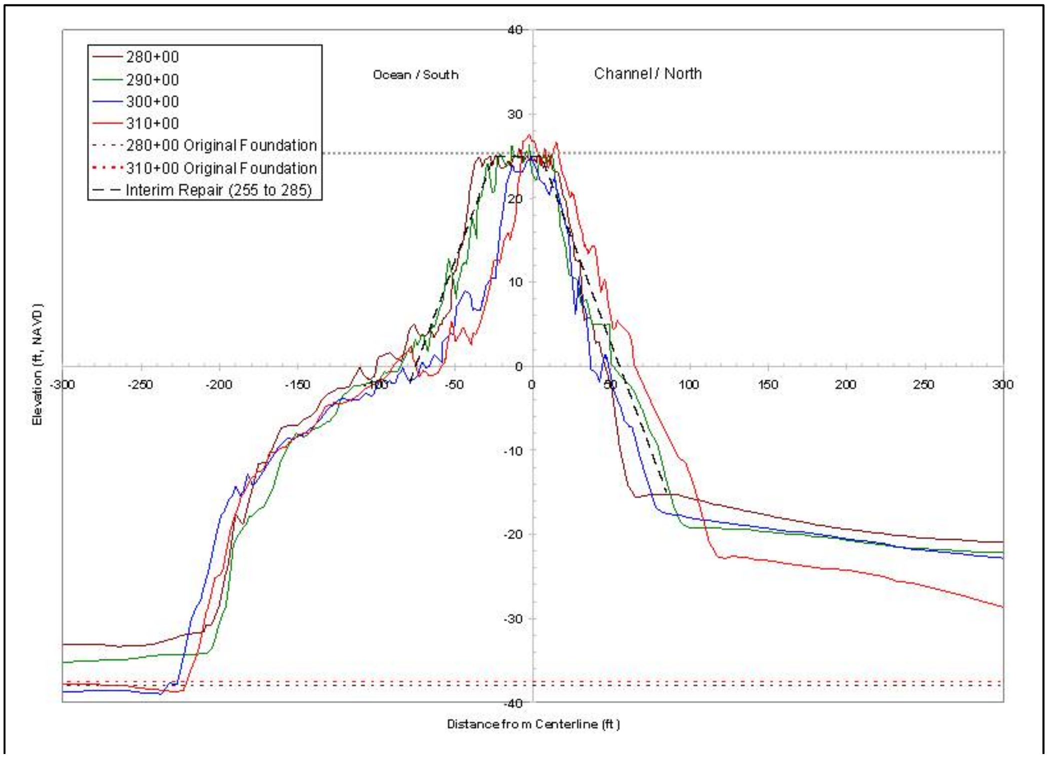


Figure A1- 138. South Jetty – Reach 5

The final design reach for the South Jetty is the head of the structure which is proposed for reconstruction to Station 313 to 315 (Figure A1- 139). Existing crest elevations and crest widths for this reach range from 7 to 20 ft, MLLW and 6 to 30 ft, respectively. A large relic base exists which will provide the base to construct the new jetty head. Primary design concerns include the 3 directions of severe wave attack and overtopping as well as the need to maintain the underwater shoal evolution.

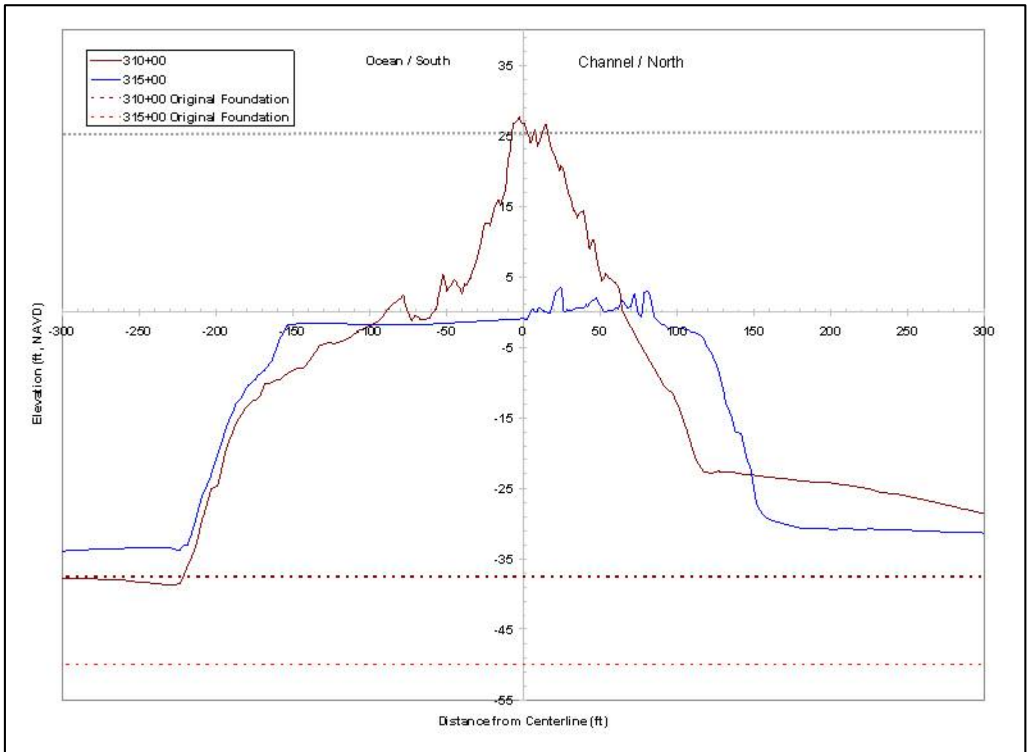


Figure A1- 139. South Jetty – Reach 6

3. Jetty A Design Reaches

Jetty A is divided into four reaches and is shown in Figure A1- 96 and Figure A1- 140 and Table A1- 7. The design parameters provided in Table A1- 7 are valid only for the existing condition. These parameters will change in the future due to morphological changes and future damage to the Jetty A. Jetty A was constructed as a very large spur groin directed perpendicularly into the Columbia River to help train the navigation channel away from the North Jetty foundation. While it is exposed to a lesser wave climate than the other two primary jetties, it has suffered severe scour at its southern tip which has contributed to its recession. In addition, wave modeling at the MCR entrance has identified an area of increased wave attack at the center part of the jetty length. Wave attack on this jetty is limited to the ocean or western side of the structure. Similar to the other two jetties, Jetty A was constructed on top of a large underwater shoal, the continued erosion of which will undermine the structure as it has already done on the southern end. Figure A1- 141 and Figure A1- 142 illustrate crest elevation and foundation changes for Jetty A. Figure A1- 143 through Figure A1- 146 show pictures of the different reaches of the Jetty A and Figure A1- 147 through Figure A1- 154 illustrate the respective cross sections.

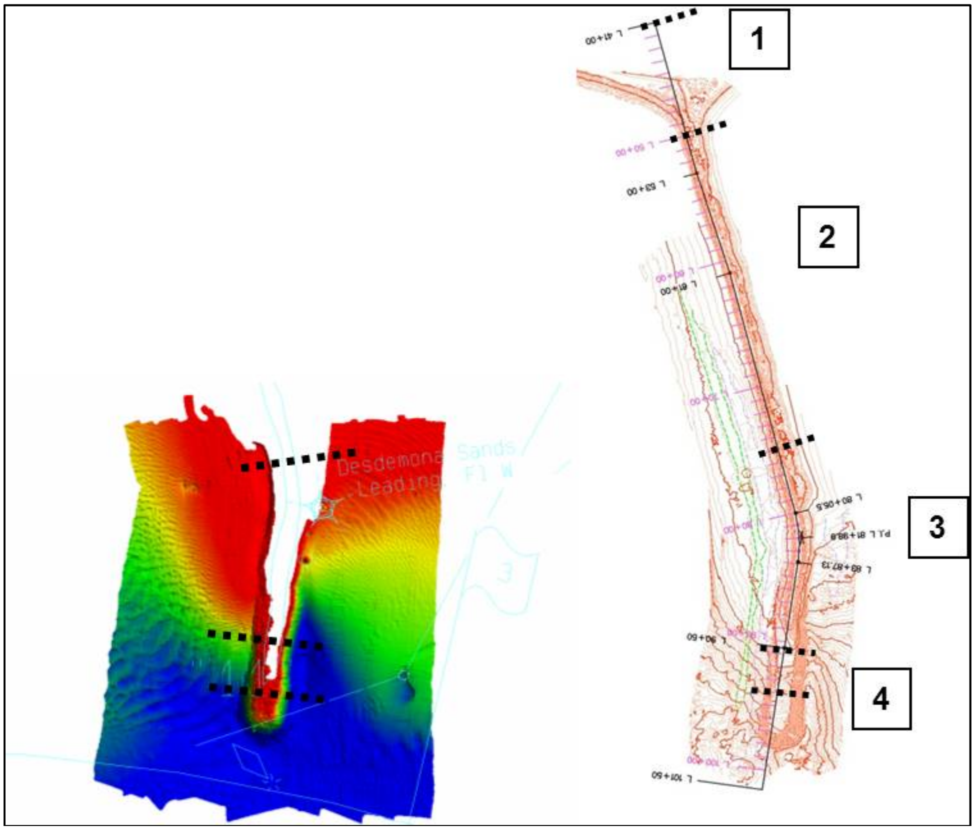


Figure A1- 140. Jetty A Bathymetry and Design Reaches

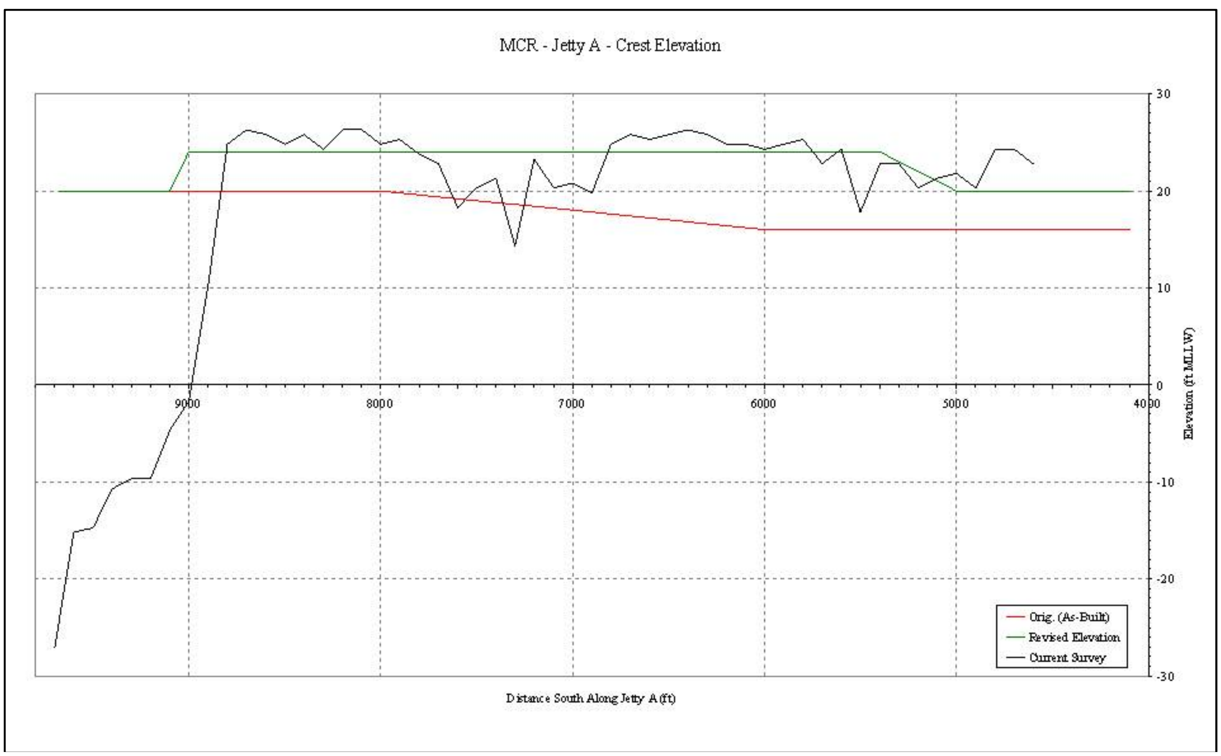


Figure A1- 141. Jetty A Crest Elevation Changes

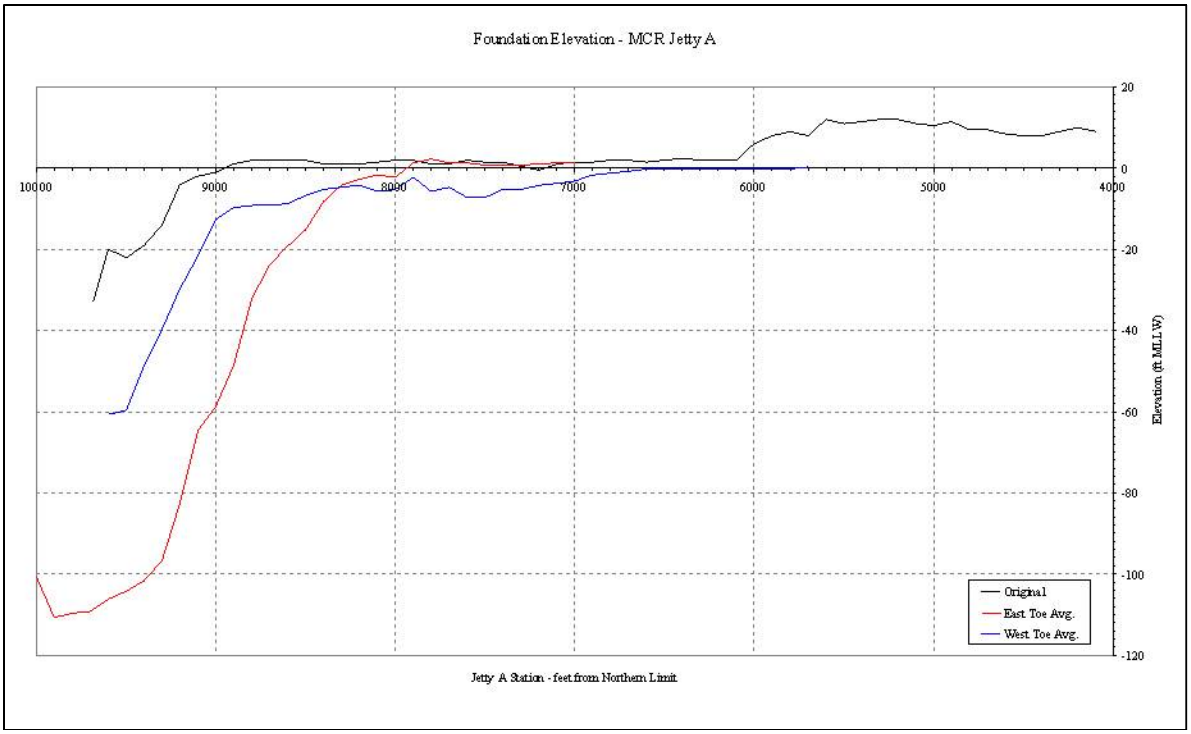


Figure A1- 142. Jetty A Foundation Changes

Figure A1- 143. Jetty A and Ilwaco Channel

Figure A1- 144. Jetty A and Root

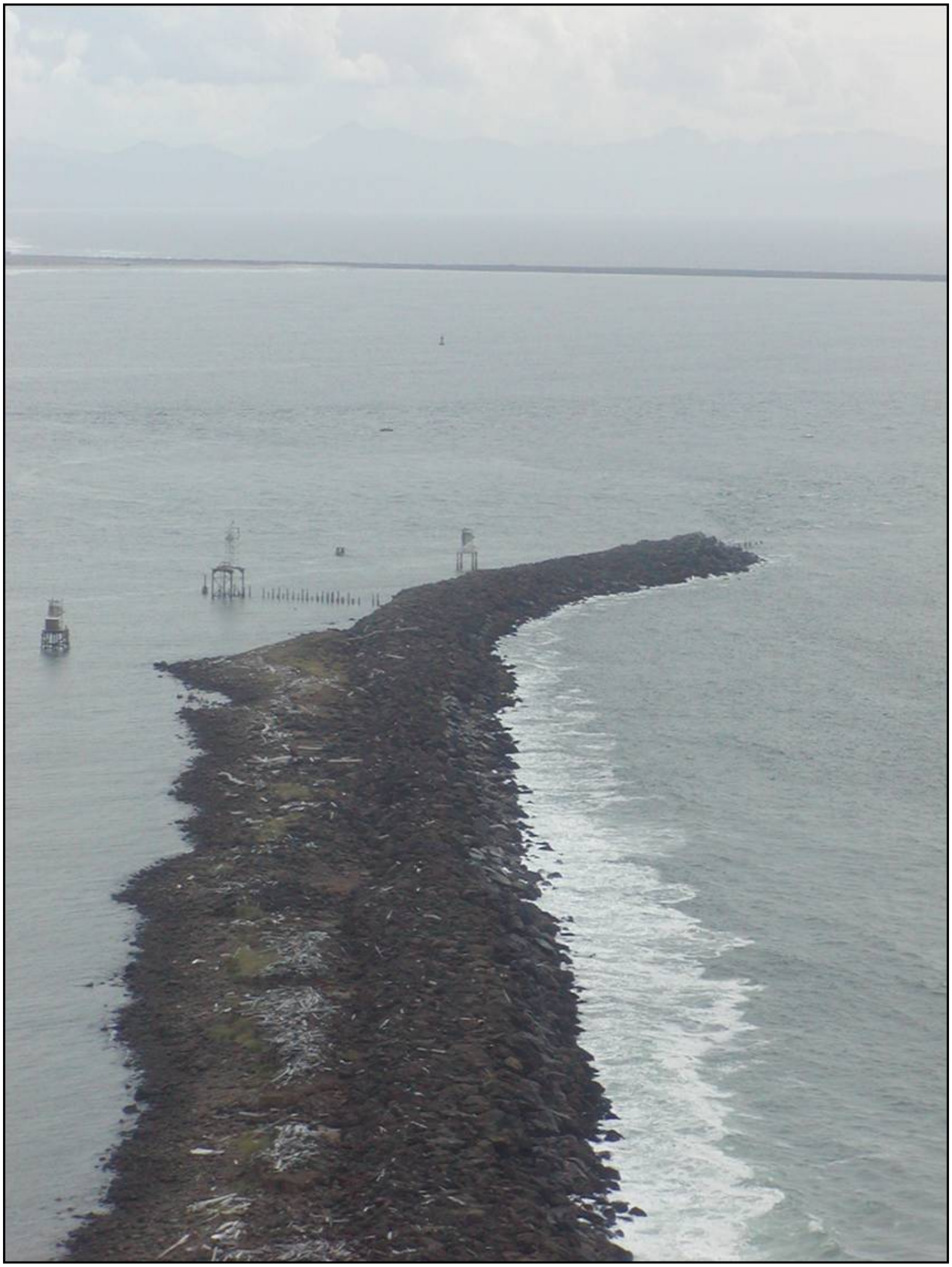


Figure A1- 145. Jetty A Trunk

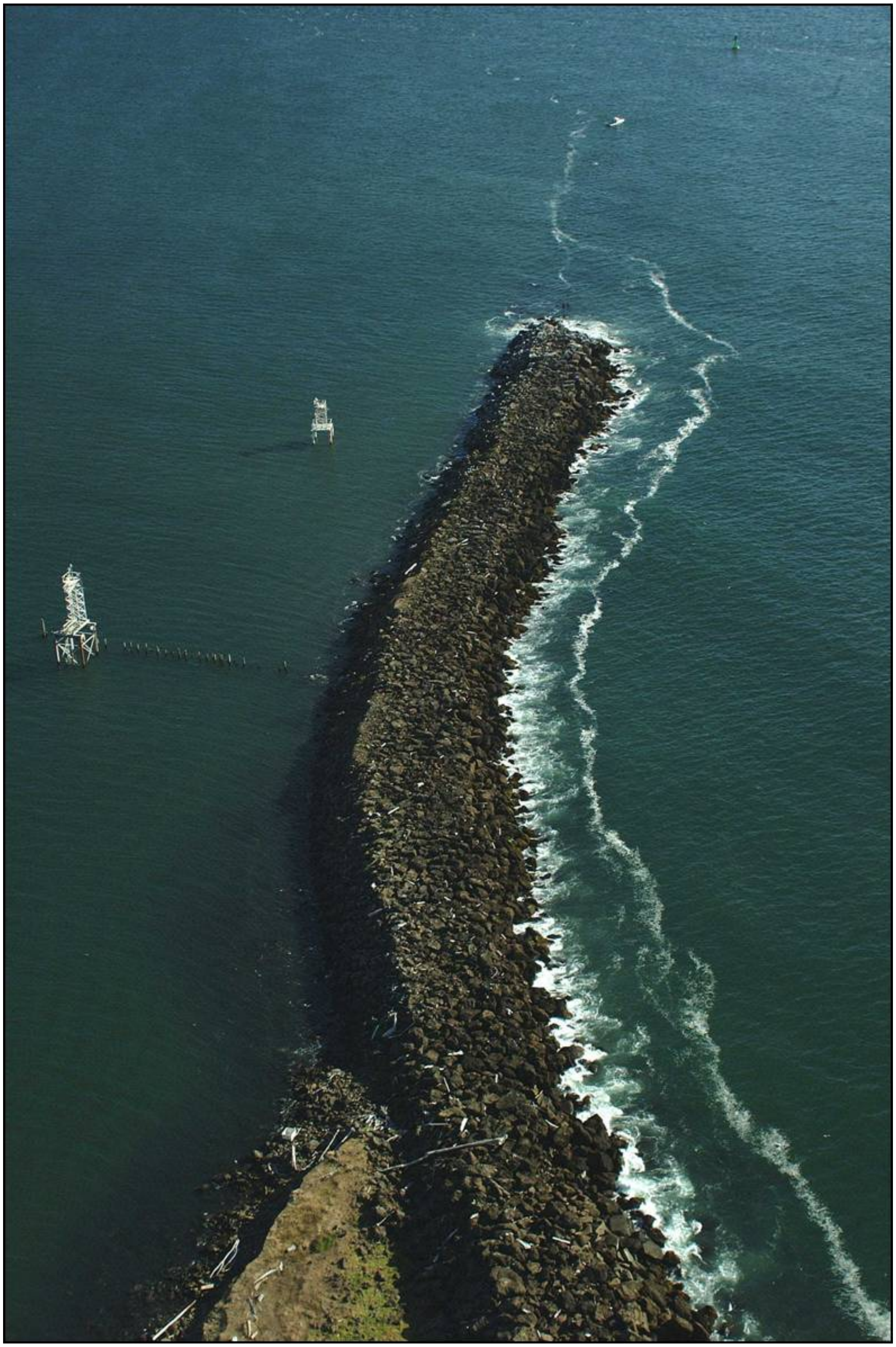


Figure A1- 146. Jetty A Head

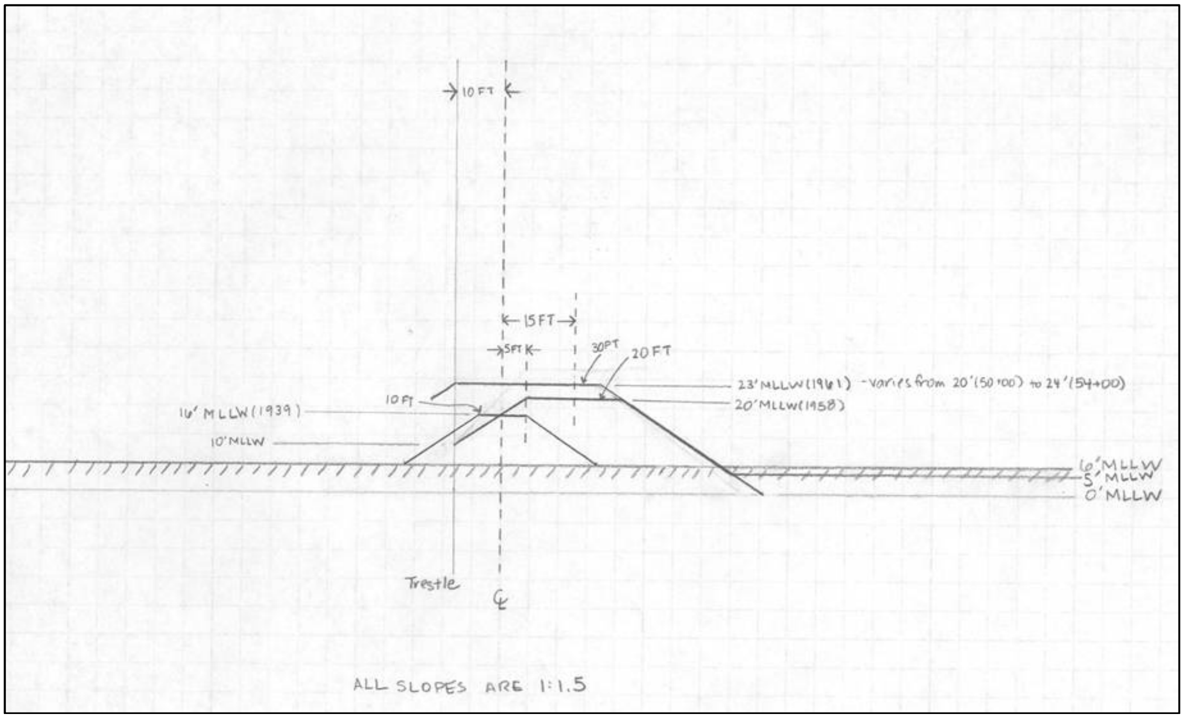


Figure A1- 147. Jetty A Cross Section Templates - 41 to 53 – Root

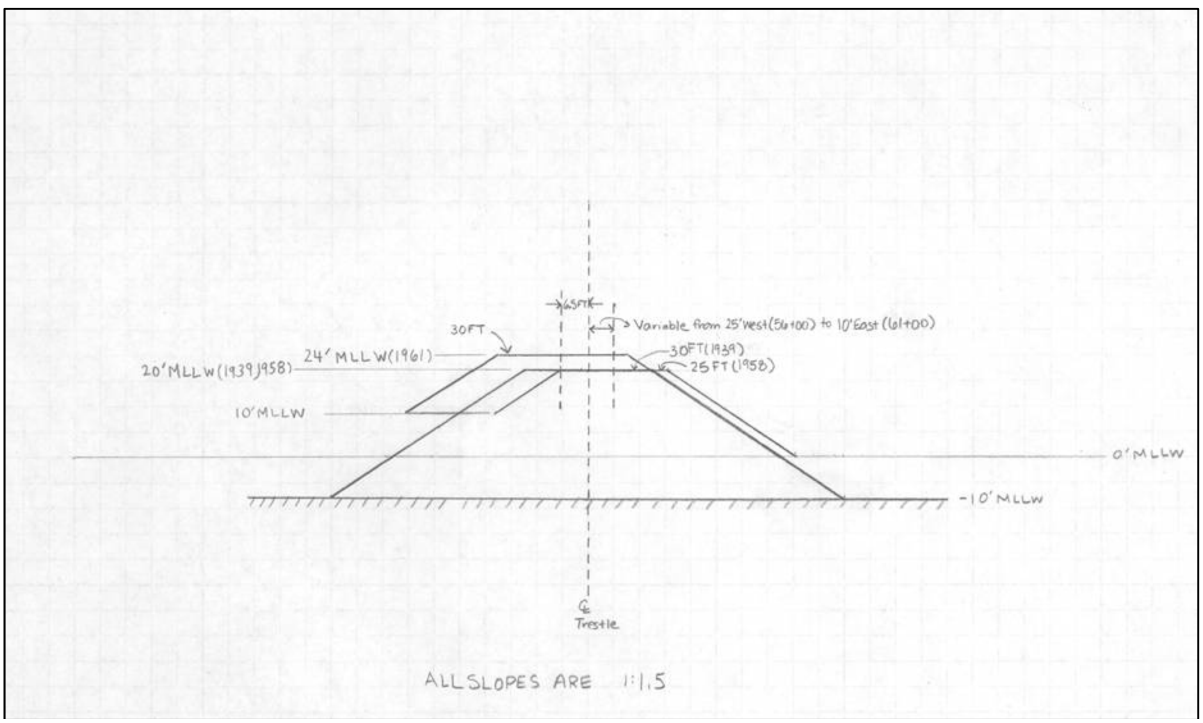


Figure A1- 148. Jetty A Cross Section Templates - 56 to 61 – Trunk

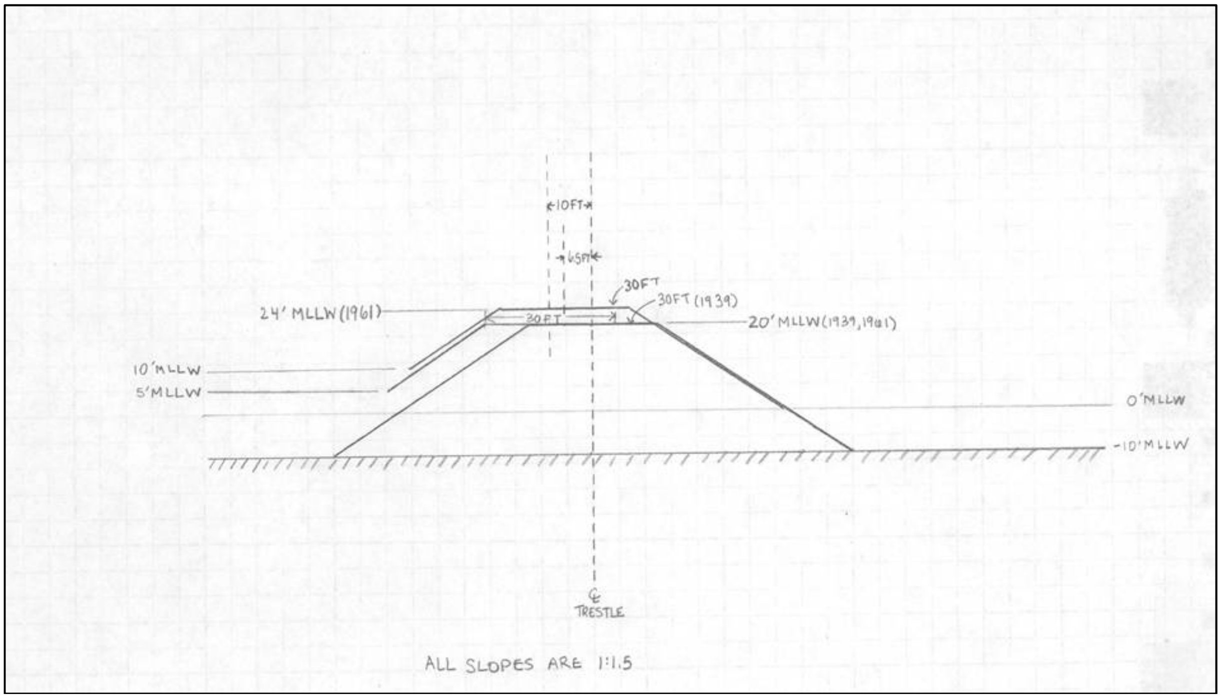


Figure A1- 149. Jetty A Cross Section Templates - 61 to 68 and 76+50 to 78 – Trunk

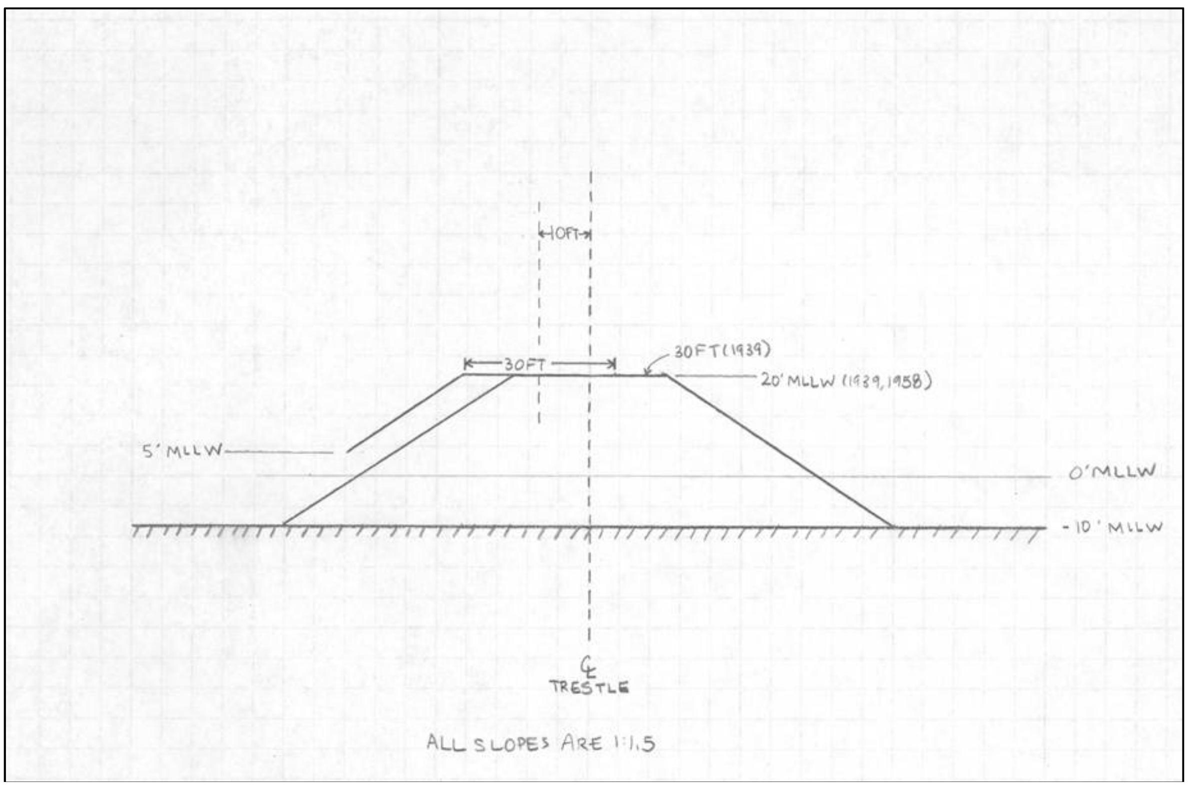


Figure A1- 150. Jetty A Cross Section Templates - 68 to 76+50 - Trunk

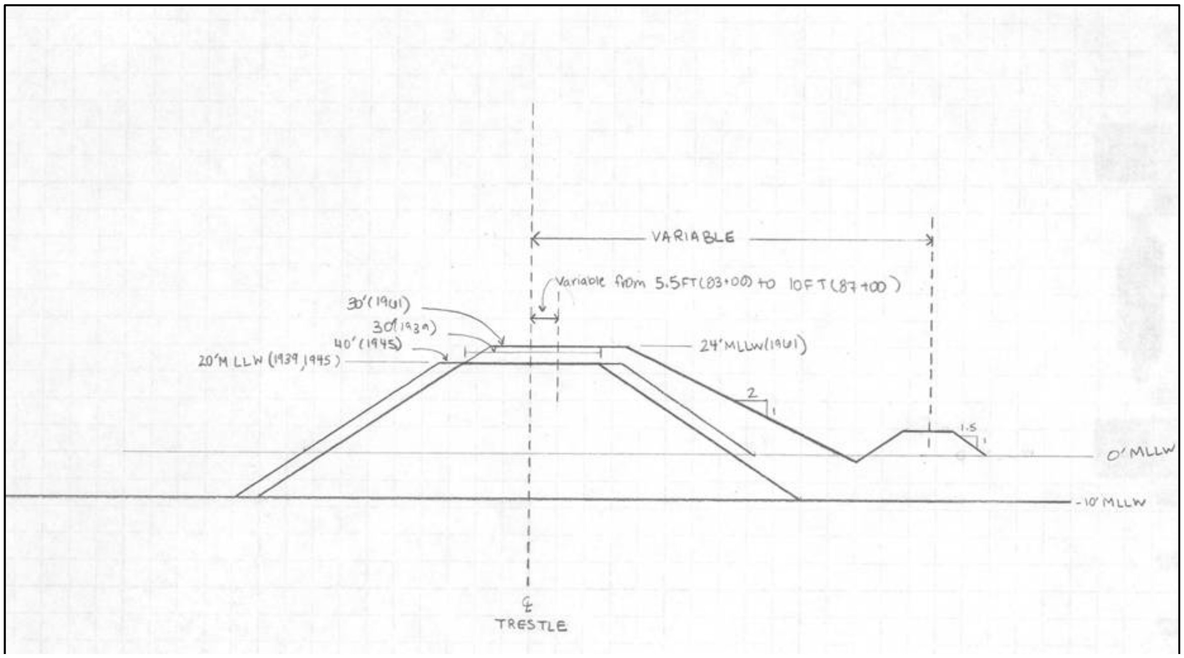


Figure A1- 151. Jetty A Cross Section Templates - 79 to 90 - Trunk

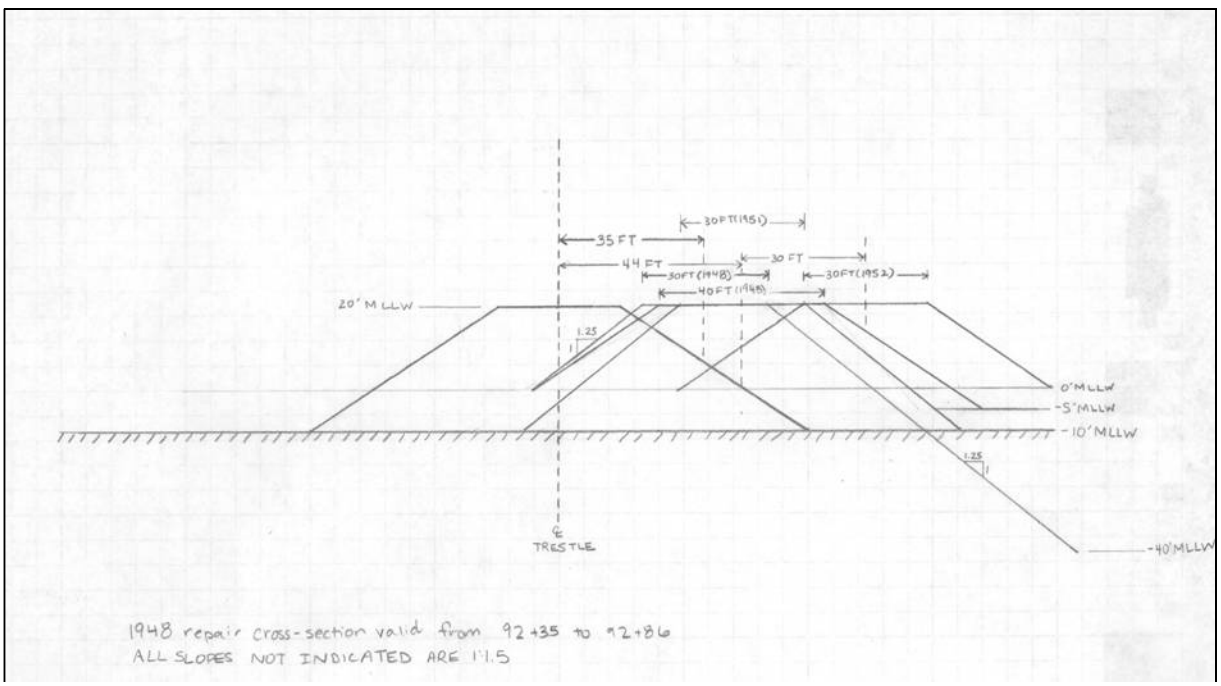


Figure A1- 152. Jetty A Cross Section Templates - 91+50 to 92+86 – Trunk

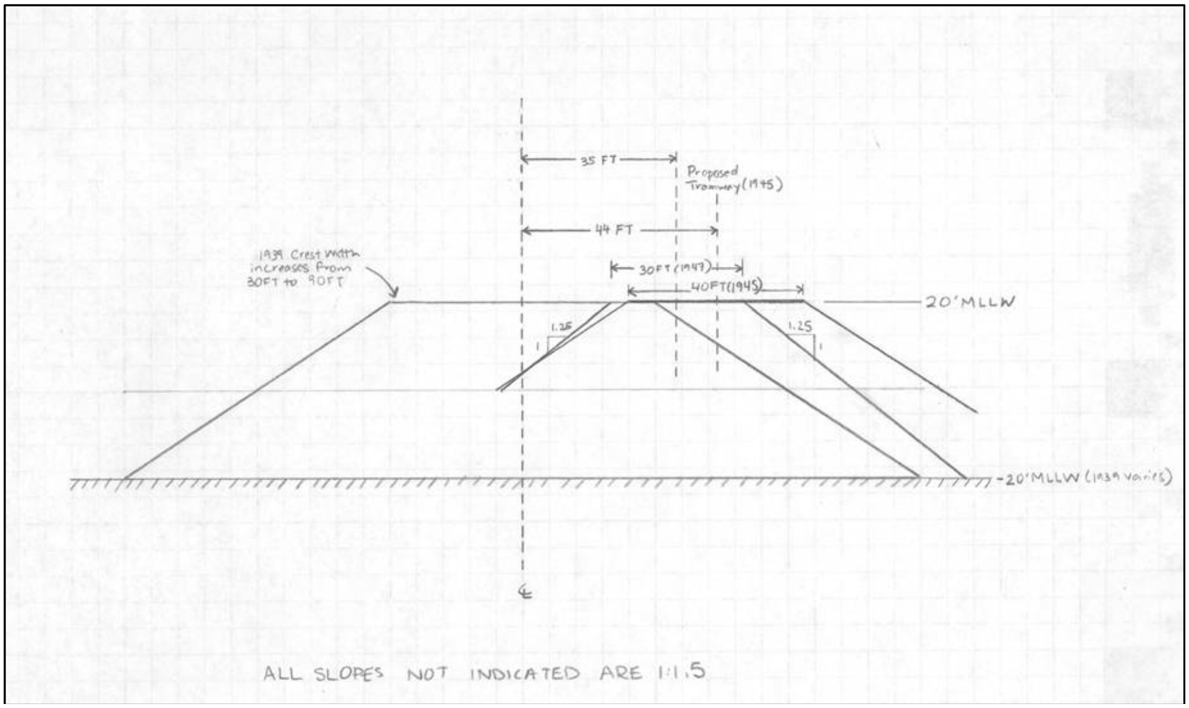


Figure A1- 153. Jetty A Cross Section Templates - 94 to 96 – Trunk

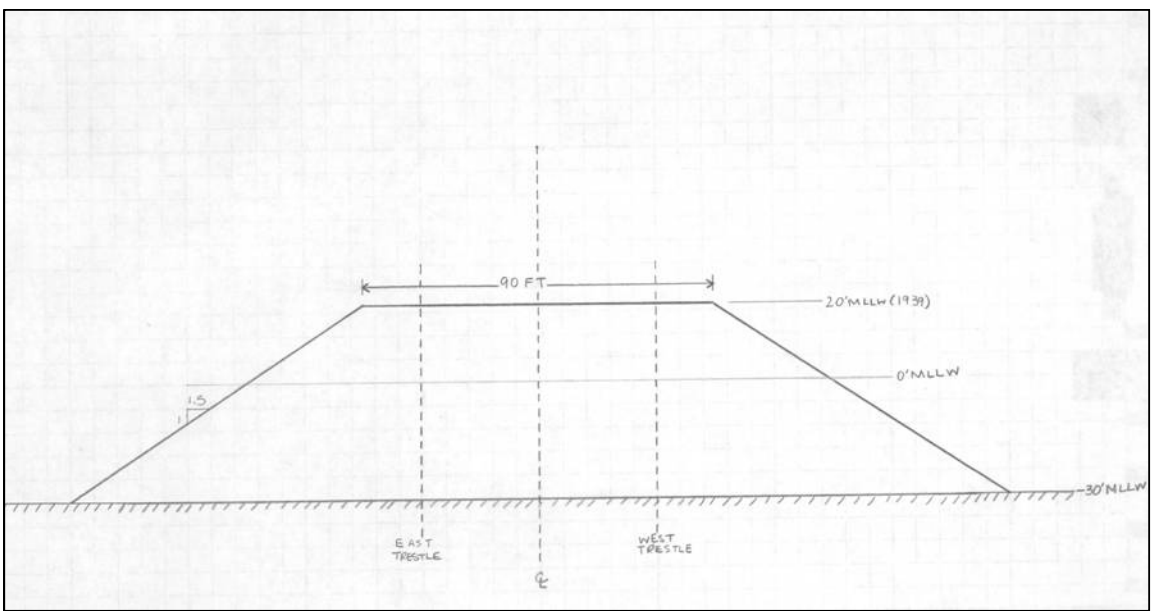


Figure A1- 154. Jetty A Cross Section Templates - 96+83 - Head

The first design reach for Jetty A extends from Station 40 to Station 50 (Figure A1- 155). A portion of this reach is backed by land and is protected. Design wave heights along this reach are expected to range from 5 to 12 ft. Existing crest elevations and crest widths range from 20 to 22 ft, MLLW and 40 to 45 ft, respectively. Primary design issues along this reach deal with basic maintenance.

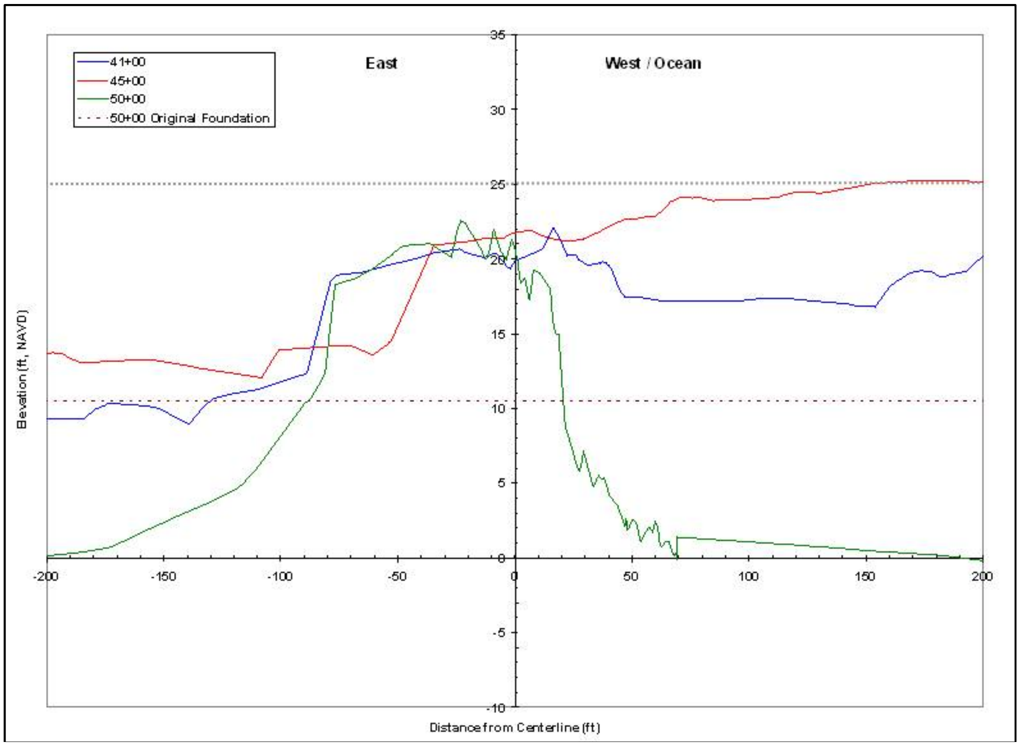


Figure A1- 155. Jetty A - Reach 1

Table A1- 7. Jetty A Design Input Parameters

Reach/ Stations	Crest Elevation (ft, MLLW)	Crest Width (ft)	Design Wave Height (ft)		Depth at Toe (ft, MLLW)		Design Issue
			Ocean	Channel	Ocean	Channel	
Reach 1 (Stations 40 to 50)	20 to 22	40 to 50	5 to 11.5	0	+2 to +18	0 to +14	Minor frontslope wave attack (1)
Reach 2 (Stations 50 to 75)	20 to 25	20 to 50	11.5 to 22.5	3.5	0 to -8	0 to +2	Major frontslope wave attack (1), Overtopping (1),
Reach 3 (Stations 75 to 90)	18 to 25	15 to 50	17 to 20	5.5	-8 to -20	0 to -75	Moderate frontslope wave attack (1), Overtopping (1), Foundation loss (2)
Reach 4 (Head)	-2 to 20	NA	20	5.5	-15 to -50	-75 to -105	Moderate frontslope wave attack (1), Overtopping (1), Foundation loss (2)

Note: These design input parameters are valid only for the existing condition

The second design reach extends from Station 50 to Station 75 (Figure A1- 156). Modeling has shown that this reach of the jetty is exposed to the largest wave heights along the structure ranging from 12 to 23 ft in height. Foundation depths along the oceanside range from -8 to 0 and from 0 to +/-2 on the channelside. Existing crest elevations and crest widths range from 20 to 25 ft MLLW and 20 to 50 ft. Primary design issues along this reach deal with the heightened wave attack and overtopping.

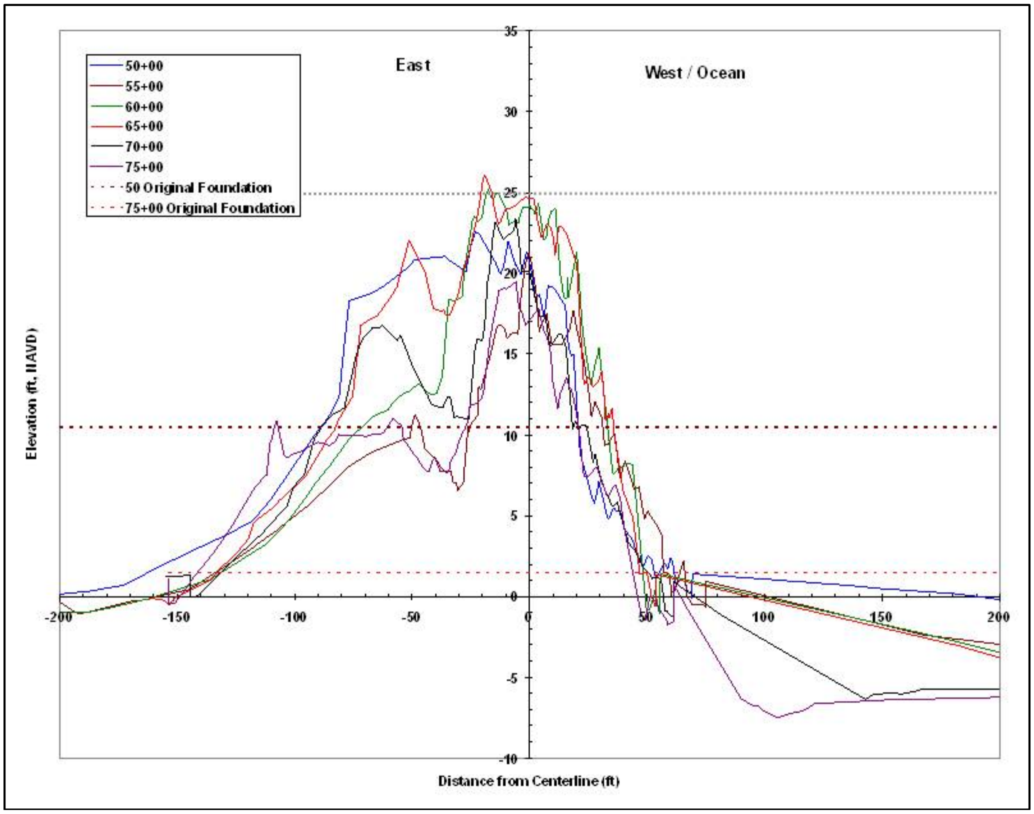


Figure A1- 156. Jetty A – Reach 2

The third reach along Jetty A extends from Station 75 to Station 90 (Figure A1- 157). Design wave heights are expected to range from 17 to 20 ft. This reach currently has oceanside and channelside foundation depths ranging from-20 to -8 and -75 to 0, with increasing rates of erosion on both sides. Attempts to stabilize the underwater shoal could help stabilize this reach of the jetty. Primary design issues include the moderate wave attack and overtopping and the foundation loss.

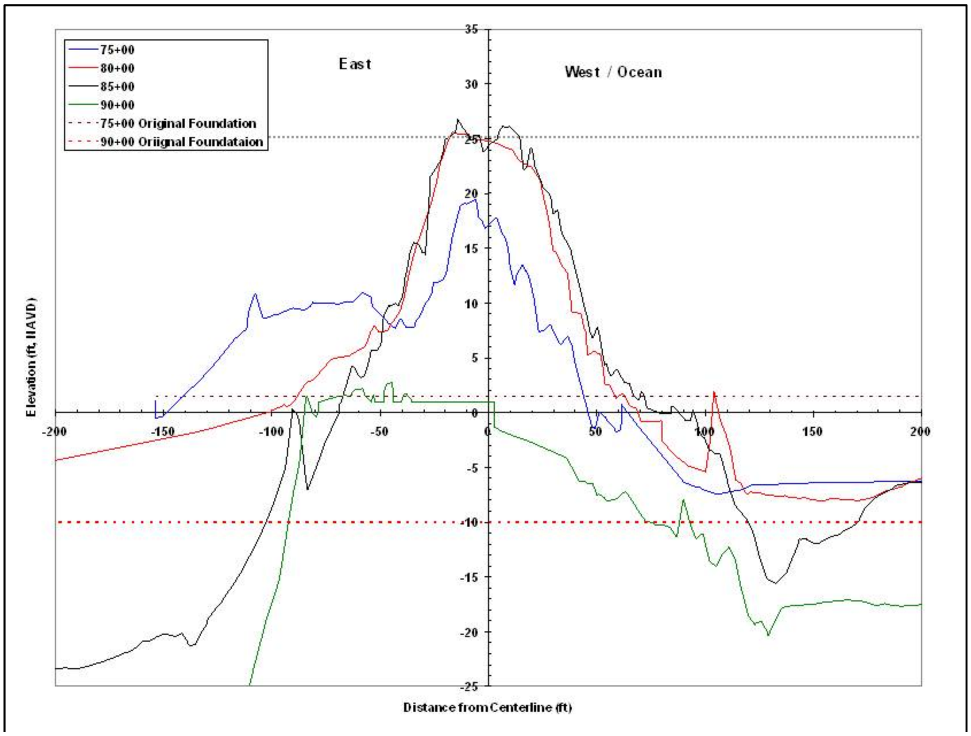


Figure A1- 157. Jetty A – Reach 3

The final reach for Jetty A is reconstruction and stabilization of the head of the structure, expected to occur from Station 90 to 93 (Figure A1- 158). Current crest elevations along this reach range from -2 ft to +2 ft MLLW.

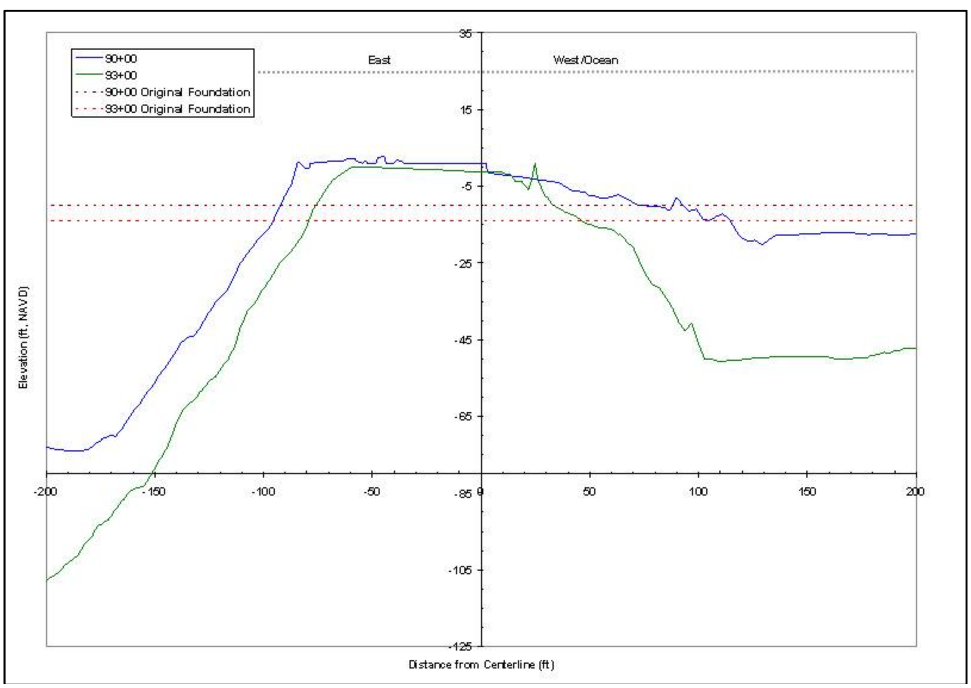


Figure A1- 158. Jetty A – Reach 4

9. Design of Jetty Cross Section Repair

a. Cross Section Intent and Design Philosophy

Cross section development for jetty repairs was guided by the following constraints. The repair template must be cost-effective in terms of construction materials as well as quantity of material, to allow the maximum repair within funding limitations. Quarried stone is expected to be used for the majority of the work. The vast majority of the repair stone which will be needed for the jetty repair will be within the easily acquired stone size range. Quarried armor stone is available from numerous sources in the Pacific Northwest. Concrete armor units are considered as an option for only the most extreme part of each structure. The repair template must be constructible. In order to limit potential impacts to the surrounding environment, the minimum modification to the jetty footprint is desirable. The jetty repair should be structurally consistent with the present jetty configuration and future rehabilitation scenarios. There should be no dissimilar attributes between the present jetty section and the repair template. Areas of the jetty that are repaired, using the repair template, must be able to be augmented later if necessary. Each action taken should be directed toward improving the long-term reliability of the jetty system and its function to protect the navigation channel. Table A1- 1 to Table A1- 3 summarizes the design cross section history for the three jetties.

Early in this investigation it was determined that portions of both the North Jetty and the South Jetty were close to failure. Interim repairs which address only the upper part of the cross section damage and are only expected to last 10 to 15 years, were recently constructed (2005 to 2007) on approximately 25% of the length of both the North and South jetties. Interim Repair actions were executed for Stations 55 to 85 on the North Jetty and Stations 224 to 245 and 255 to 285 on the South Jetty (Figure A1- 159 through Figure A1- 161). The intent of the Interim Repair was to address the loss of jetty cross section above -10 ft MLLW due to slope failure and direct wave action in order to address short term stability problems. Figure A1- 162 contrasts the Interim Repair template with a more substantial template which addresses the full jetty cross section.

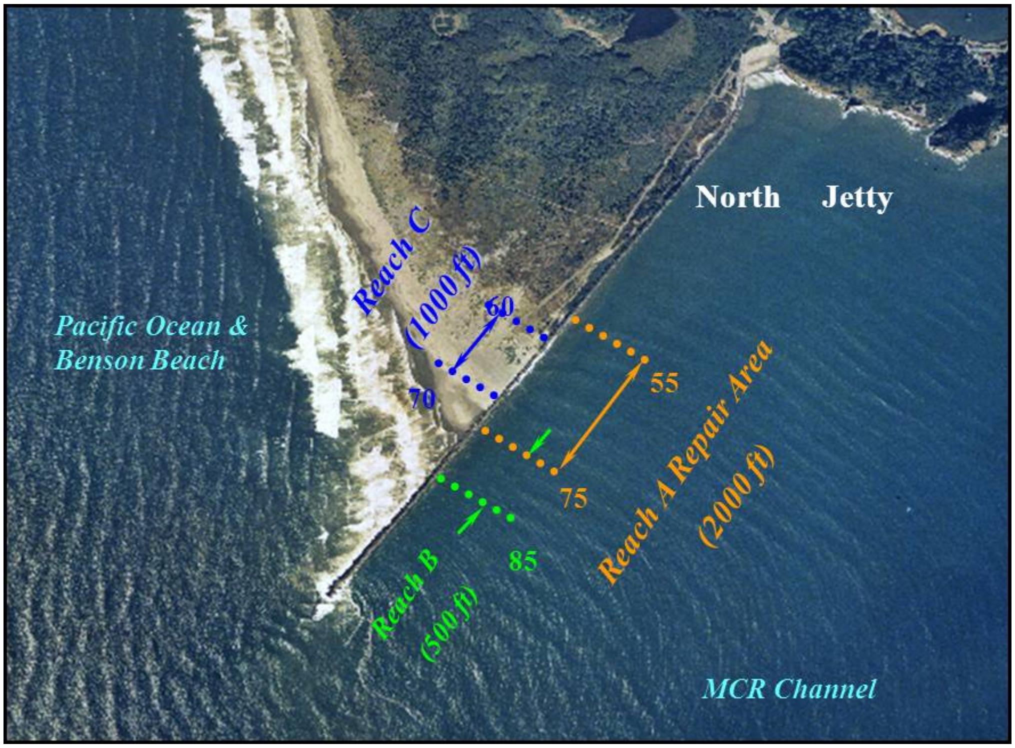


Figure A1- 159. North Jetty Interim Repair Limits – 2005

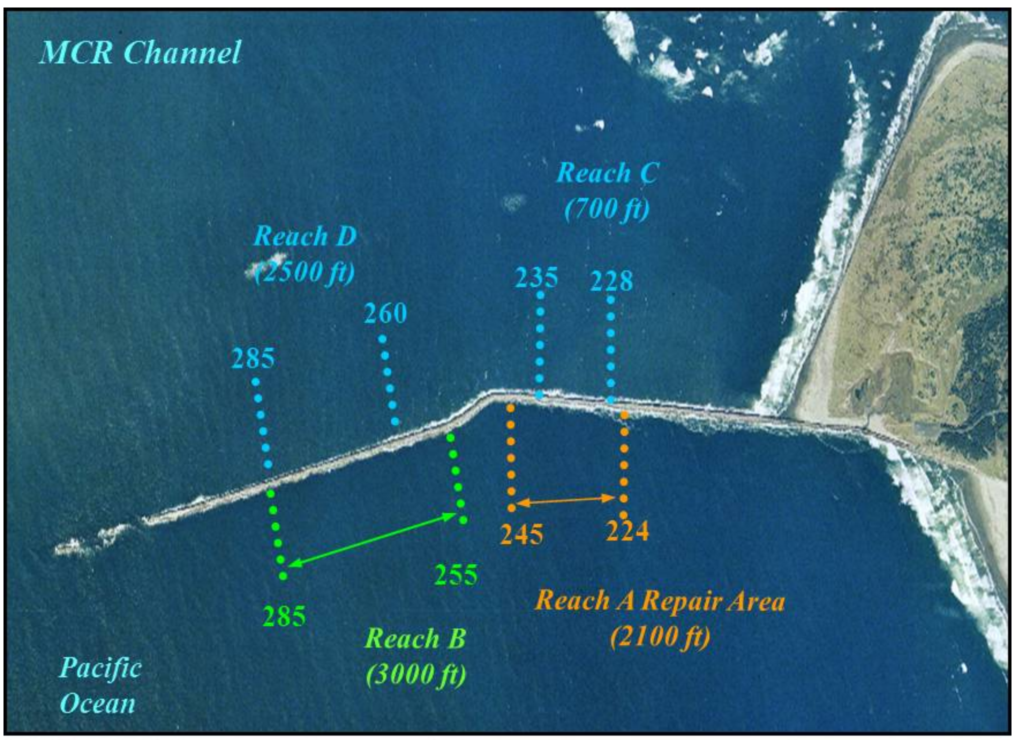


Figure A1- 160. South Jetty Interim Repair Limits – 2006 and 2007

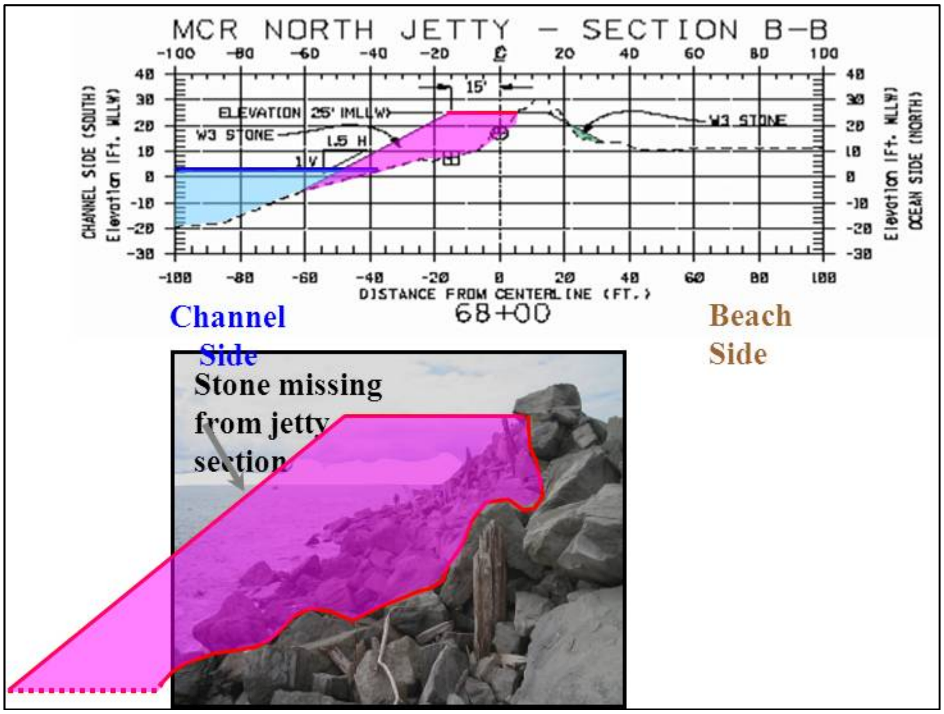


Figure A1- 161. Typical Cross Section – Interim Repair

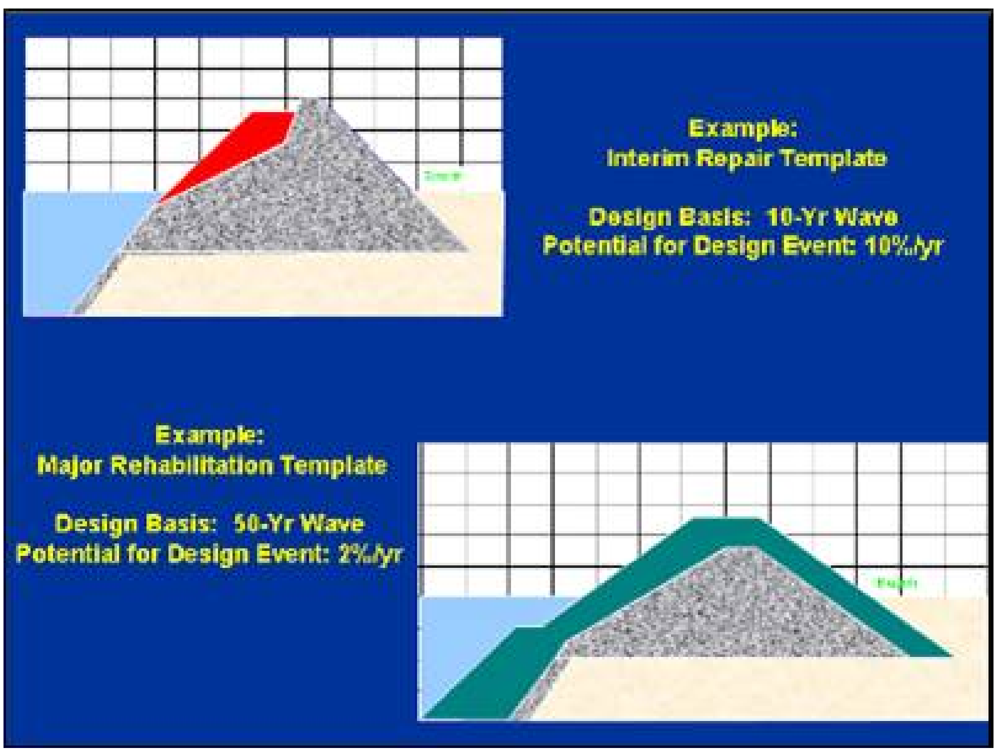


Figure A1- 162. Contrast between Interim Repair and Rehabilitation Templates

b. Design Cross Section Repair Development

Design template attributes for future repair alternatives are selected to minimize the cost of repairs while achieving sufficient stability and life-cycle restoration for each portion of the jetty. Due to the variability in design climate and repair history, alternatives vary between the three structures, and along the length of each structure. Jetty cross section options for future repair examined crest elevation, crest width, and sideslope adjustments. The location along the jetty alignment was important to the degree of robustness needed for each design parameter. Figure A1- 163 illustrates a typical jetty layout with its respective design and consequence concerns. In addition, for those jetty reaches where foundation stability was a concern, special designs were developed for the toe berm area of the cross section in order to stabilize the upper portion of the section over the long term. Above and below water adjustments were made in cross section design to address both variability in design forcing and accuracy and expected method of construction. Two-dimensional physical modeling was used to assess and fine tune the cross section designs. After the cross section refinement in the modeling, each cross section was tested for long term reliability in the life cycle analysis model for the rehabilitation study.

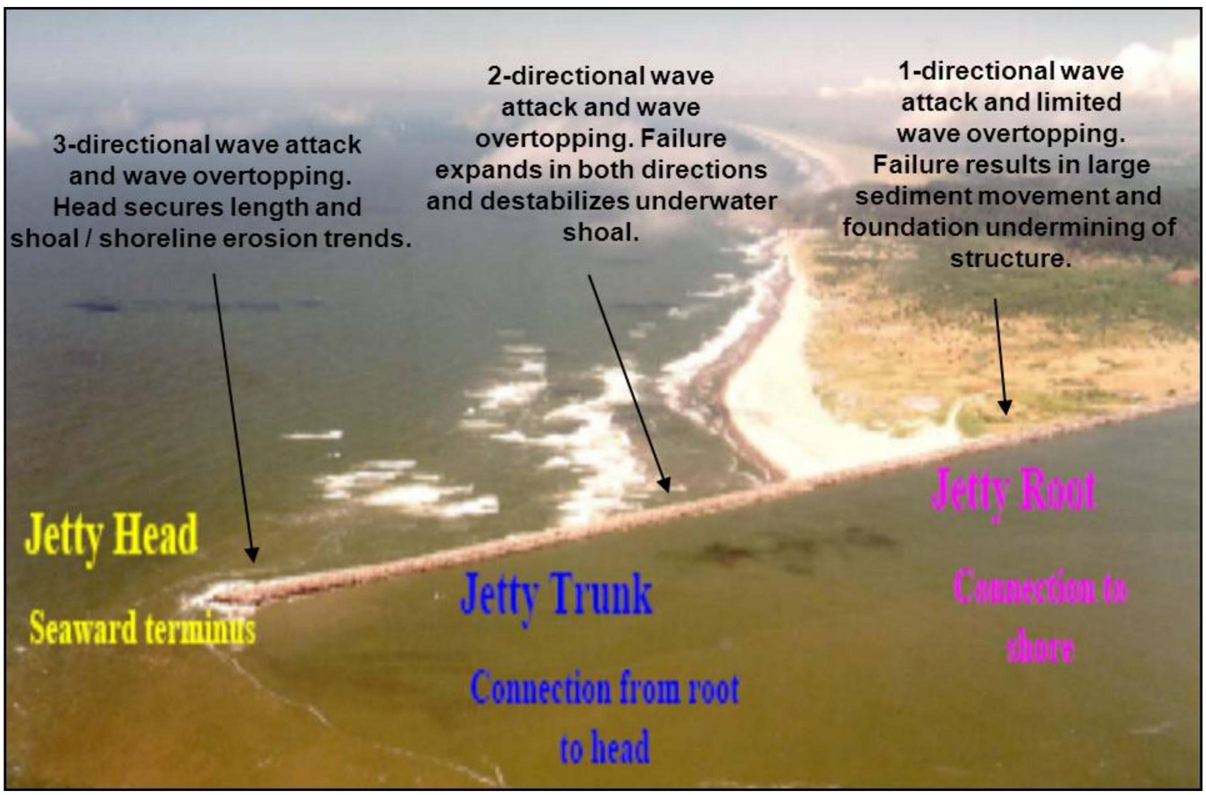


Figure A1- 163. Typical Jetty Design / Exposure Reaches

Historical performance of previous jetty designs, expected and feasible construction techniques, as well as existing structure configuration were considered when specifying structure design parameters. Verification of proposed design cross section elements in the project environment was conducted in the 2-dimensional physical model. Due to the extreme wave climate along the northern Oregon coast, the design of a rubblemound structure to eliminate overtopping is infeasible. In addition, the crest width and to some extent the crest elevation for these structures is related to construction method. Early original construction of Northwest coast jetties in the 1800s was attempted using similar construction methods as east coast jetty construction of the time by floating marine plant. After several notable failures due to the Pacific Ocean working environment, it was soon determined that the Northwest coast would require another construction approach. Since that time, the predominant method of construction for the Oregon coast jetties has been from the top of the crest of the structure down. Using this method of construction has necessitated a crest width that is wide enough to safely accommodate the necessary construction equipment. In addition, especially for the exposed area of construction, the crest elevation is required to be high enough for the equipment to be safely out of the wave attack area.

c. Crest Elevation

Key issues to consider when assessing the crest elevation of a rubblemound jetty are the sensitivity of the established crest elevation to cross section stability as well as the significant impact on cost as a function of crest elevation. Referring to Figure A1- 163, depending on where the design section is located, the structure may be exposed to 1- 2-, or 3-sided overtopping forces. A general reference to assess overtopping forces on the backside of a structure is the work conducted by Walker, Palmer and Dunham as shown in Figure A1- 164 (Walker et al., 1975). Since backside armor exposed to overtopping waves has no jetty section to push up against (as the front side armor does), those armor stones are more easily dislodged. The relationship illustrated in the figure shows how the parameter of freeboard over wave height impacts the ratio of weight required of backside armor to front side armor. A crest elevation design (or freeboard) which starts to increase the backside armor stone weight needs to be evaluated carefully. The figure displays approximately where the 3 jetties fall using a 25 ft crest elevation and a high water level of +12.2 ft MLLW for a range of incident design waves. While both Jetty A and the North Jetty are predominantly on the stable side of the figure using a 25 ft crest elevation, the South Jetty toward the seaward end is exposed to heavy overtopping forces. Figure A1- 165 illustrates how the freeboard over wave height parameter is related to the incident wave height with respect to three different crest elevations (+20, +25, and +30). The vertical dotted line indicates the stable location for equal back-side to front-side armor size.

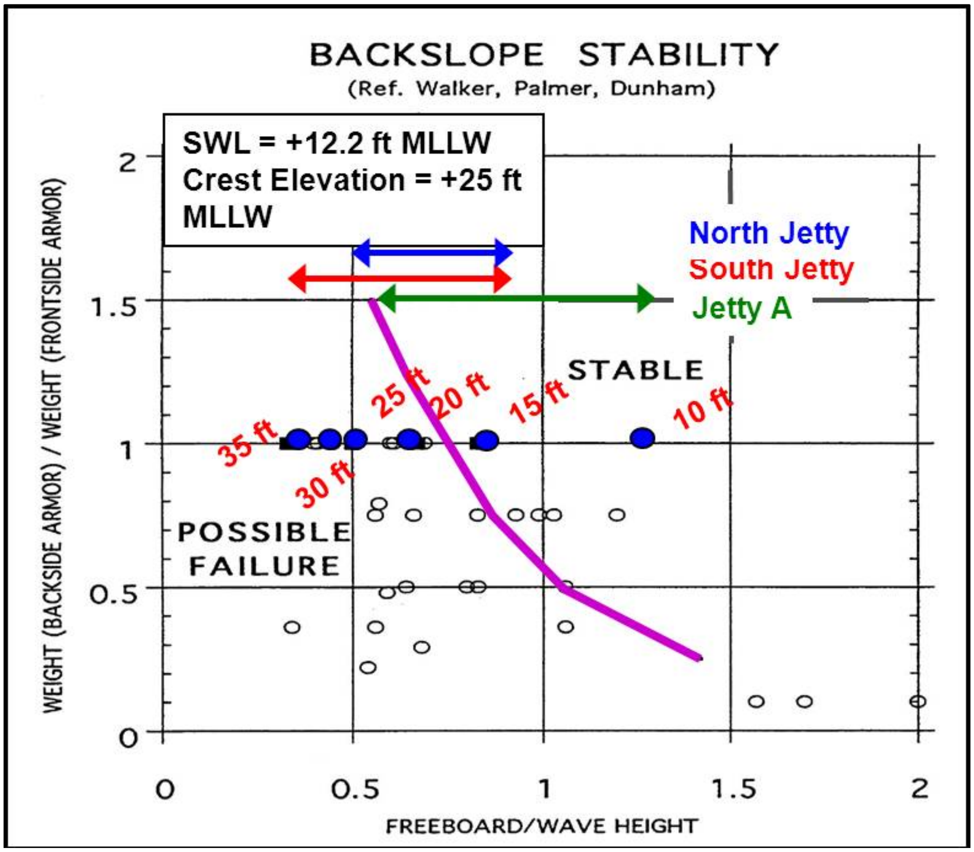


Figure A1- 164. Backslope Stability Relationship

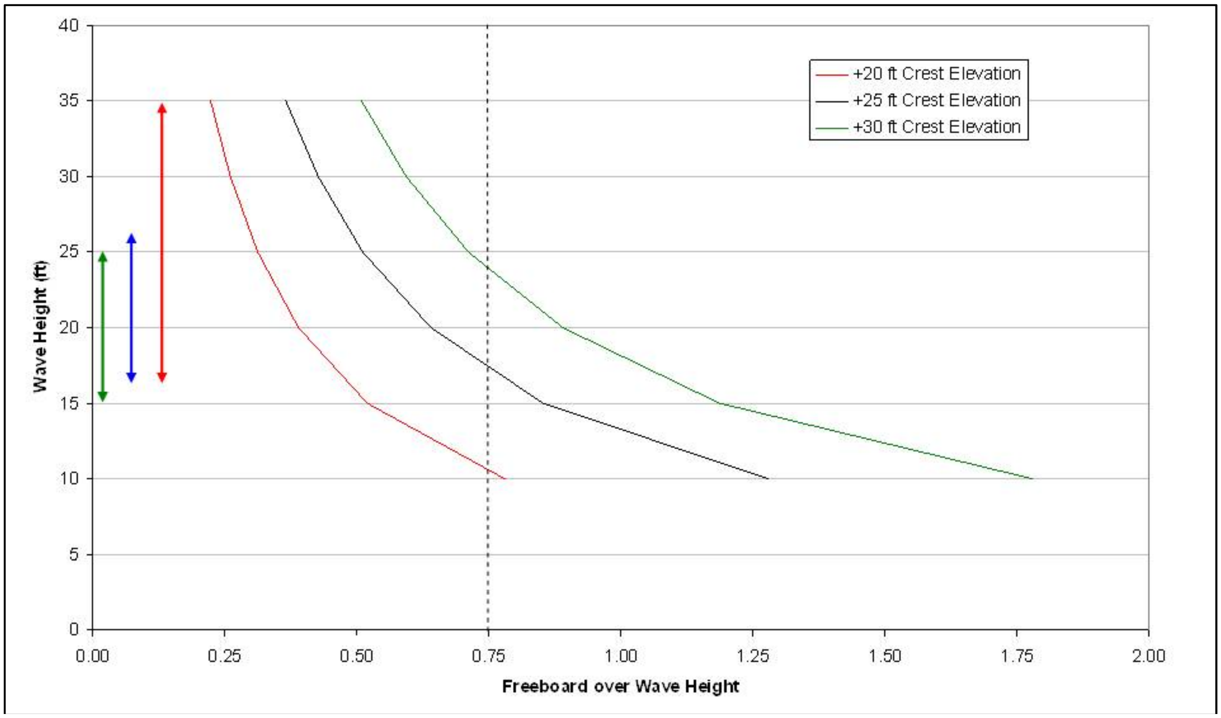


Figure A1- 165. Incident Wave Height vs Overtopping Parameter

Other issues considered while determining proposed crest elevations included the existing configuration of the jetty as well as the goal of minimizing any modifications to the jetty footprint. Working in an optimized manner with the existing structure is part of a cost-effective design. This involves minimal re-working of the structure, particularly tearing down portions of the structure that currently exist. On the design reach cross section figures it can be seen that consistently, substantial jetty sections currently exist along much of the three structures. Establishing a crest elevation lower than the existing and/or historical elevations would need to be supported by substantial justification, since reducing crest elevation can have serious impacts to overall section stability in addition to the cost to achieve it.

Initial crest elevations for the South Jetty were established in 1913 ranging from +10 ft to +24 ft MLLW. Repairs since that time have utilized crest elevations of +20 to +30 ft MLLW. Current crest elevations along the jetty range from +14 to +25. One added feature that the South Jetty can take advantage of with future repairs is the very wide relic base that is the product of numerous historical jetty repairs. While structure width is not as efficient at reducing overtopping as increased elevation, a wide structure can provide further reduction in those forces. This effect is born out in the 2-dimensionsal physical modeling results. Initial crest elevations for the North Jetty were established in 1917 ranging from +15 ft to +32 ft MLLW. Subsequent repair work has been conducted on the seaward half of the jetty utilizing crest elevations of +24 to +26 ft MLLW. Current crest elevations along the jetty range from +14 ft to +27 ft, MLLW. Initial crest elevations for Jetty A were established in 1939 ranging from +16 ft to +20 ft MLLW. Repairs occurring since original construction have utilized crest elevations of +20 to +24 ft MLLW. Existing crest elevations along Jetty A range from 18 to 25 ft MLLW.

A +25 ft MLLW crest elevation was chosen for the majority of the North and South jetties to work within the existing structure and provide long term stability to the design reaches without increasing jetty footprint. The heads of both the North and South Jetties were set at a crest elevation of +20 ft MLLW in order to facilitate construction of the head solely on the relic stone base. The additional width of the head design provided by both the wide adjacent toe berms as well as the wider main body crest width should provide sufficient robustness for the jetty feature to resist the wave overtopping. A similar head design has been employed at the Yaquina North Jetty (constructed in 2001) with positive results.

A +20 ft MLLW crest elevation was chosen for the majority of Jetty A since this jetty is exposed to a much reduced wave climate compared to the other jetties and is only exposed to a 1-directional wave overtopping process. As can be seen in Figure A1- 145, this structure also has a fairly wide overall relic structure which can provide added buffer against overtopping forces. For the head construction at Jetty A, a +15 ft MLLW crest elevation was determined. Again, construction of the jetty head on a precarious relic stone base is a controlling factor for the head cross section dimensions. This jetty head will only be exposed to overtopping from one side and it also has wide toe berms for additional stabilization.

d. Crest Width

Some of the crest width design concerns have been discussed above. Desired output is minimal reworking of the existing structure, minimal stone quantity, minimal modification to the jetty footprint to provide long-term reliability and robustness of the jetty cross section. For the MCR jetties, the minimal 30 ft crest width typically required for equipment access is more than sufficient to meet the typical three armor stone width requirement recommended for rubble mound jetty crest design. A 30 ft crest width would be equivalent to three 83 ton stones in width. Since all of the jetty stone design for this application is smaller than 83 ton, the crest width meets design requirements.

Initial crest widths for the South Jetty were established in 1913 ranging from 10 to 25 ft. Repairs since that time have utilized crest widths of 25 to 40 ft. Existing crest widths along the jetty range from 4 to 40 ft. Once again the added feature of the very wide relic base for the South Jetty is the product of numerous historical jetty repairs. Initial crest widths for the North Jetty were established in 1917 at 25 ft. Original construction of the North Jetty benefited from the lessons learned on the South Jetty construction. Subsequent repair work has been conducted on the seaward half of the jetty utilizing crest widths of 30 ft. Existing crest widths along the jetty range from 10 to 40 ft. Initial crest widths for Jetty A were established in 1939 ranging from 10 ft to 90 ft. Construction of Jetty A and the South Jetty utilized a double trestle setup which impacted final crest width parameters. Repairs occurring since original construction have utilized crest widths of 20 to 30 ft. Current crest width along Jetty A ranges from 20 to 50 ft.

A 30-ft crest width is needed to allow equipment access (if land-based construction is used) and provide a sufficiently thick cross-section with reserve capacity to allow some damage (displacement) of the armor stone by scour-induced settlement or wave action. For the bullnose section at the heads of the three jetties, a 40 ft crest width is used for additional robustness and to withstand the 3-dimensional overtopping forces that occur there.

e. Sideslope

The specification of sideslope impacts three primary cross section elements: stone size required for stability, quantity of stone required and potential size of modified footprint. Since this design effort attempts to minimize stone quantity and footprint modifications, attempts were made to achieve the minimum sideslope feasible for each design reach. In addition, in extremely deep areas along the jetties, flatter sideslopes result in large quantity increases to achieve the cross section. However, per the Hudson armor stone design equation, as the sideslope is steepened, required armor sizes increase.

Historically on the three jetties, sideslopes have ranged from 1V:1.25H to 1V:2H. Some sideslopes were also a function of what was achievable with the equipment being used for construction. Early construction work did not involve individual stone placement but rather achieved the design section by dumping rock from the railroad trestle on top of the jetty.

The minimum side-slope allowed for jetty design is 1V:1.5H [USACE 1984]. Sideslopes of 1V:1.5H to 1V: 3.5H were considered. Steeper slopes are usable along some of the more protected areas of the three jetties, channelside areas with less wave exposure and most landward reaches of the jetties. A 1V:2H to 1V:3.5H sideslope is needed where wave action is more extreme, exposed ocean slopes, seaward reaches of the jetties, and head construction. Another constraint on sideslope occurs for those design templates which attempt to stay completely on top of the existing jetty section, requiring a steeper slope. This can be done either to control the jetty footprint impact or to achieve building on the relic stone base. Construction at the head of the three jetties was a multi-variable tradeoff between sideslope stability and control of size of head feature. More physical modeling will be required to optimize this design in subsequent phases.

Another area of potential variability in sideslope is in areas outside of the wave impact zone. This is typically one wave height below the still water line. Some of the toe berm features designed to help control foundation scour and provide robustness for the upper jetty cross section is proposed using a 1V:1.5H sideslope.

f. Armor Stone Unit Weight

Rock unit weights in the Pacific Northwest typically range from 165 lb/ft^3 to 200 lb/ft^3. A minimum rock unit weight of 167 lb/ft^3 is needed to achieve workable armor stone sizes, based on the wave action incident at the MCR jetties. However, a higher unit weight stone is most desirable. For the same design wave height, armor stone produced from rock with a unit weight of 190 lb/ft^3 is 40% less weight (per armor stone) than armor stone produced from rock with unit weight of 167 lb/ft^3. Although 14% more of the denser armor stone would be needed (190 lb/ft^3 vs 167 lb/ft^3), armor stone with significantly less weight per unit is easier to produce, transport, and place; which translates into net cost savings.

g. Core Stone and Bedding Stone

Repair of 100-year-old structures that have already been repaired multiple times is a significantly different construction activity than building a new jetty. The foundation and mass of the jetty structure is already there. The repair construction activity will involve some rearrangement of the existing section but will consist primarily of adding layers of stone to the outside of the base structure. The candidate areas proposed for repair have varying degrees of damage; from large gaping holes within the jetty cross-section to small but deep scallops. There is too much irregularity within the damage areas to apply a continuous or complete jetty repair section, with attendant bedding, core and armor stone layers. Because of this, very little core or bedding stone is required. Armor stone (large size stone) is used for the majority of the repair template, to ensure that all of the stone placed within the repair areas is effective at preventing excessive wave damage. An exception to this is in areas where the cross section is broadened as it extends down to the seabed for foundation stabilization purposes. For those cross sections, bedding and smaller-size stone is proposed for constructing the toe berm.

h. Above and Below Water Repair Areas

Design of above and below water sections on the jetty are controlled primarily by two factors: variable exposure to wave attack and expected degree of control over placement. An understanding of the feasible and probable construction techniques for the different portions of the jetty cross section is essential to development of a robust and constructible design. Armor stone placement above water can be closely controlled resulting in a higher level of certainty of interlocking parameters. However, areas further down along the cross section slope and further away from the jetty crest (i.e., greater reach length for equipment) are likely to have lesser degrees of control over placement quality. In very deep areas along the jetty toe (e.g., -70 ft MLLW depth along channelside of the North Jetty), construction is likely to be achieved by dumping of material from a marine plant. Stone sizing and structure feature elements need to be adjusted accordingly to allow for uncertainty in final cross section placement.

i. Armor Stone Gradation

The gradation range for armor stone is usually specified as 0.75*W_{50} to 1.25* W_{50} , where W_{50} is the design armor stone weight (per unit) [USACE 1984]. The calculation of W_{50} is an essential element for jetty design and is described below. In terms of quarry operations, the above gradation range is very narrow and much rock must be quarried to produce requisite amounts of the armor stone (the effective % yield of armor stone from the quarry may be 2%-6%). As mentioned in above text, stone acquisition for repair of an existing structure is already skewed toward the higher end of stone sizing specification because of the outer cross section repair characteristics of the design stone.

To improve the quarry production and transport of armor stone and achieve a high degree of stone-to-stone interlocking, the gradation range for armor stone to be used for repair of MCR jetties will be widened to approximately 0.6*W_{50} to 1.5*W_{50}. In addition, 10% of the overall tonnage for each class of armor stone can consist of 0.3*W_{50} to 0.6*W_{50}. The smaller stone within the lower 10% of the gradation range will be used to achieve a tight and well-placed armor stone template. For armor stone used along the South Jetty, stones larger than maximum gradation size are permitted for up to 20% of the total armor stone.

j. Armor Stone Placement

As mentioned above, varying degrees of armor stone placement control can be expected for each jetty and along the length of each jetty. Wherever possible, armor stone should be placed in a controlled method such that all sides of each stone are seated against adjacent stones, except for the outer armor layer. The level of the control will vary, however, in areas above water where significant wave exposure occurs, special placement will be required. The intent of controlled armor stone placement is to achieve maximum interlocking of the armor stone to achieve a solid mass with minimum voids. Target percentage voids (porosity) are 0.25-0.30. Each armor stone should be individually placed. Armor stone should not be dropped into position from a height exceeding 1-2 ft. Refer to Section 18 (Construction

Considerations) for additional details concerning jetty stone placement. The armor stone is assumed to have a rough angular shape.

k. Jetty Armor Size Calculations

Armor unit size (W_{50}) for the repairs of the MCR jetties was determined using the Hudson Equation [USACE 1984]. Comprehensive investigations were made by Hudson and Jackson (1953-61) to develop a formula for determining the stability of armor units on rubblemound structures, in response to direct wave attack. The destabilizing effects of direct wave action on the windward side of a jetty are manifested in the upper region of the jetty (from the jetty crest down to –10 ft MLLW).

The Hudson equation is based on extensive small-scale modeling testing. Verification has been made using prototype data. The Hudson equation is used when the crest of a structure is high enough to prevent overtopping by waves and the armor layer slope is not steeper than 1V:1.5H. Armor layer slopes steeper that 1:1.5 are not recommended by the USACE [USACE 1984]. Median armor stone size (weight, W_{50}) for the wave-ward slope face is determined as follows:

$$W_{50} = \frac{\gamma r * H^3}{K_d * (Sr-1)^3 * \text{Cot}\theta}$$

where

W_{50} = median armor stone — θ = side slope of armor layer from horizontal
γr = armor unit weight — H = incident wave height, $H_{1/3}$ in this case
K_d = stability coefficient — Sr = specific gravity of armor units

The parameters of stone density (γr) and armor layer side slope (θ) were previously defined. Specification of the stability coefficient (K_d) can be problematic. Figure A1- 70 and Figure A1- 166 through Figure A1- 174 show how armor stone size (W_{50}) can vary based on the variation of stability coefficient, sideslope, and armor density. Figure A1- 175 notes potential incompatibility challenges when introducing CAU's to a rubblemound structure. An important consideration for jetty design is to attempt to keep the armor stone weight at or below 35 tons where feasible, to ensure achievable construction, transportation, and placement options. Note that armor stone weight is a function of H^3. Determination of incident wave height (H) is the critical element to get right when calculating the size of armor stone. Significant effort was expended to estimate the design (incident) wave height for various reaches along the jetties. Figure A1- 176 and Figure A1- 177 provide estimates for design stone requirements along the length of the South and North jetties, respectively.

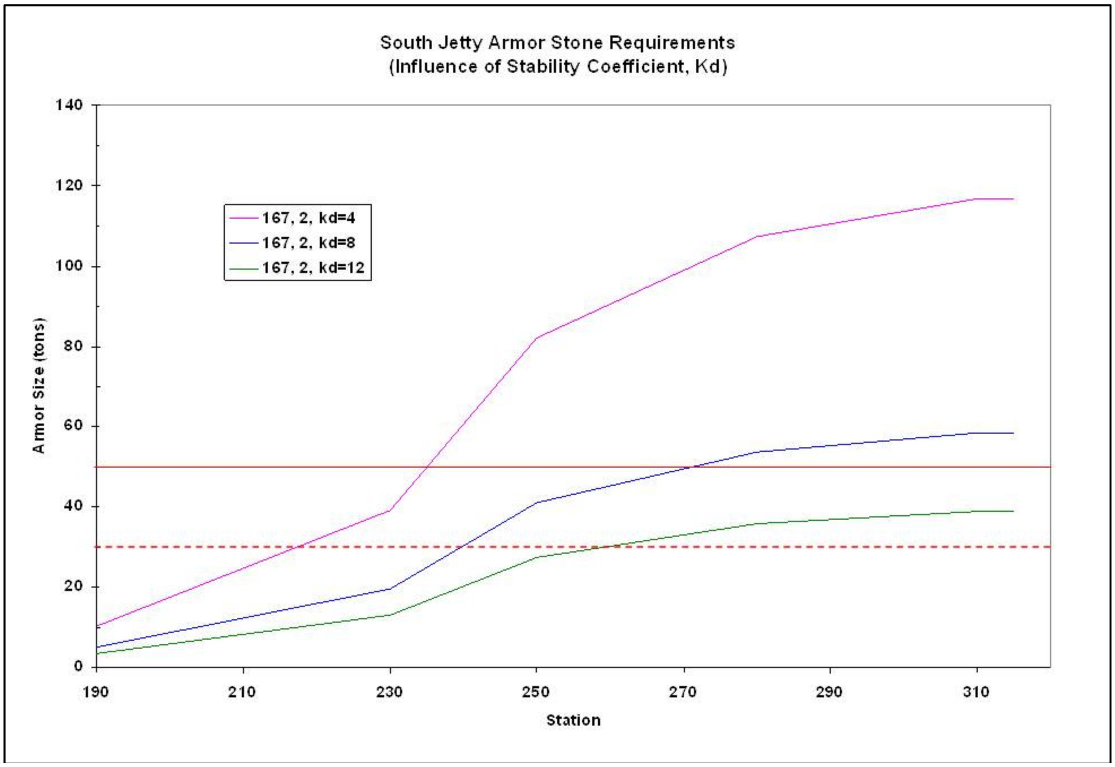


Figure A1- 166. Influence of Stability Coefficient on South Jetty Armor Stone Requirements

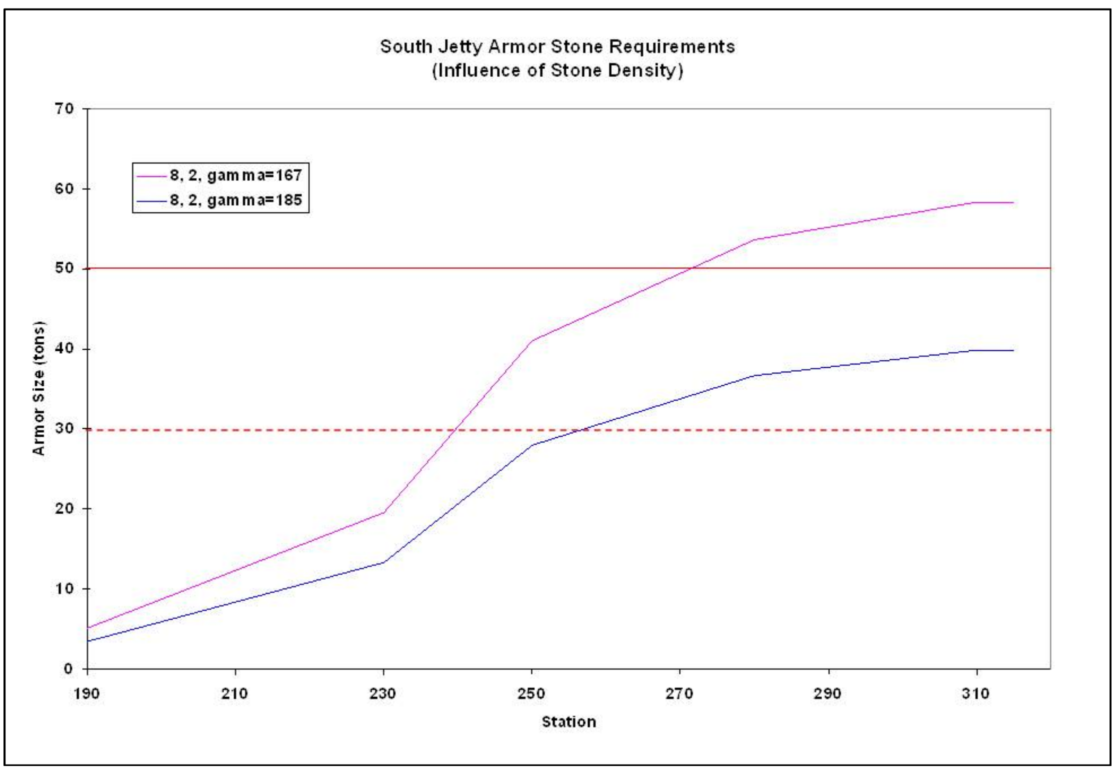


Figure A1- 167. Influence of Stone Density on South Jetty Armor Stone Requirements

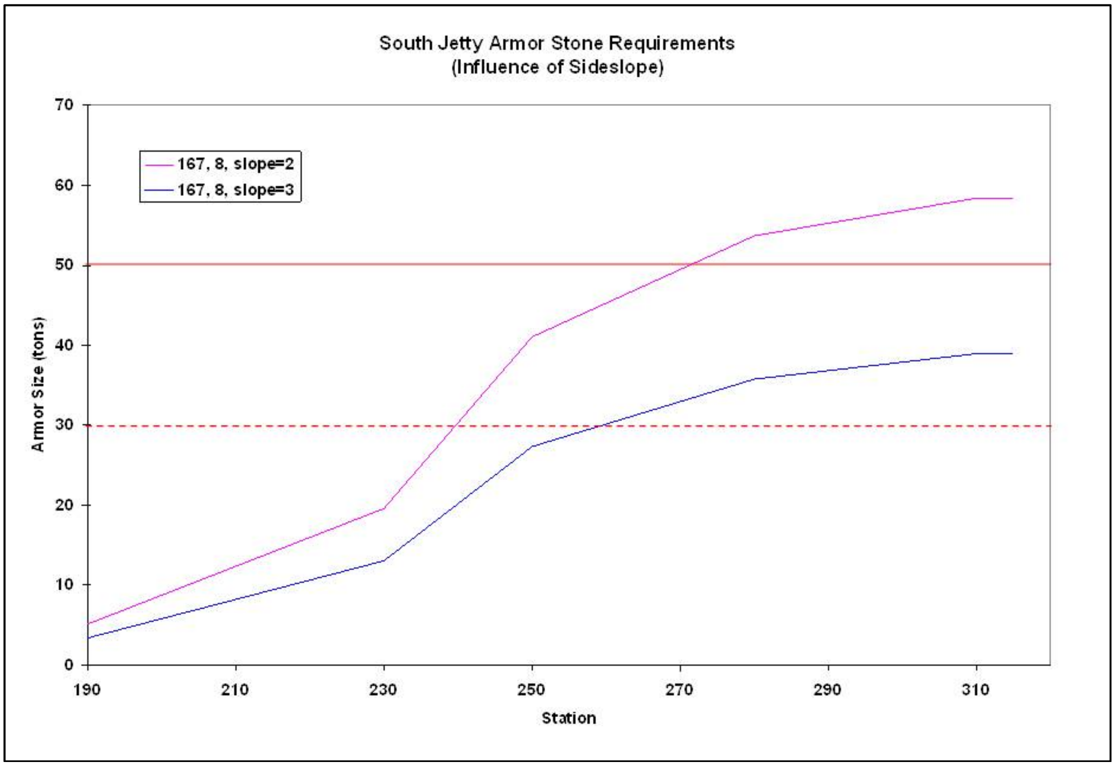


Figure A1- 168. Influence of Sideslope on South Jetty Armour Stone Requirements

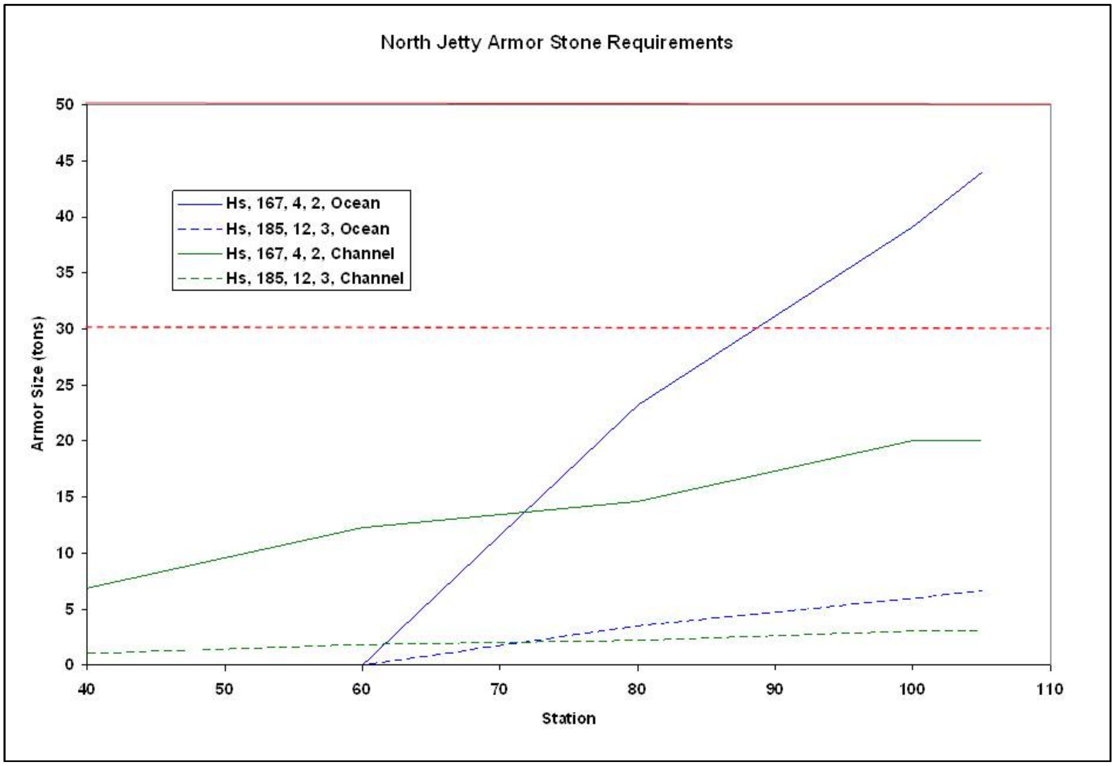


Figure A1- 169. North Jetty Stone Requirements

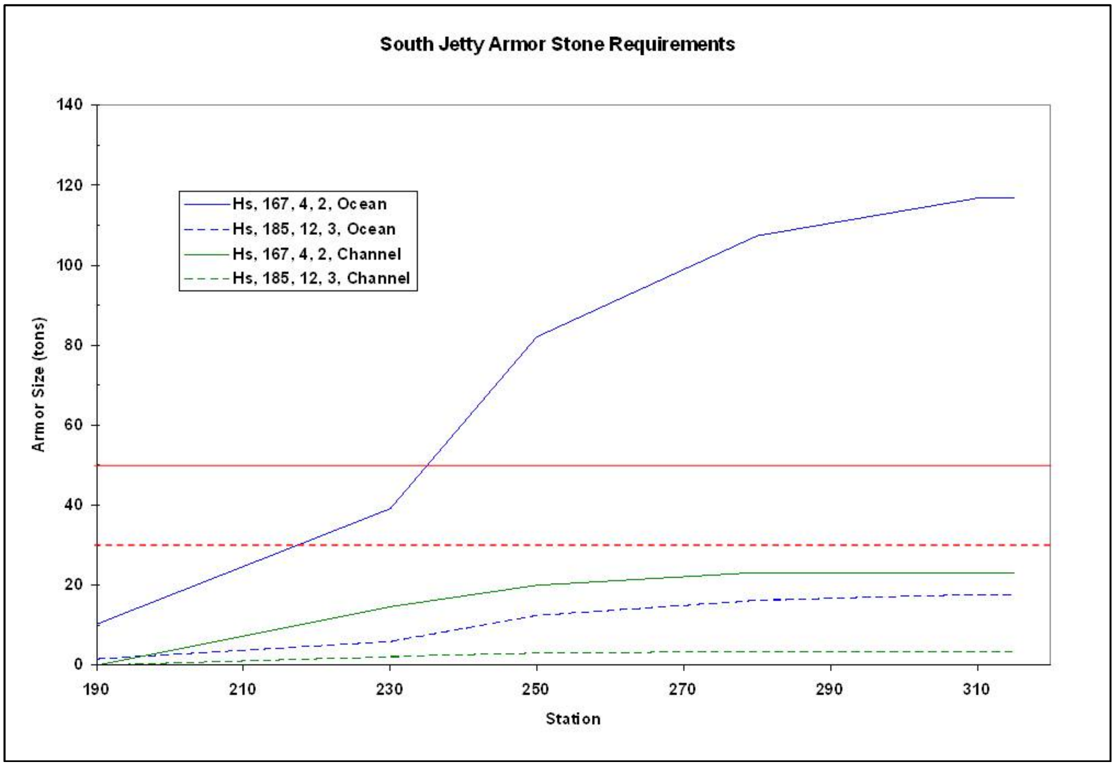


Figure A1- 170. South Jetty Stone Requirements

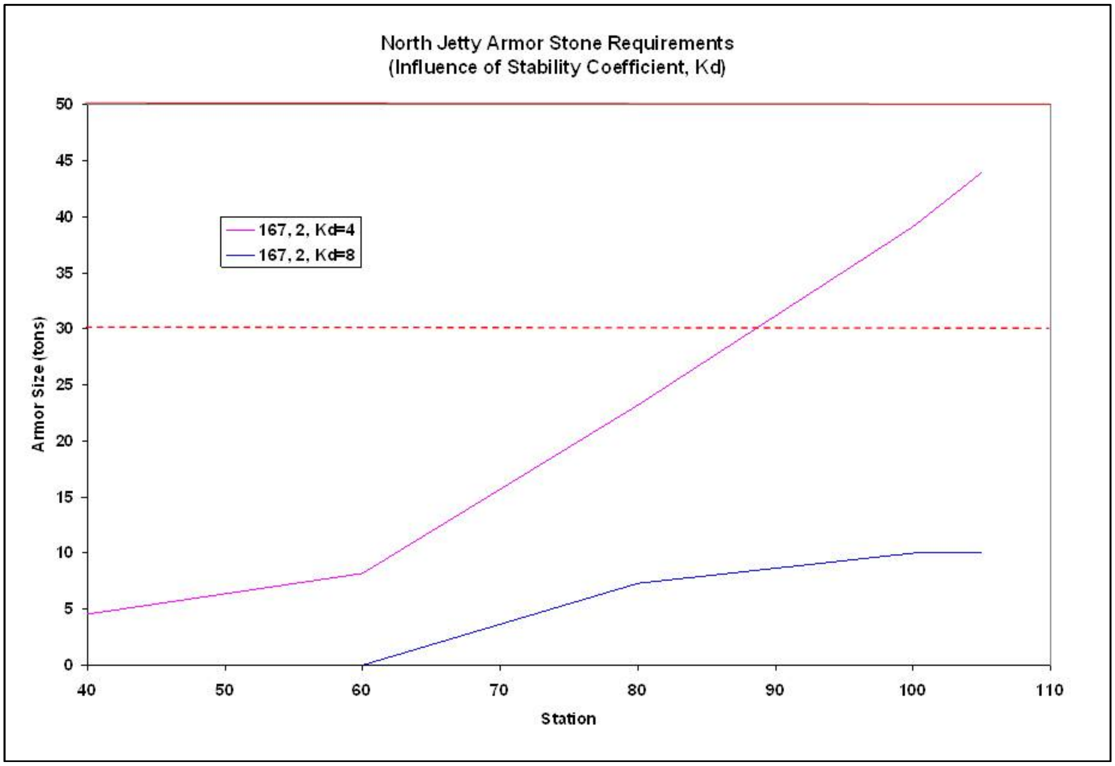


Figure A1- 171. Influence of Stability Coefficient on North Jetty Armor Stone Requirements

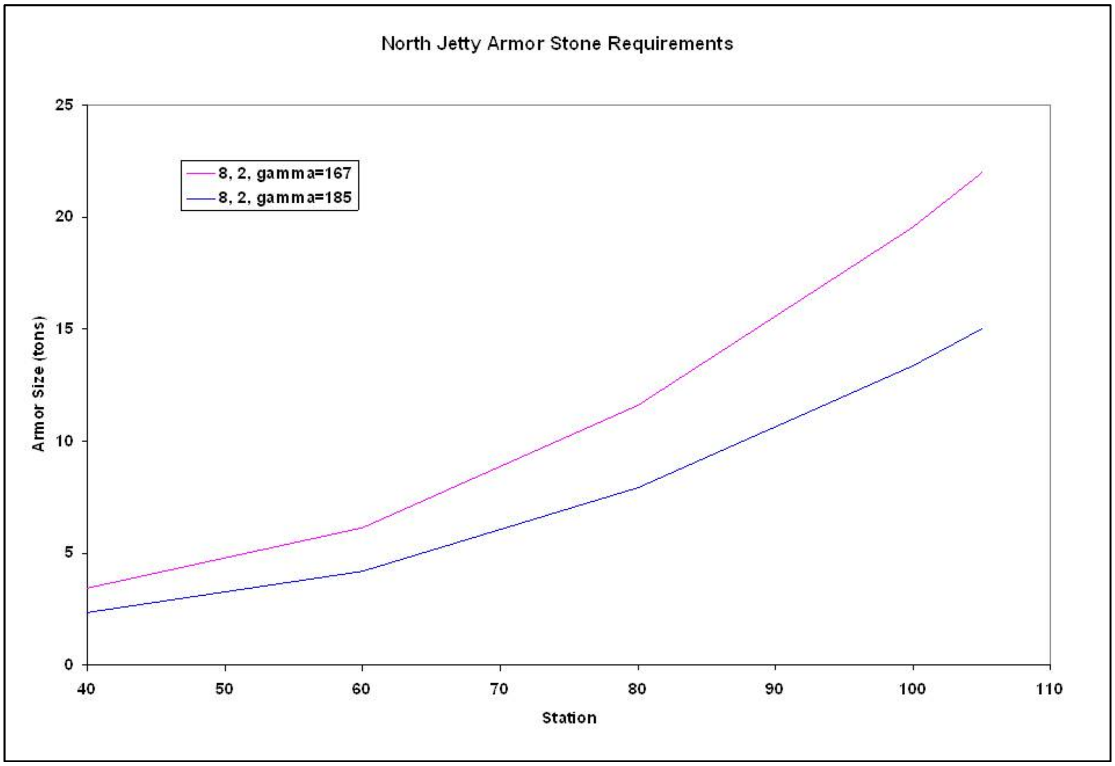


Figure A1- 172. Influence of Stone Density on North Jetty Armor Stone Requirements

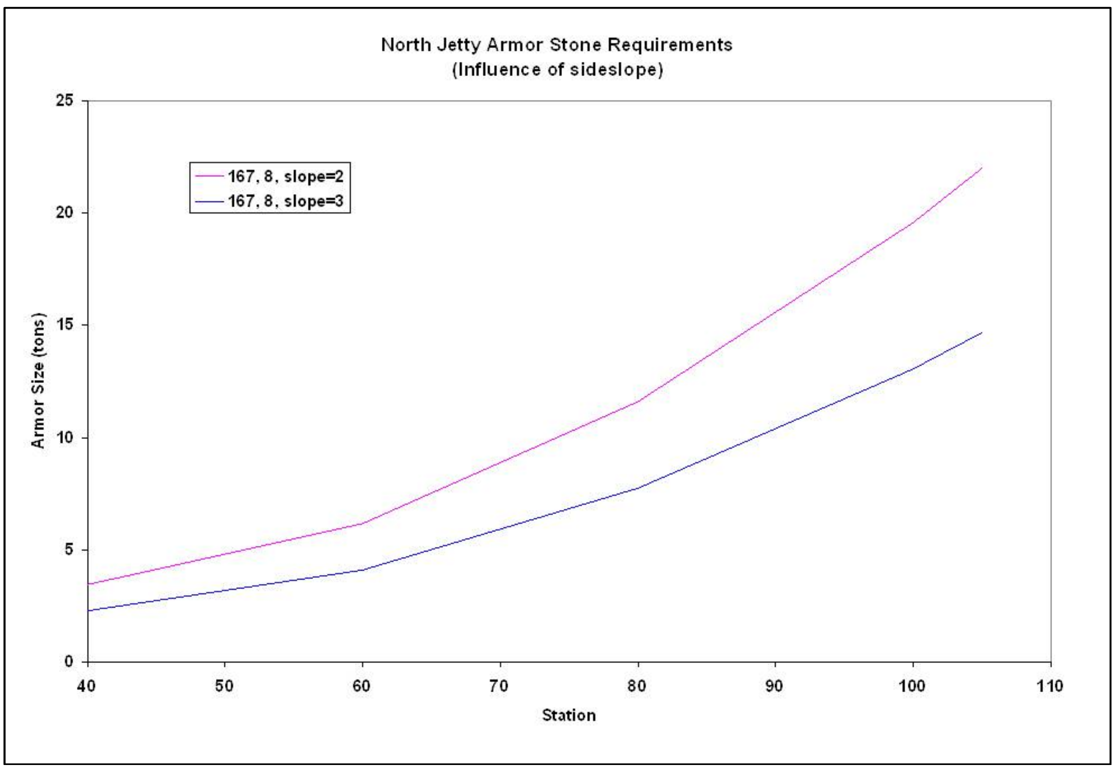


Figure A1- 173. Influence of Sideslope on North Jetty Armor Stone Requirements

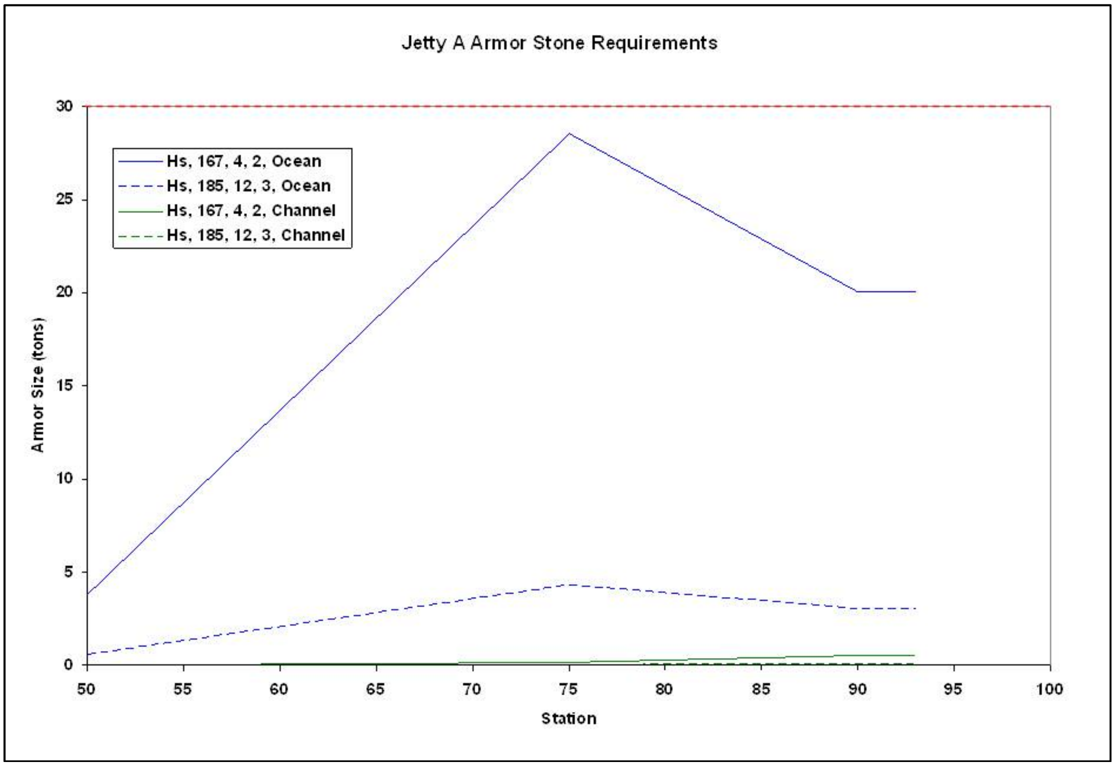


Figure A1- 174. Jetty A Armor Stone Requirements

Concrete armor units also perform differently on heavily overtopped structures.

Incompatibility Challenges
Between Concrete Armor Unit and Quarry Stone

Figure A1- 175. Incompatibility Challenges between Concrete Armor Unit and Quary Stone

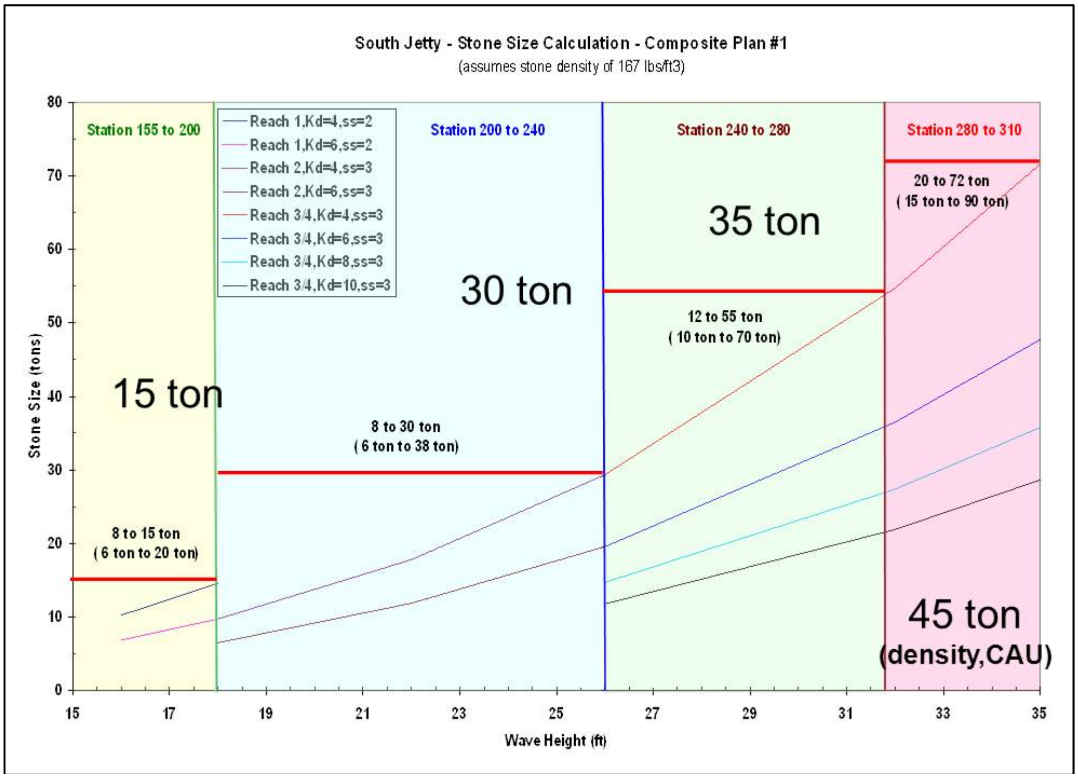


Figure A1- 176. South Jetty – Stone Size Calculation Range

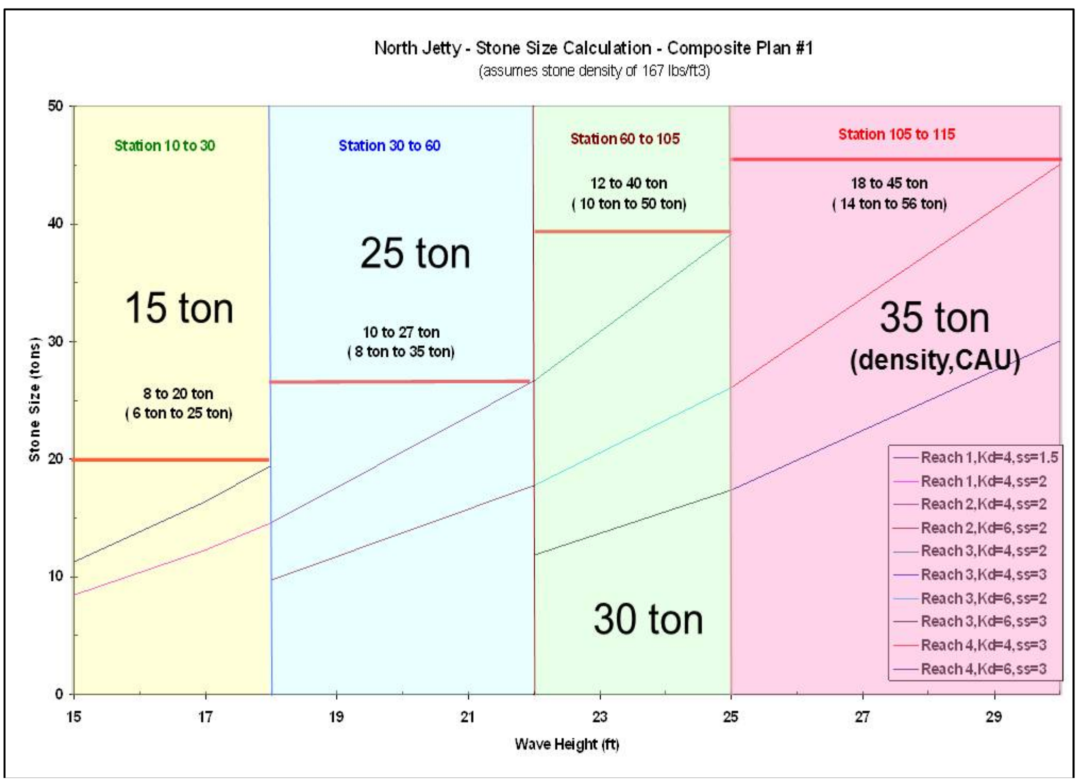


Figure A1- 177. North Jetty – Stone Size Calculation Range

l. Armor Stone Stability (K_d) Number

The stability number located in the denominator of the Hudson equation has a great influence on the calculation of stable design stone weight. It also is the parameter most influenced by the location on the structure and construction technique used. Stability numbers (K_d) of 6.0 and 4.0 (above and below water) were selected for the design templates for this study. These values correspond to rough angular stone placed in a controlled manner. The value of K_d used for the previous repair of the North Jetty (in 1964) was 7.1. The previous repair of the South Jetty (1982) used a K_d of 10 for above MLLW armor stone and a K_d of 5 for armor stone placed below water. Higher values of K_d generate a smaller required armor stone size, for the same wave height as compared to a low-valued K_d; however, over-estimation of this parameter results in an unstable cross section very soon into its constructed life.

m. Summary of Armor Stone Sizes

The median armor stone size (W_{50} , weight) was determined for each candidate jetty reach using the values of incident wave height. Note that for the largest armor stone range, armor stones larger than maximum gradation size are permitted (for up to 20% of the stone). Figure A1- 70 illustrates the sensitivity of armor unit size to wave height, unit weight, sideslope, and stability coefficient. Figure A1- 166 through Figure A1- 174 illustrate the potential range in armor unit sizes along the North and South jetties and Jetty A as a function of armor unit weight, stability coefficient, and sideslope.

n. Armor Stone Quantity Calculations

A high-resolution digital elevation model (DEM) was developed for the MCR and jetties. The MCR DEM describes the present surface of each jetty and the bathymetry of MCR. The DEM of the present jetty condition was used to compare the existing condition of each jetty to the 'as-built' (or as previously repaired) condition. The difference between the two surfaces was used to estimate the volume of armor stone needed to implement the repair template, along candidate reaches of the jetties.

10. Two-Dimensional Physical Model Study

a. General

The primary failure modes impacting cross section design vary along each structure but are generally believed to be a combination of one or more of the following: (1) armor instability due to direct wave impact, (2) armor instability due to overtopping, (3) toe scour de-stabilization, and (4) static instability of underwater slope. The primary issues from the structural design perspective are: (1) technical viability given the condition of the existing structures and the Pacific Ocean environment, (2) risk and/or robustness of design to achieve a minimum 50-year life under extreme annual loading, and (3) reliable constructability of design.

The Corps' Engineering Research and Development Center in Vicksburg, Mississippi was contracted to conduct a 2-dimensional physical model of the jetty cross section design. The range of structural repair types addressed in the model included: crest elevation and crest widths variations, sideslope variations, underwater berms, armor stone and concrete armor unit options. The purpose for the 2-D physical model was three-fold:

1. Assist in defining damage initiation and damage progression relationships (damage function) for existing condition and proposed alternatives to feed into a reliability analysis of the structures.
2. Conduct a qualitative screening of a wide range of alternatives that will bracket potential structural and material-type options that could be applied on the three structures.
3. Assist in cross section optimization and material type design for the range of alternatives to be assessed in the general rehabilitation study.

Both the North and South jetties were tested under low and high water conditions. Incident wave heights up to 35 ft were applied to the jetty cross sections. Armor units tested included quarry stone and dolos concrete armor units. An additional concrete armor unit was tested called a C-roc. The C-roc armor unit is shown in figures Figure A1- 178 through Figure A1-183 and more closely resembles a large rock with interlocking members. Due to its rock-like configuration, it is expected to be less fragile than concrete armor units which have thinner flange-like elements.

Figure A1- 178. Side View of Stone and C-roc 2-Dimensional Model

Figure A1- 179. Front View of Dolos and Stone 2-Dimensional Model

Figure A1- 180. Cross Section Side View of 2-Dimensional Model

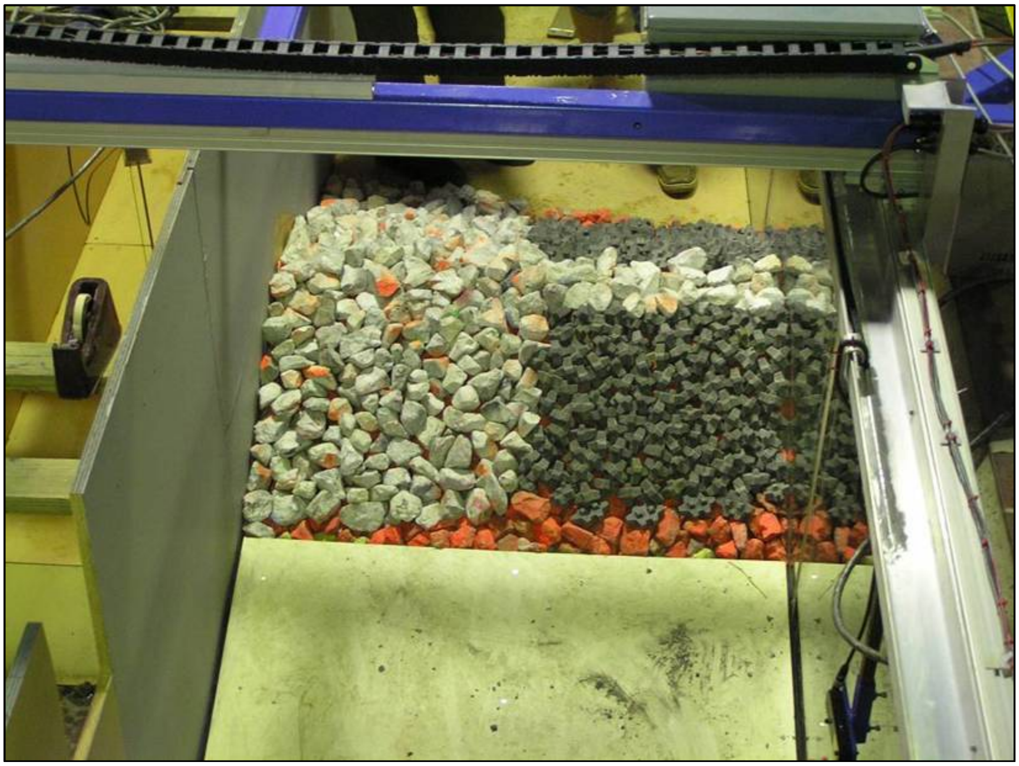


Figure A1- 181. Stone and C-roc Cross Sections in 2-D Model

Figure A1- 182. Overstopping of Cross Section in Model

Figure A1- 183. Stone and C-roc used in Model

Both existing condition and potential design alternative cross sections were modeled. The physical model testing of the jetty cross section resulted in a range of graduated design options that achieve varying levels of structure reliability. These design options were carried forward into the life cycle analysis model of the jetty system. The general categories of plans tested in the physical model included in graduated levels of robustness:

- Existing jetty cross section
- Interim Repair cross section
- Minimum repair cross section possible – encasement
- Increased slope and increased toe berm
- Extended slope cross section
- Combination berm/sideslope cross sections
- Increased crest elevation cross section

b. Model Setup

The Engineer Research and Development Center, Coastal and Hydraulics Laboratory, maintains and operates extensive laboratory facilities used for designing and testing coastal structures. Large two-dimensional wave flumes are used to test designs for rubblemound trunk armor stability and to quantify wave runup, overtopping, and transmission. In addition, these wave flumes are used to explore the physics of water wave propagation, wave transformation and wave-structure interaction. Figure A1- 184 and Figure A1- 185 show the general layout of the 2-dimensional flume used for the study. A 10 ft wide glass-walled flume 208 ft long was used for the MCR jetties study. It is 5 ft deep. The flume is equipped with a computer-controlled electro-hydraulic wave generator. The wave generator was capable of creating irregular waves with a maximum wave height of 0.46 m (1.5 ft), and wave periods of 0.75-10.0 secs. A steady flow system is also an integral part of the flumes. The facility includes an automated data acquisition and control system, extensive fluid measurement instruments and a laser profiling system. To expedite the testing of a large number of jetty cross sections, the 10 ft flume was divided into two 5 ft sections, each containing a separate cross section.

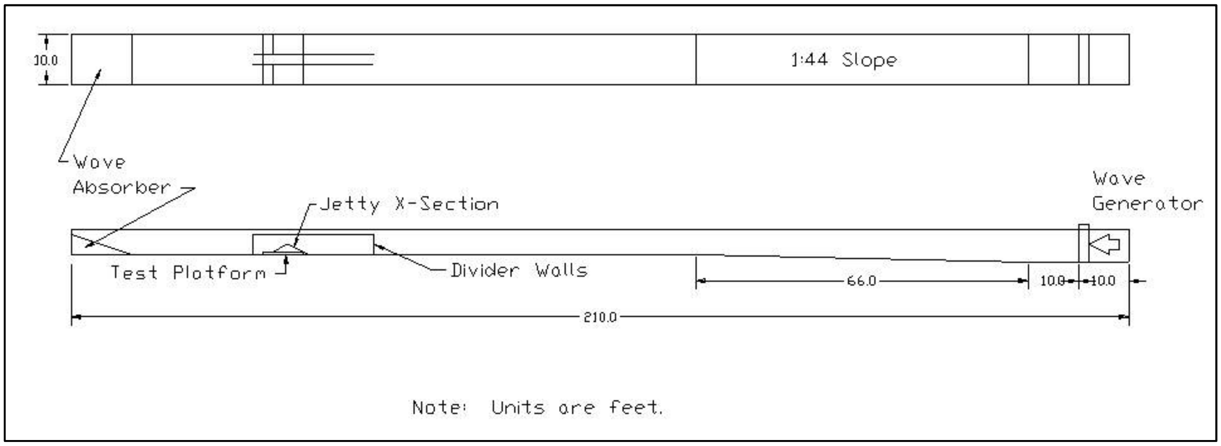


Figure A1- 184. Physical Model Schematic

Figure A1- 185. Physical Model – 10 ft Flume

c. Model Stages

The first task was to evaluate and document the reliability of the existing condition and the interim repair sections for the seaward end of the North and South jetties. Those sections can be seen in Figure A1- 186 and Figure A1- 187. For the North Jetty tests, both existing and interim repair cross sections were conducted with and without a sand lens on the channelside of the structure in place. The intent was to determine if the presence of this transitory sand lens might affect the damage relationship of those sections. Specific damage and performance information was collected in order to define variables for the reliability analysis. Cross sections were tested to identify damage initiation conditions, damage progression and complete failure conditions. Figure A1- 178 through Figure A1- 183 show photos of the model setup.

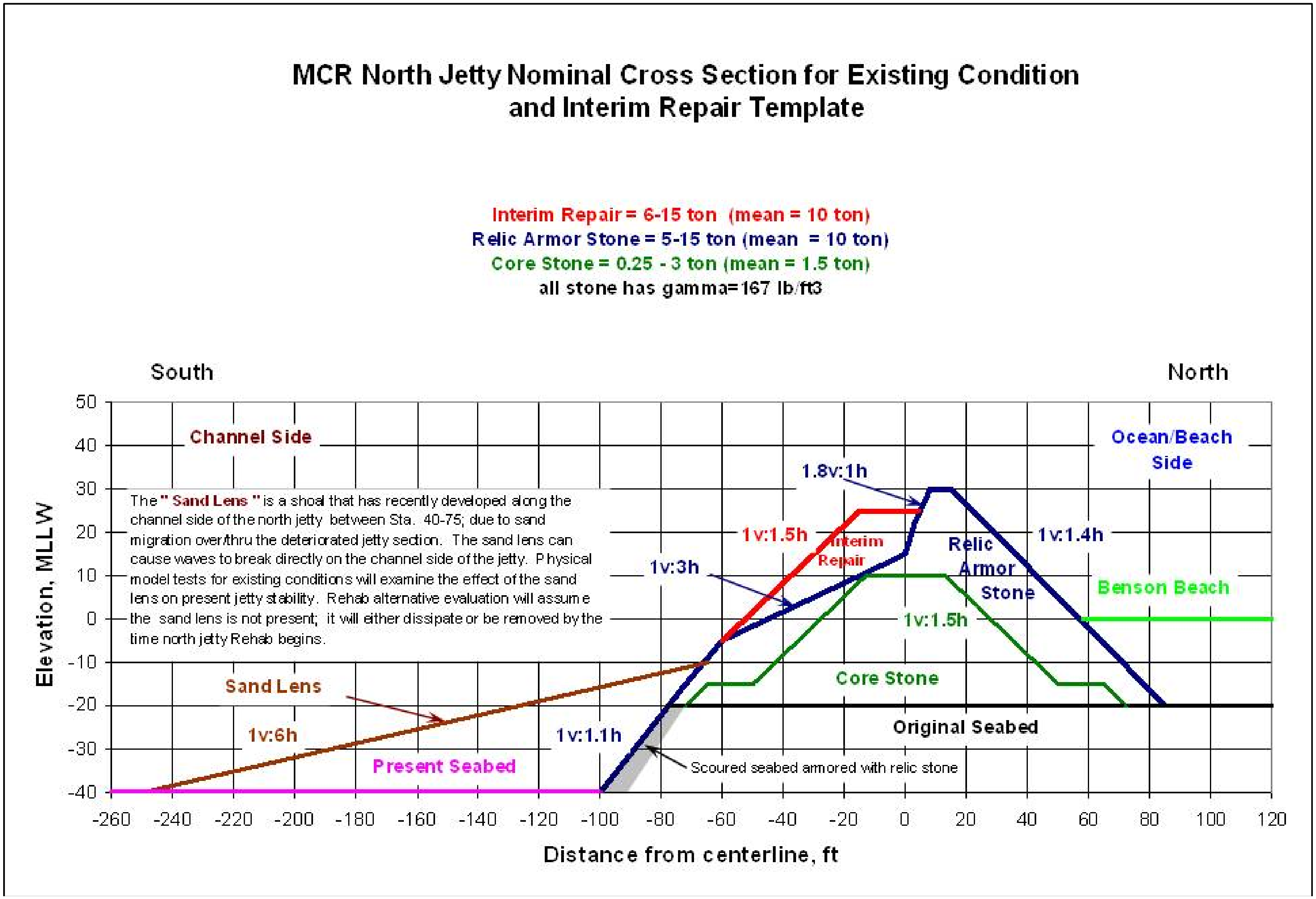


Figure A1- 186. North Jetty Existing and Interim Repair Template

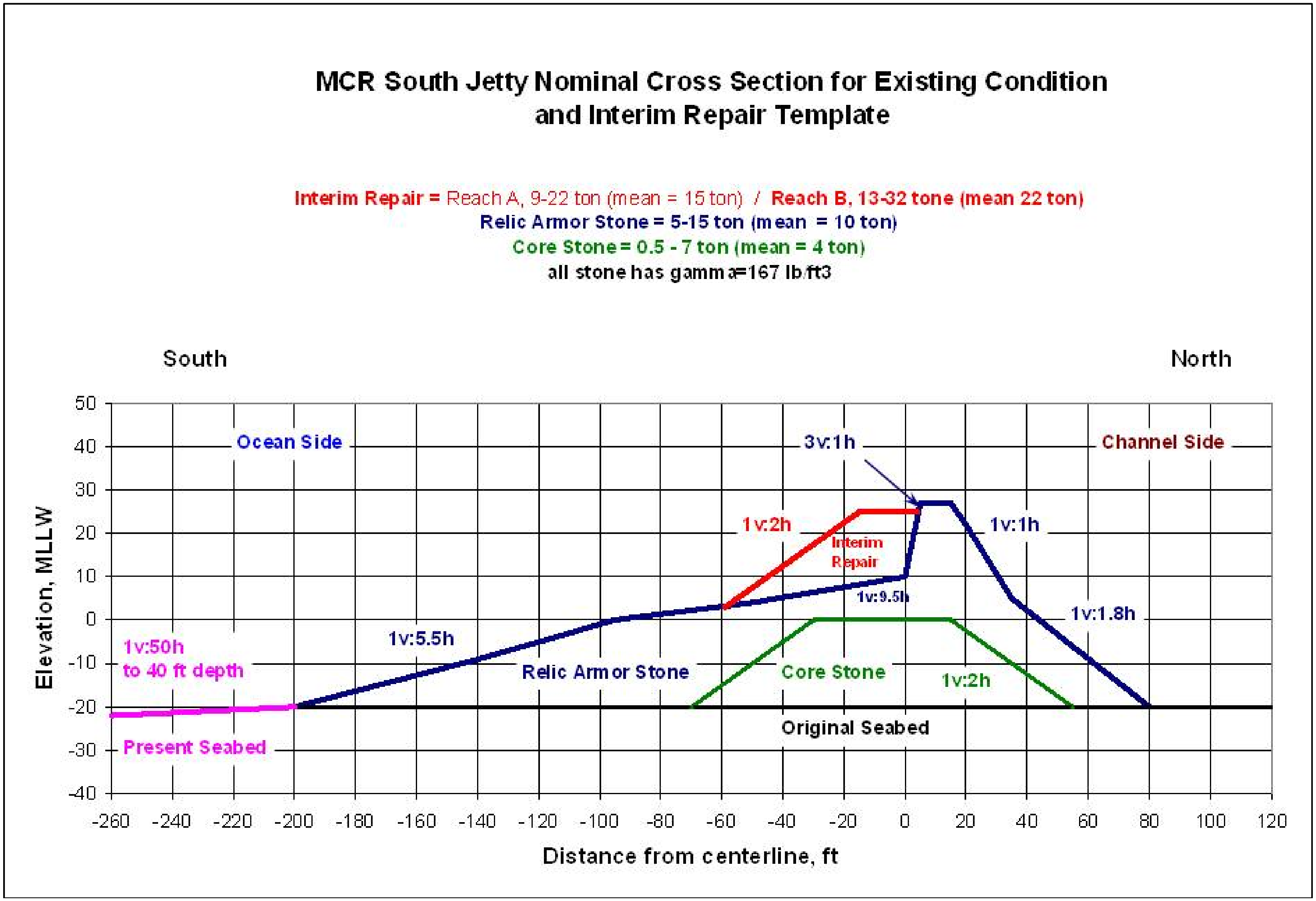


Figure A1- 187. South Jetty Existing and Interim Repair Template

The second task was to quickly run a broad range of potential alternative cross section improvements and material types for the north and south jetties in order to narrow down feasible options for more quantitative testing. The third task was to evaluate and document the reliability of a range of potential alternatives for the seaward end of the north and south jetties. Information obtained from this phase was utilized in the reliability analysis and in development of cross sections for cost estimating purposes.

d. Existing Structure Results

The existing condition is a greatly deteriorated, loosely stacked mound of relic armor stone. The crest has been eroded away to just a single stone width in places. Remaining stones are not well-keyed and are in danger of being displaced. The core stone is thinly covered in places and in danger of becoming exposed. If exposed, core stone is readily washed away and can lead to progressive failure of the structure.

The sand lens shown in Figure A1- 186 is a transient feature. It was necessary to determine if degradation of the jetty was worse with or without the sand lens. Accordingly, tests were conducted with and without the sand lens for both existing and interim repair profiles. With the plywood sand lens removed, the model has a steep 1:1.1 slope from the bottom of the model structure at -20 ft MLLW to the bottom of the flume at -40 ft MLLW. Stability on this slope was not tested. Instead, relic armor stones were glued to a piece of plywood to provide the necessary roughness while the plywood underlayer made an impermeable barrier. The relic stones were loosely placed above -20 ft MLLW following the cross-section. Figure A1-186 shows the model in place for existing conditions without sand lens prior to testing at the high water level. In all cases both a high still water level and a low still water level test were conducted. The model for the existing condition and interim repair (high water without sand lens) were constructed with the aid and assistance of engineers from Portland District.

e. Alternatives Tested

General alternatives and design concepts are summarized below and shown in Figure A1- 188 through Figure A1- 196.

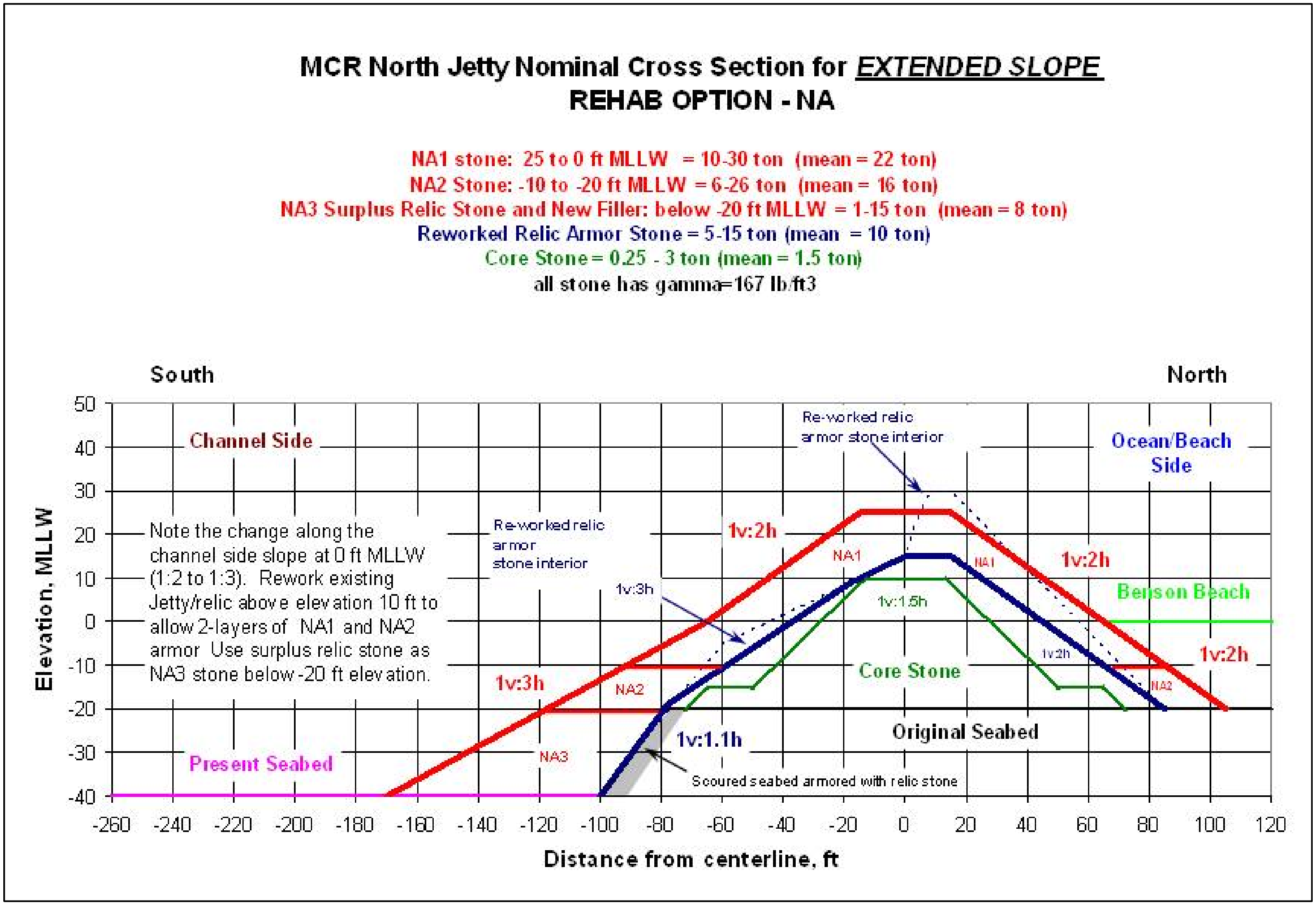


Figure A1- 188. ***North Jetty Extended Slope Section - NA***

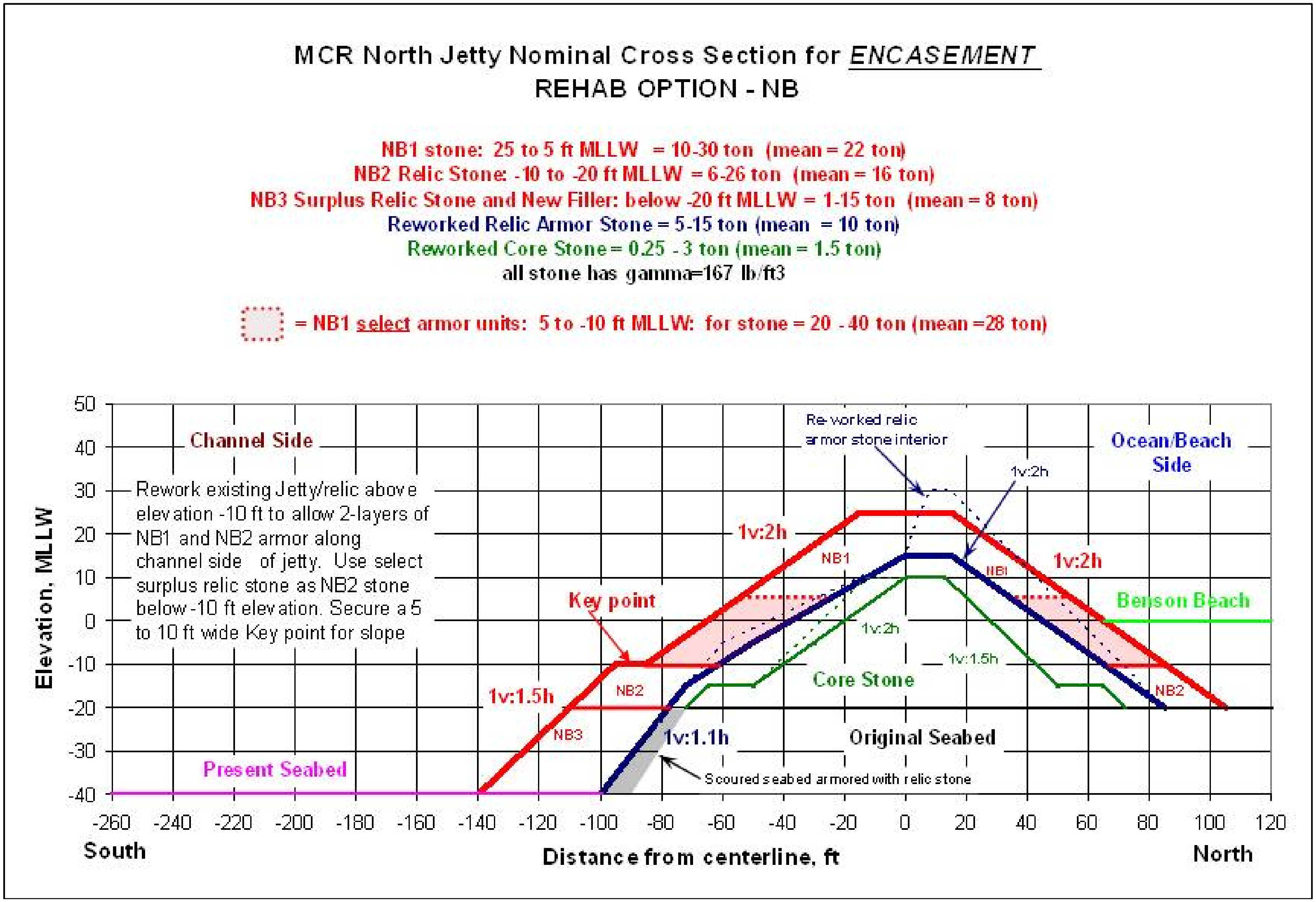


Figure A1- 189. North Jetty Encasement Slope Section - NB

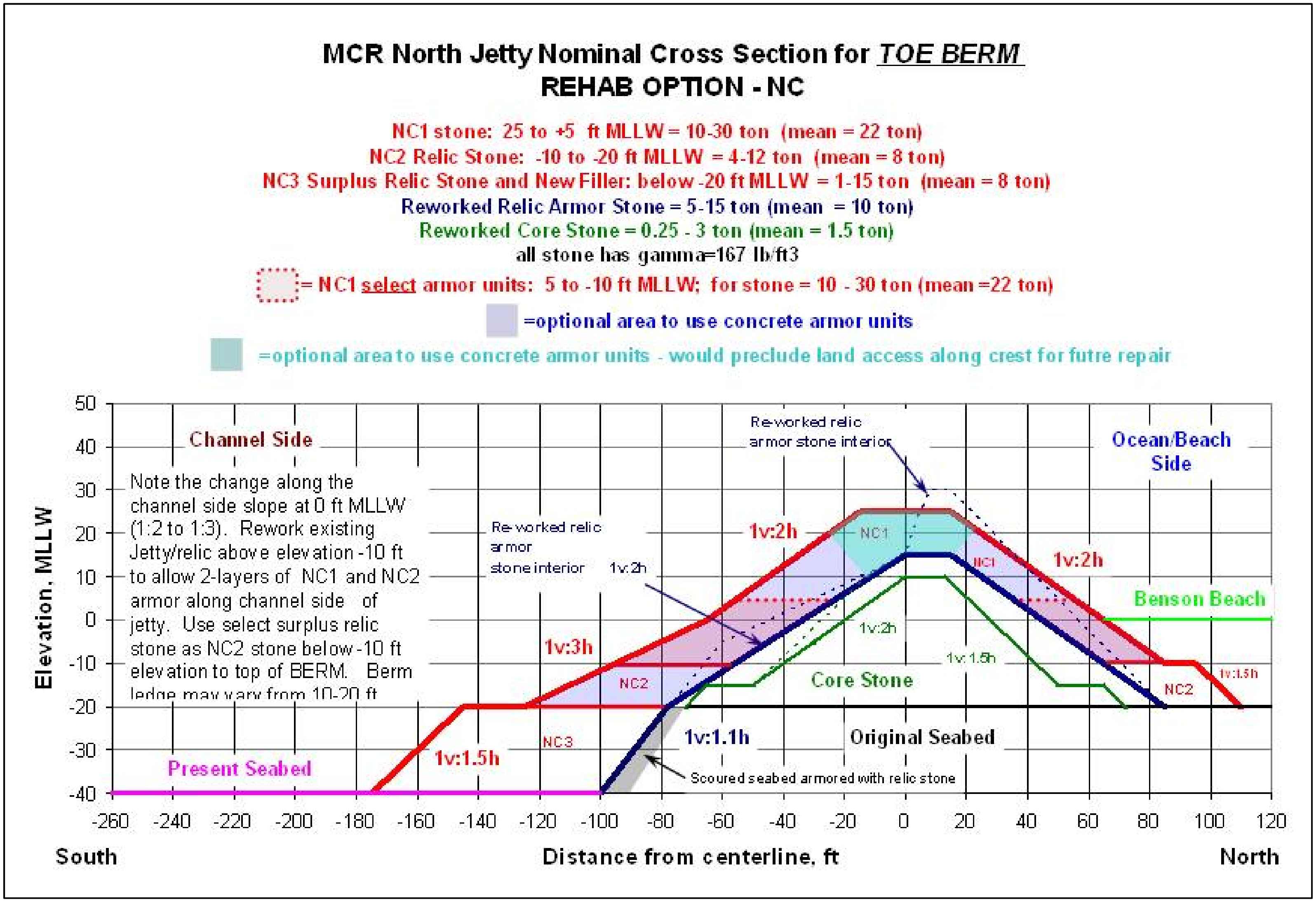


Figure A1- 190. North Jetty Toe-Berm Section - NC

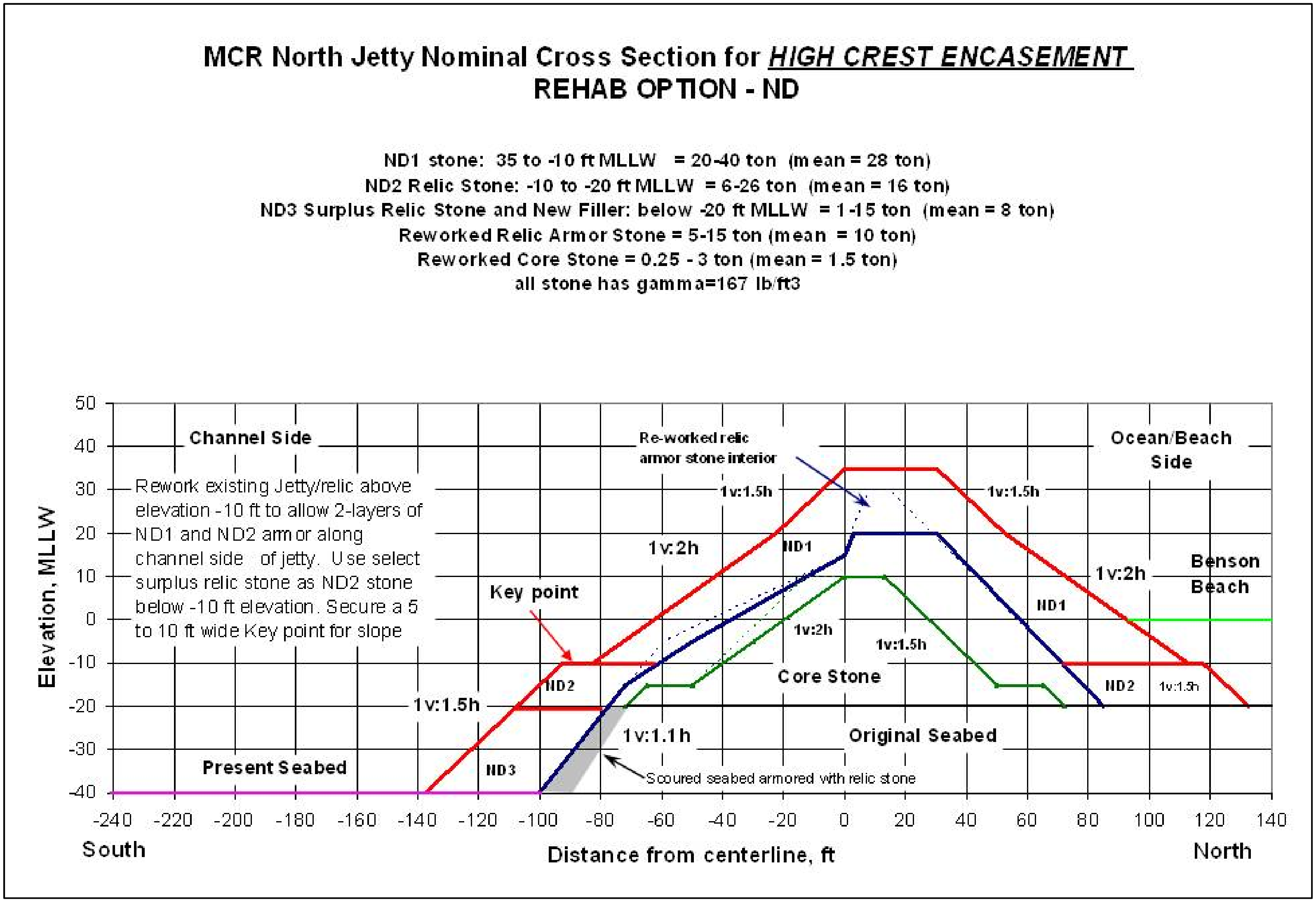


Figure A1- 191. North Jetty Elevated Crest Section

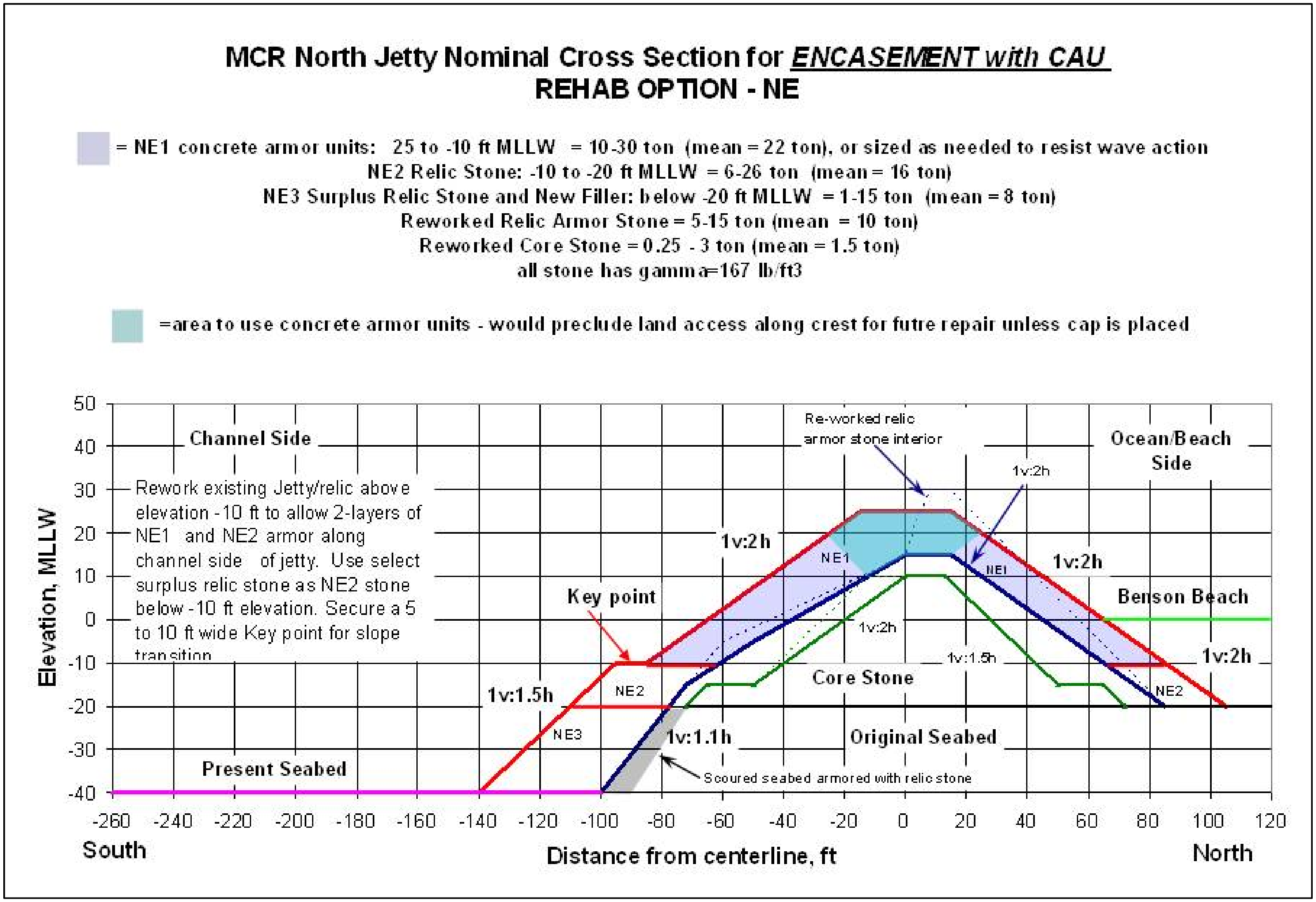


Figure A1- 192. North Jetty Encasement Secton with CAU's

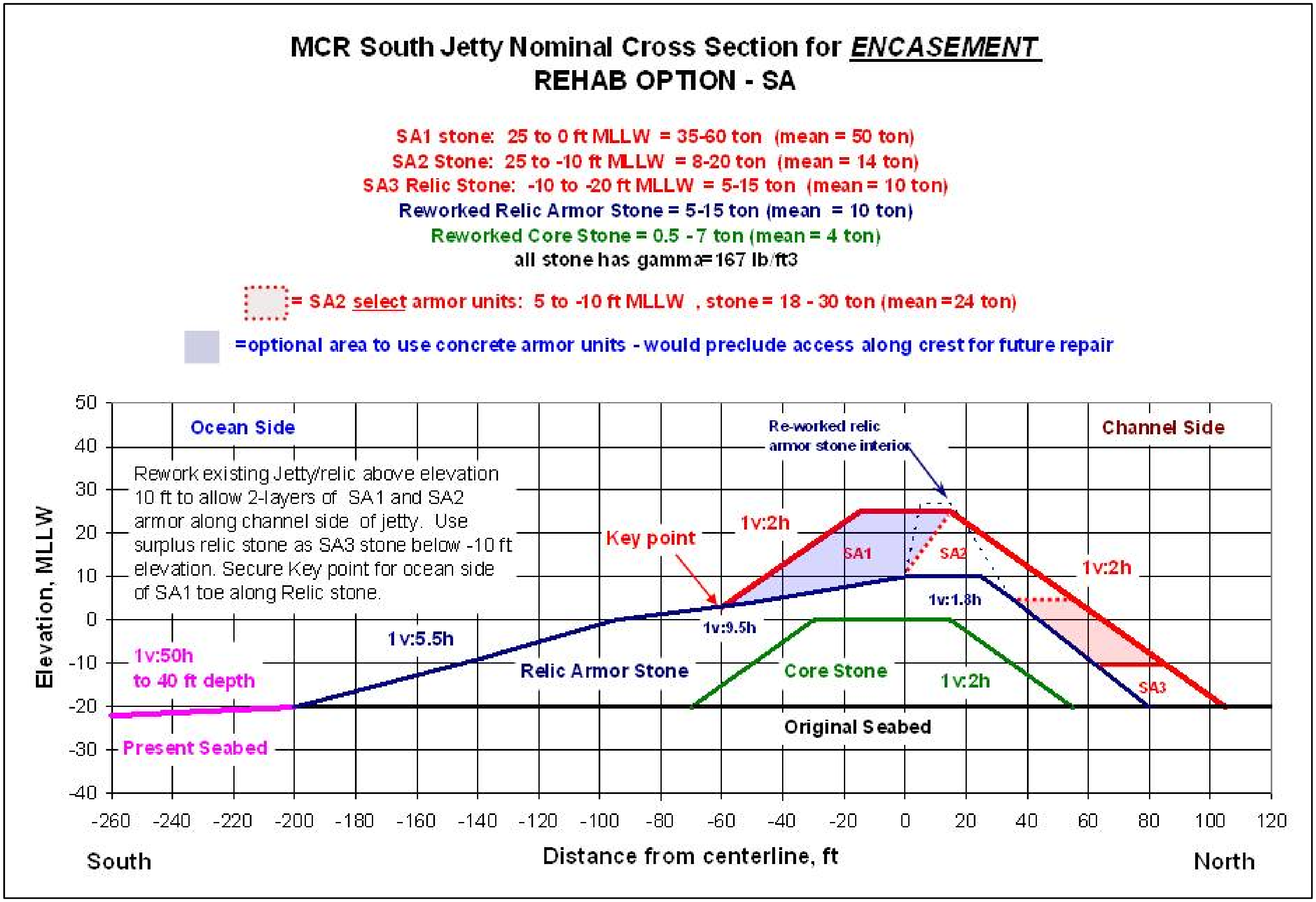


Figure A1- 193. South Jetty Encasement Section - SA

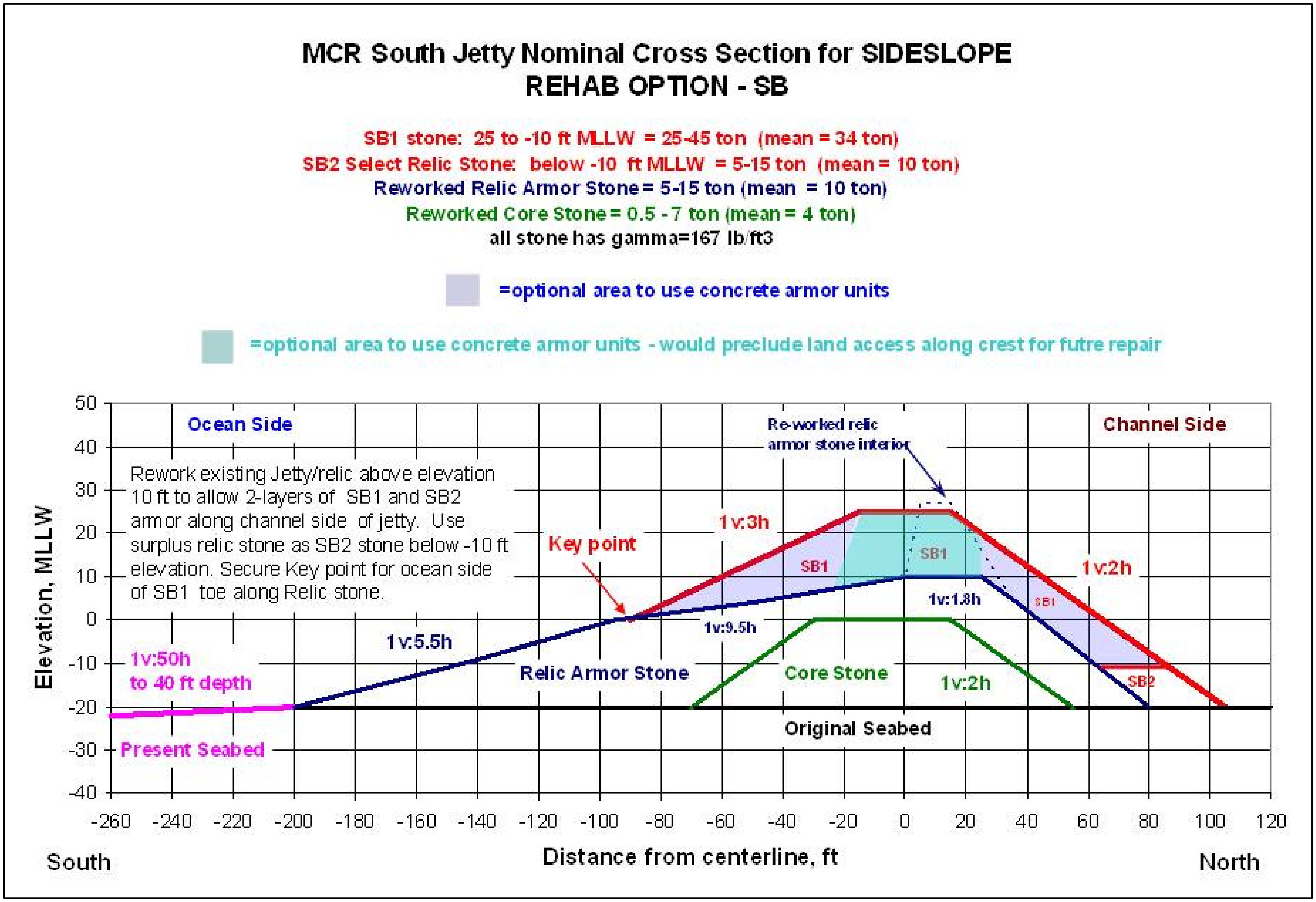


Figure A1- 194. South Jetty Sideslope Section - SB

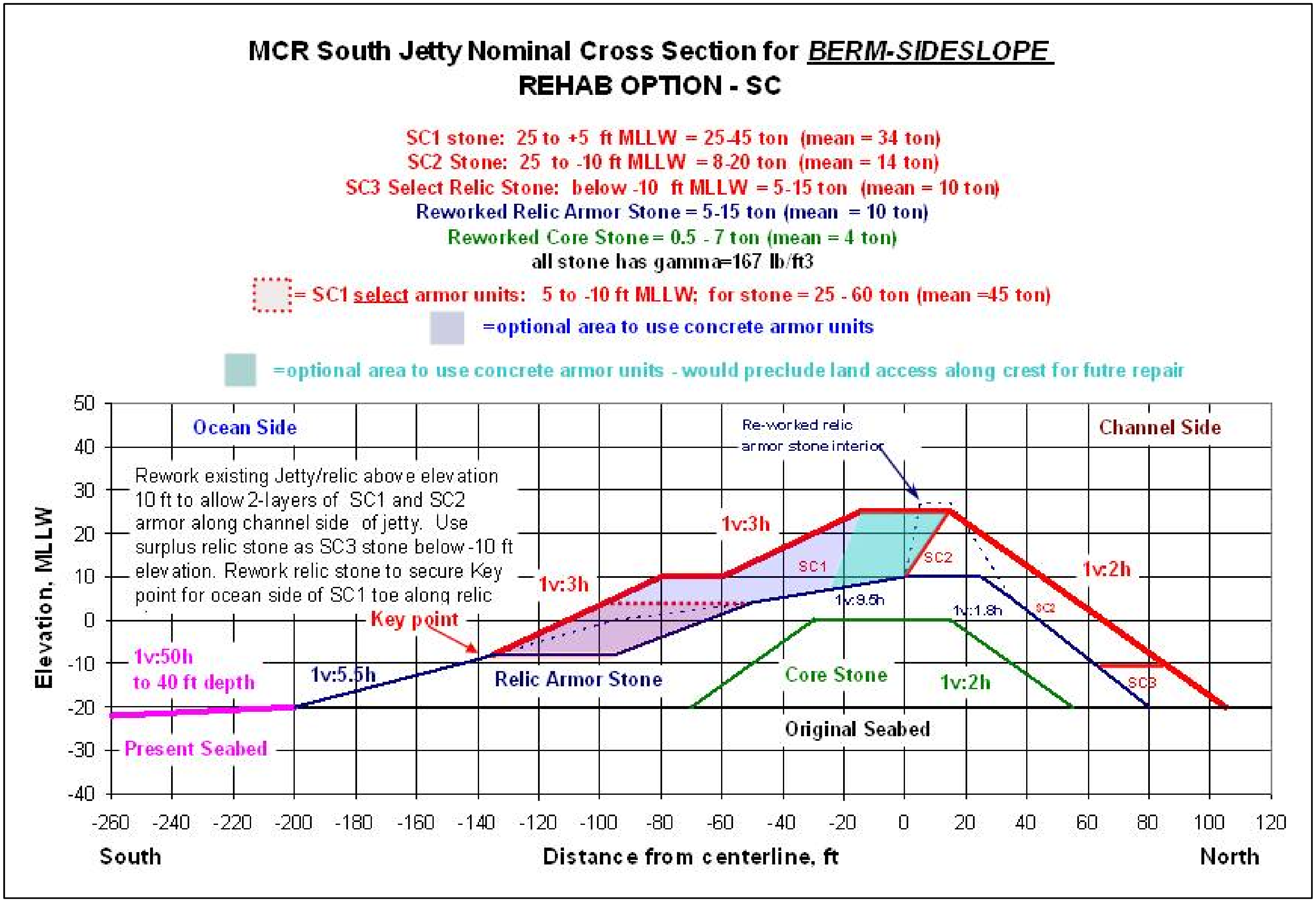


Figure A1- 195. South Jetty Berm Sideslope Section - SC

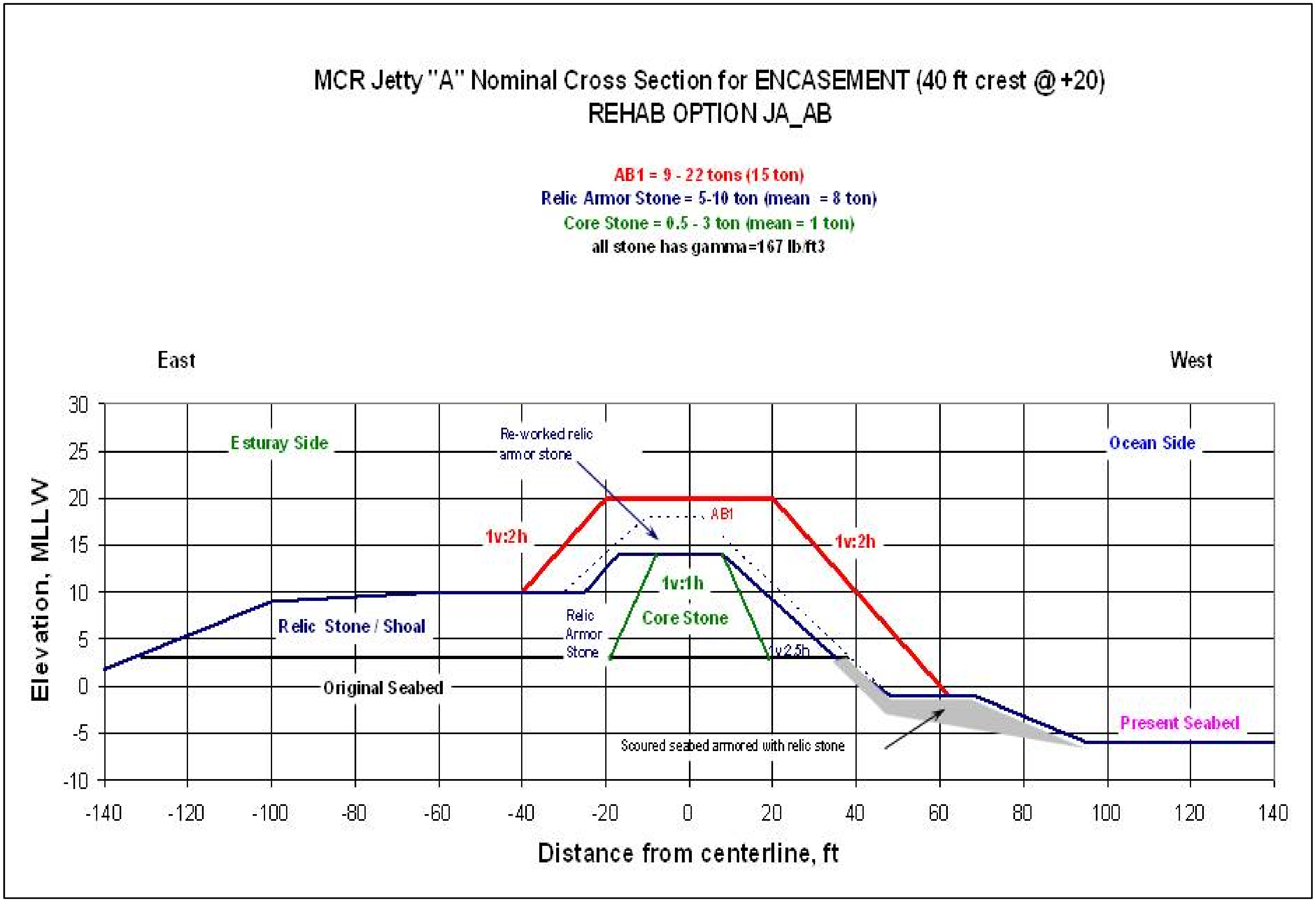


Figure A1- 196. Jetty A Encasement Section – AB

North 1A. Base slope of 1:3 channel side assumed to reduce wave action before attacking upper cross-section with 1:2 slope. 1:3 slope allows smaller armor stone size and forms stable base for some premitigated foundation scour protection. 25 ft crest elevation used to reduce stone quantity. Stone size increased from 10-30 tons to 20-40 tons based on initial model study results that indicated that 10-30 ton armor stone was too small. The effect of using 1:3 slope may be acting to 'ramp' waves onto the cross-section producing more severe wave damage. If true, this result is counter-intuitive to the hypothesis that a flatter slope makes more stable slope.

North 1B. Base slope of 1:1.5 channel side used to reduce stone volume along lower part of cross section, while providing a minimal bench to allow a key point for supporting a less steep upper cross section with 1:2 slope. NB1 select stone provides resistance to wave action near SWL where wave action is assumed to be worst. 25 ft crest elevation used to reduce stone quantity.

North 1C. Basal berm with bench used to serve as advance mitigation for toe scour to defer destabilization of lower and upper slope of jetty for 50 years. Berm to be constructed of small stone with slope of 1:1.5 to minimize volume. 1:3 mid-slope allows use of lower armor stone size and was assumed to dissipate wave action. Upper slope on channel side 1:2 to reduce stone volume. NC1 Select stone provides resistance to wave action near SWL, where wave action is assumed to be worst. Application of CAUs (concrete armor units) proposed as an option along upper slope. Berm and bench on beach side to premitigate toe scour. 25 ft crest elevation used to reduce stone quantity.

North 1D (improvement on 1B). 35 ft crest elevation used to eliminate wave overtopping and related instability on lee side. Stone size increased along entire upper cross section to reduce wave damage. Composite upper slope (1:1.5 to 1:2 variation) used to reduce stone volume. Assumed that above 20 ft MLLW, wave action is reduced such that 1:1.5 slope can be used. Improvement made in response to initial model study results that suggested wave overtopping crest of jetty was destabilizing crest and back slope.

North 1E (improvement on 1A). Concrete armor units used instead of stone to increase slope resistance to wave action. Improvement made in response to initial model study results that suggested wave overtopping crest of jetty was destabilizing crest and back slope due to undersized armor stone. Front slope of 1:3 may also be acting to 'ramp' waves making wave action more severe.

f. Results of Alternative Models Tested

Physical modeling results showed that the primary failure modes for the North/South jetties were high water level wave attack and overtopping. Individual results are summarized below.

1. Armor Unit Assessment:

- Majority of North Jetty can be reliably designed using attainable rock; seaward head of jetty may require advanced design.

- On the channel-side front face, 22-ton stone is too small (option A), 28-ton stone is marginal (option F) for a 1:2 slope.
- Channel-side toe of 16-ton stone between -10 ft and -20 ft MLLW and 8-ton stone down to -40 ft MLLW works very well at least when tested at high water (options A, D, F).
- Channel-side toe of 16-ton stone between -10 ft and -20 ft MLLW and 8-ton stone down to -40 ft MLLW works very well at least when tested at high water (options A, D, F).
- Ocean side toe: 16-ton stone from -10 ft to -20 ft MLLW worked well.
- Inner half of South Jetty can utilize rock; outer half may require combination approach.
- Dolos did not hold up well in the tests; very flat slopes needed.
- C-roc appeared to hold up well during the preliminary testing (concerns regarding C-roc application include question of reliability of one-layer system, never field-tested, elaborate construction control requirements, and uncertainty about interlocking with relic base).

2. Cross Section Element Assessment (preliminary):

- Heavy overtopping may require special crest and leeside design in some areas.
- Large toe berm not needed on South Jetty due to existing relic base.
- Sideslopes of 2 to 3 provide reliable section designs.

3. Damage Relationship Information Used in Reliability Analysis and Design:

- Existing and interim damage relationships define base condition.
- Various alternative damage relationships define alternative reliability.
- Alternative information interpolated for design based on position on jetty.

11. Engineering Features that Address System Degradation

a. General

Since original jetty construction, several large physical process changes have altered the current and projected future reliability of the system. It has been shown that as increased channel depths have been secured within the MCR inlet, larger waves are able to enter the channel and attack the jetties in addition to undermining the sandy foundation upon which they rest. These increased depths primarily affect the interior underwater shoals and the channelside of the jetties, and in particular the North Jetty, which is closer to the navigation channel.

Along the landward half of the North Jetty, another de-stabilizing flow path has developed through the structure as tidal flow moves through the structure to the accreted part of Peacock Spit, along the north side of the structure. In addition increased storm activity and intensity over recent decades has accelerated adjacent shoreline erosion exposing the deteriorated jetty root structure on both the North and South jetties.

The jetties continue to recede back from their original length. The South, North, and Jetty A head positions are currently shorter than authorized lengths by 6,200 ft, 2,200 ft, and 900 ft, respectively. Due to the interaction of wave patterns and currents with jetty configuration, the shorter jetty lengths can increase underwater shoal erosion and motivate increased recession of shoreline position adjacent to the jetties. Loss of jetty length also exposes the remaining structure to increased forces. Engineering features evaluated are summarized below.

South Jetty Existing Spur Groins. Historical records indicate that six spur groins were constructed along the channelside of the South Jetty. A 115-ft long spur was built landward of the jetty for shore protection. A 510-ft long sand-catch, consisting of heavy beach drift and loose brush, was built on the south side of the landward end of the jetty to continue filling the old outlet of a lagoon at the extreme end of Point Adams. Four of the groins are buried by accreted shoreline or sand shoal. The two visible seawardmost spur groins at approximately Stations 309+33 and 333+46 clearly show an influence on the surrounding underwater contours. The 100-ft spur groins push channelward the location of the more extreme tidal velocities so that the shoal material at the base of the jetty is stabilized. Figure A1- 57 illustrates the important effect these small features have on the surrounding contours. Even with the larger spacing of approximately 2500 ft between the groins, each one has a positive impact on stabilizing the underwater shoal and protecting the South Jetty. Processes important to long-term structural stability of the jetties that these small structural features help with include (1) offsetting the loss of jetty length and ebb tidal shoal extent and (2) offsetting the shoreline erosion occurring at the root of the jetty.

The basic purpose of jetties is to control and focus tidal velocities to a constricted area in an ocean inlet so that a navigation channel can be reliably maintained. An unintended consequence of that action is that the increased tidal velocities have the tendency to scour the foundation of the very structures that are channeling their flow. The majority of the spur groins proposed and analyzed in this study are intended to perform similar functions to the existing spurs on the channelside of the South Jetty. Those functions are to reduce the scour along the foundation of the jetty by reducing the velocity of the localized current that can develop along the length of the jetty along certain times in the tidal cycle. The intent is to reduce the bottom velocity only in a localized area along the base of the jetty. Since there is such a long distance between the jetties (about 2 miles), any application of spur groins at this inlet has a very localized hydrodynamic effect. Experience along the South Jetty has shown that spur groins work effectively at maintaining the critical shoal foundation supporting the jetty structure. One additional purpose for spur groins was evaluated and that was to slow down the adjacent shoreline erosion occurring on the oceanside at the jetty root. Both the North and South Jetties have experienced increased erosion at those locations.

Jetty Length Rebuild and Stabilization. All three jetties have receded significantly from their original authorized length and the protective jetty head construction has been lost. Continued jetty head recession is expected to occur at a rate of 5 to 50 feet per year, depending on the jetty. Due to the interaction of wave patterns and currents with the jetty configuration, the shorter jetty lengths can increase underwater shoal erosion as well as influence shoreline position adjacent to the jetties. Due to its increased exposure to wave attack from all directions as well as its critical protective function for the rest of the structure, the jetty head design is much more substantial than a typical jetty trunk section. Determining how much of the original jetty structure should be rebuilt and where the actual jetty head should be constructed was an important element of study. Parameters evaluated in assessing recommended jetty length included possible impacts on tidal velocities and salinity, protecting the navigation entrance from waves, impacts on adjacent shoreline and ebb tidal shoal erosion, and impacts on dredged material disposal activities. The extent and distribution of the relic stone base left over from past construction efforts played a role in determining a cost-effective location for jetty head construction (Figure A1- 197 illustrates a similar jetty capping application at Yaquina North Jetty).

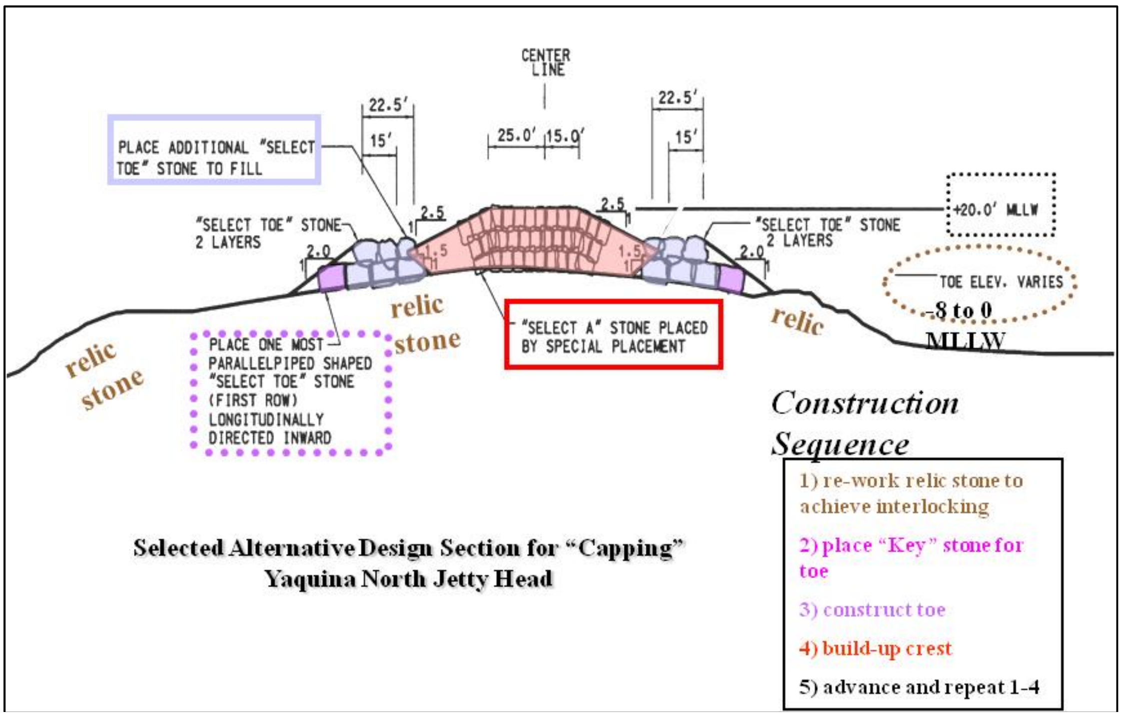


Figure A1- 197. Yaquina North Jetty Head Cappign Section

Erosion Areas at Jetty Root. An apparent increasing wave climate, erosion of the large ebb tidal shoal, and continued recession of the jetty lengths have all contributed to erosion of the shoreline adjacent to the jetty root for the North and South jetties. In addition, along the landward half of the North Jetty, another de-stabilizing flow path has developed through the structure as tidal flow moves through the structure to the eroded lagoon behind the structure.

b. Spur Groins

The present environment affecting the MCR jetties requires the application of spurs along each jetty to prevent the continual undermining of each jetty's foundation. This type of application has been used effectively both at MCR as well as other Pacific Northwest navigation entrances. A jetty spur or spur groin is a relatively short structure (in comparison to jetty length) extending outward from the main axis of a jetty. Spur groins are constructed for a range of reasons dealing with the need to effect currents and sediment transport along the jetty. Two prominent reasons why spurs are implemented are:

1. On the ocean or beach side of jetty, to deflect the longshore (rip) current and related littoral sediment away from the jetty and prevent littoral sediment from entering the navigation channel (Figure A1- 198); Figure A1- 199 illustrates how jetty length recession can also impact shore tie-in erosion conditions.
2. On the channel side of a jetty, to divert the tidal or river current away from the channel side toe of the jetty. In this application, spur(s) act to reduce the scour at the affecting the jetty's foundation while increasing the current in the navigation channel thus reducing the deposition in the channel.

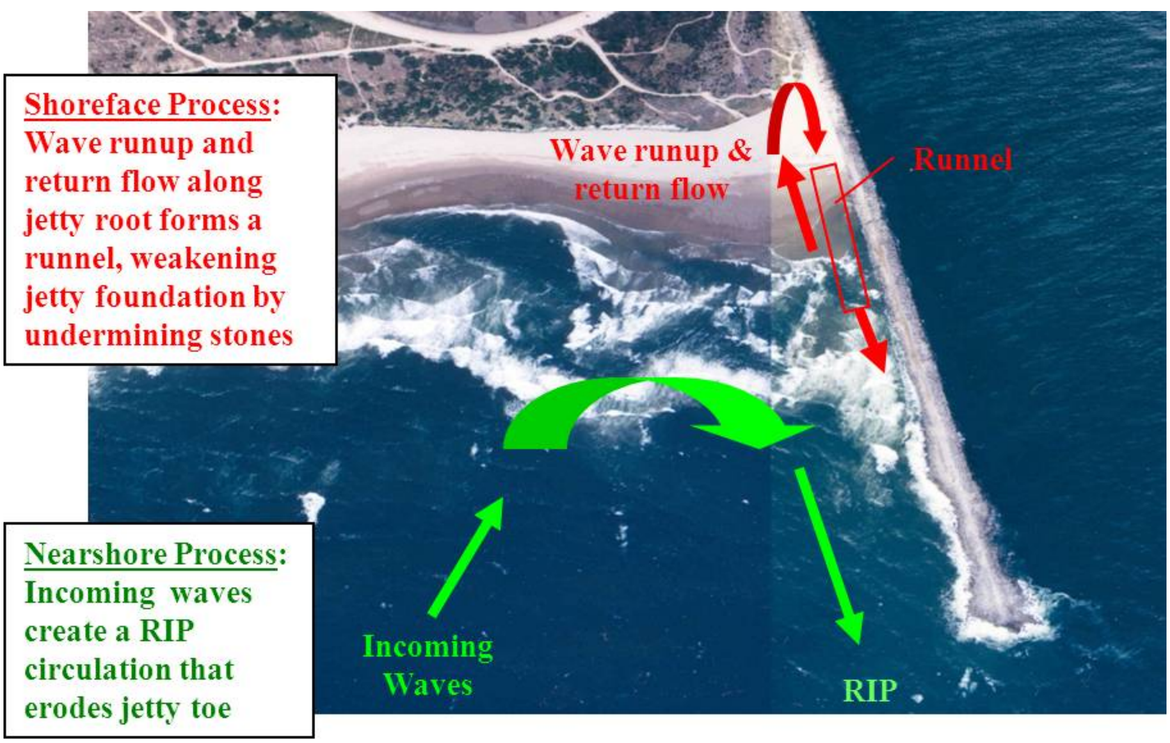


Figure A1- 198. Wave Run-up and Return Flow along Root of Jetty

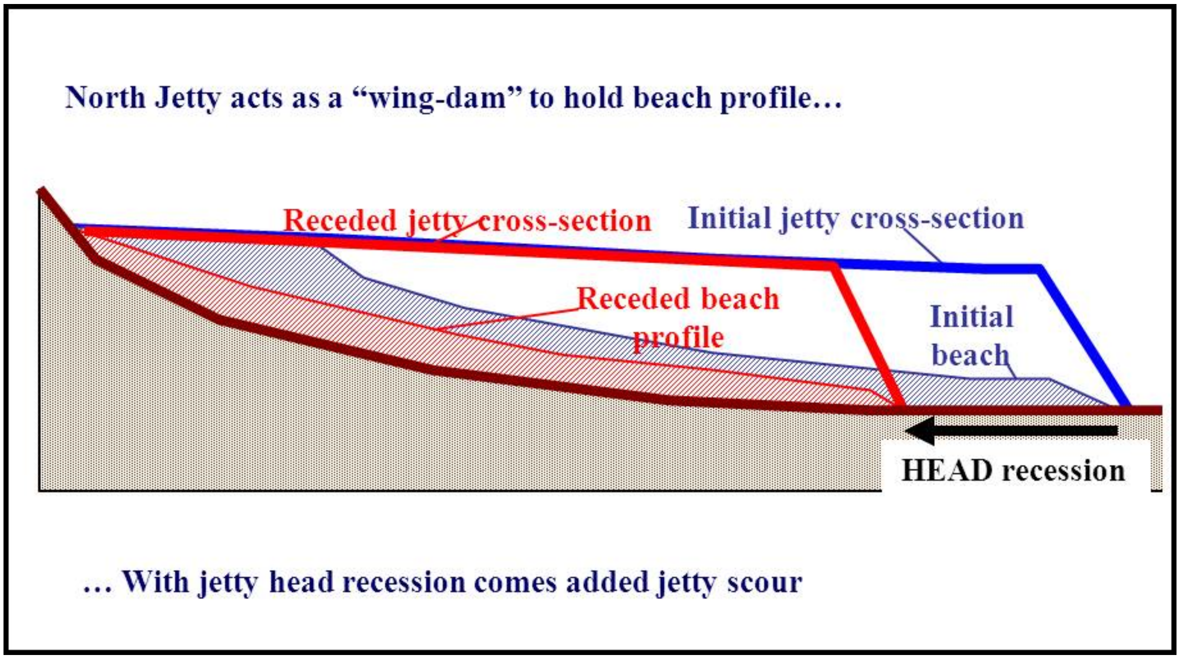


Figure A1- 199. Illustration of Jetty Length Operating as a Wing-dam

Spur application at a coastal inlet can be complex due to reversing tidal flow in the channel, possibly different primary flood and ebb flow channels, wave forcing, and wave-current interaction. Spurs are needed along each MCR jetty (on each side) to reduce the bottom current affecting the toe of the structure. See Figure A1- 200 for an illustration of existing spur groin influence along the channelside of the South Jetty at MCR.

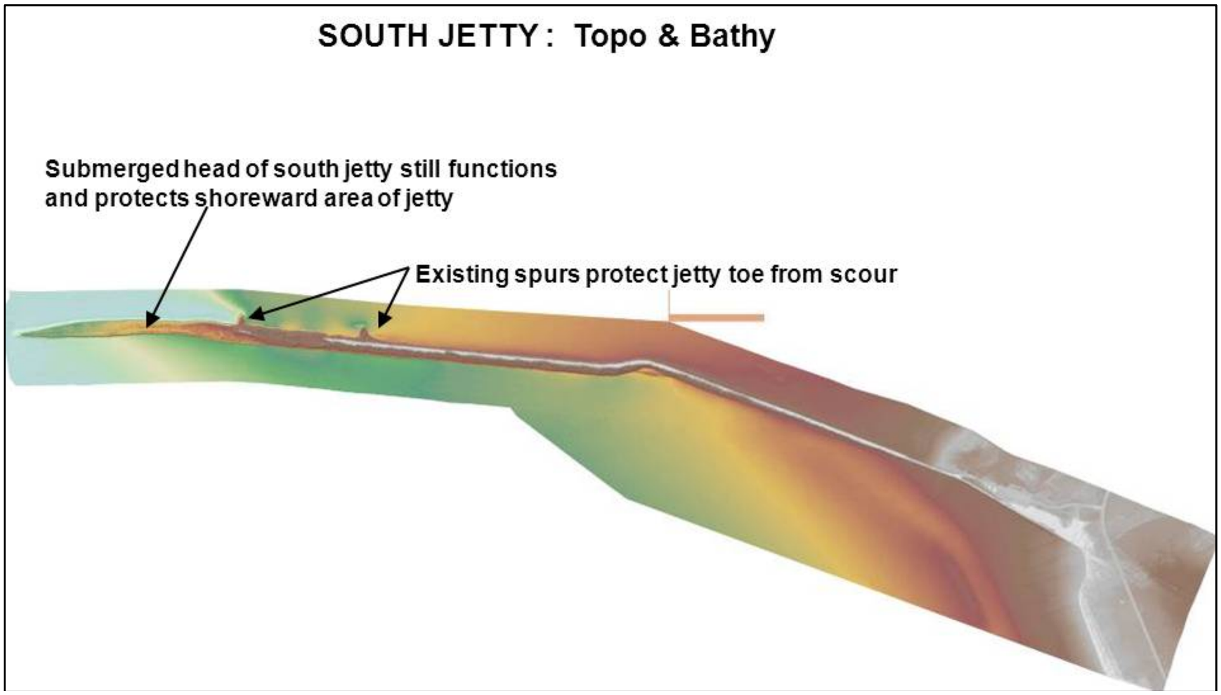


Figure A1- 200. Groins and Bathymetry around South Jetty

A range of information was utilized in developing recommended spur groin applications along the three jetties at MCR. The recommended plan was determined within the framework of trying to specify the lowest impact spur groin layouts (size and number of spurs) suitable to achieving the intended long term stability of the structures. Information utilized included knowledge of problem erosion areas along the three primary jetties, experience of spur groin application at MCR South Jetty and Yaquina South Jetty, observation of jetty relic stone wing impacts on shoreward sedimentation, other spur groin studies, and numerical hydrodynamic modeling. Figure A1- 201 and Figure A1- 202 illustrate a similar spur groin application at Yaquina Bay entrance.

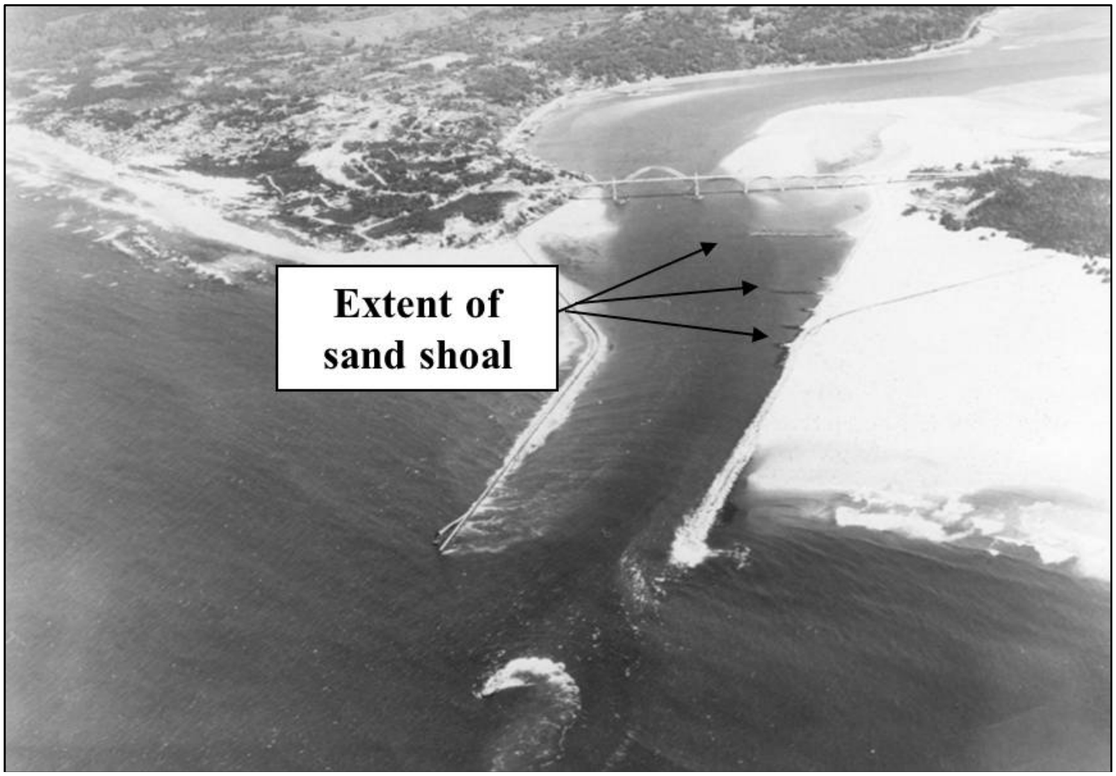


Figure A1- 201. Spur Groins and Shoaling at Yaquina Bay

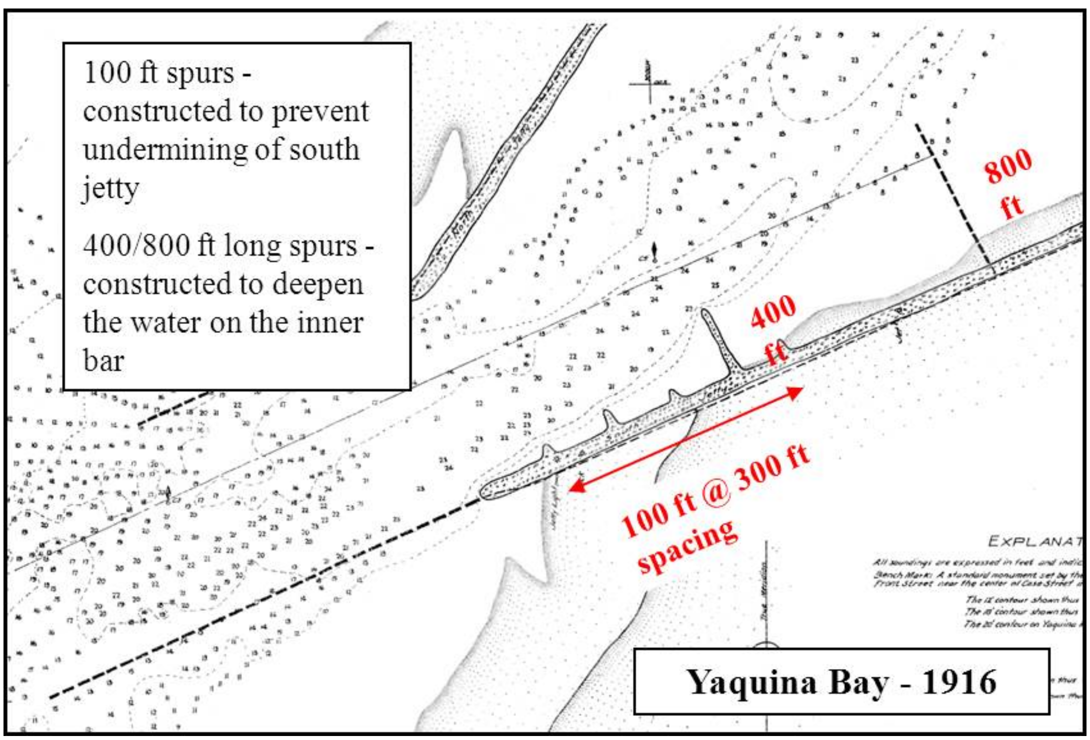


Figure A1- 202. Spur Groins along Yaquina South Jetty

The Corps' Engineering Research and Development Center in Vicksburg, Mississippi analyzed the hydrodynamics and circulation patterns in the MCR entrance as well as the potential impacts and effectiveness of placing spur groins on the jetties. This analysis was conducted with the coastal modeling system (CMS) and other models that operate within the surface water modeling system (SMS). A regional circulation model (ADCIRC) provided the tidal and wind forcing for the boundaries of project-and local-scale wave, current, sediment transport, and morphology change calculated by the CMS. The half-plane version of the wave transformation model, STWAVE, was coupled with two-dimensional and three-dimensional versions of the CMS, which calculates current, sediment transport, and morphology change. Figure A1- 203 illustrates typical spur groin configurations used in numerical modeling. Figure A1- 204 shows typical cross sections of spur groins along the channelside of the South Jetty.

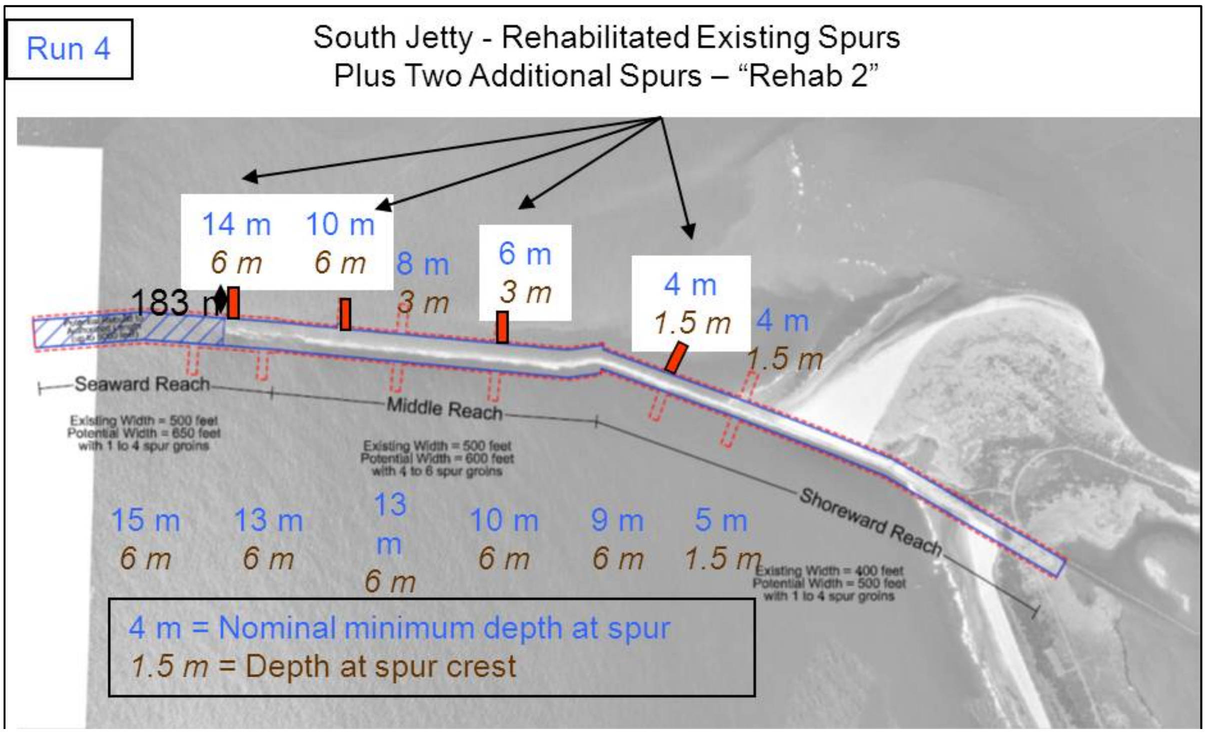


Figure A1- 203.   Spur Configuration used in Numerical Modeling

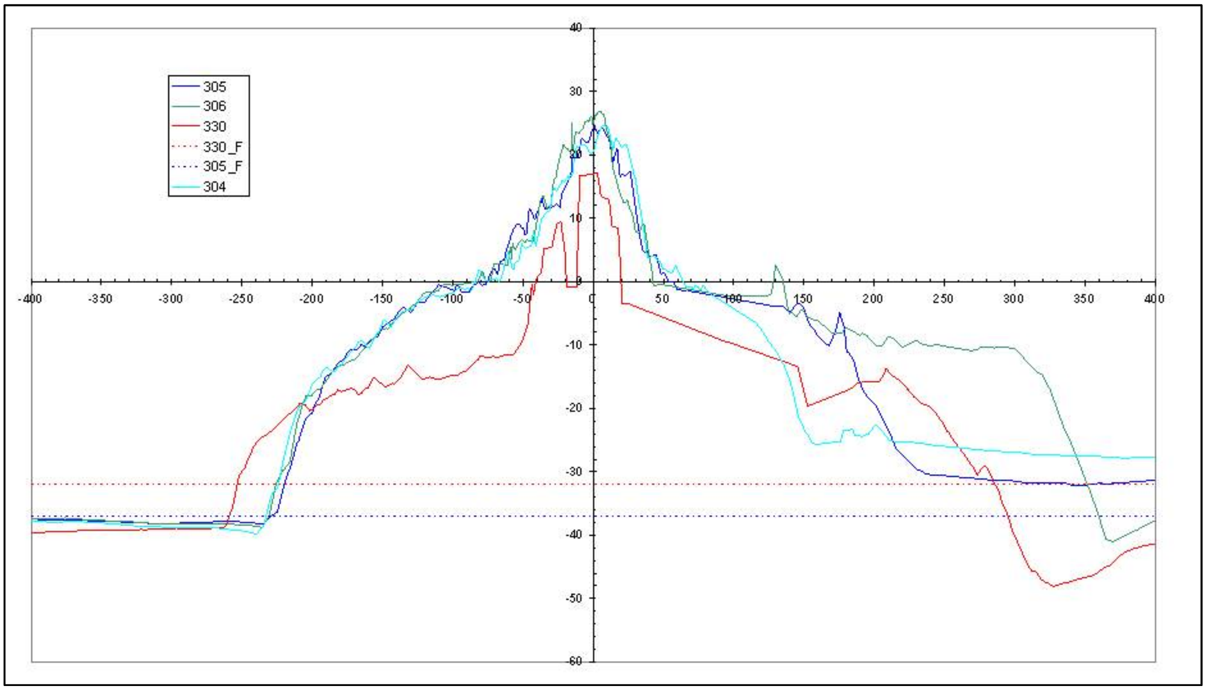


Figure A1- 204. South Jetty - Existing Spur at 306 and 330 - Channelside

The investigation was conducted by defining the largest possible plan and gradually reducing the number and size of spur groins necessary to achieve the intended purpose. The original and largest possible layout investigated of spur groins along each of the jetties is shown in Figure A1- 89 and Figure A1- 90. Studies began with 12 spur groins along the South Jetty, six along each side. Nine spur groins were proposed for study on the North Jetty, three on the north side and six on the channelside. Eight spur groins were proposed for Jetty A, four on each side. Spur groin length was originally specified as a maximum of 600 ft long. Along the South Jetty at least six spurs were originally authorized and constructed (1890-1913) with lengths of 90 ft to 1000 ft to stabilize the jetty foundation. These ‘original’ South Jetty spurs have degraded to such an extent that only two small spurs are presently discernable on the South Jetty, 60 to 80 ft widths, spaced approximately 2400 ft apart, extending 100 to 200 ft away from the side of the jetty (along the outer 1/3 of the jetty’s channel side).

Potential locations for jetty spurs were evaluated based on calculated peak ebb and flood currents as simulated with the regional-scale 2-D CMS. Locations of peak flood and ebb currents that exceeded 1 m/sec were identified. Currents that exceed 1 m/sec were identified at the tip of Jetty A, the channel side of the North Jetty, and the seaward third of the South Jetty, including the area of the existing spurs. Peak flood flow had the highest speed at the submerged tip of the South Jetty. Currents exceeding 1 m/sec for peak flood appear at the west side of Jetty A, the north side of the tip of the North Jetty, and the tip and both landward and seaward of the “knuckle” on the South Jetty. All spur groins modeled were found to decrease current to their lee by approximately 0.2 m/sec, and were found to potentially increase the current slightly off the toe of each spur by approximately 0.2 m/sec.

Based on the spur groin analysis, total spur groins along the South Jetty were reduced from the original six on each side to two spur groins on the seaside and three spur groins on the channelside (elimination of seven spur groins). In addition, the length of each of the spur groins was optimized based on the water depth at its proposed location (i.e., a shallower depth requires a shorter spur groin to have a positive impact). Proposed spur groin length along the South Jetty ranges from 60 to 180 ft with an average length of 94 ft. Figure A1- 205 illustrates the spur length estimated based on the depth of application. Total spur groins along the North Jetty were reduced from the original nine spur groins to a total of four, one on the seaside and three on the channelside (elimination of five spur groins). Proposed spur groin length along the North Jetty ranges from 60 to 250 ft with an average length of 145 ft. Total spur groins along Jetty A were reduced from the original four on each side to one on each side (elimination of six spur groins). Proposed spur groin length along Jetty A ranges from 125 ft to 135 ft, with an average of 130 ft. In summary, the proposed spur groin layout was reduced from a total of 29 spur groins to a total of 11 spur groins, a 62% reduction in number. In addition, the average length of the proposed spur groins is 120 ft compared to an original potential length of 600 ft. The final proposed approximate location of the spur groins can be seen on Figure A1- 206. Figure A1- 207 displays typical spur cross section changes with depth of application. Approximate dimensions and cross sections for the proposed spur groins can be found in Figure A1- 208 through Figure A1- 218.

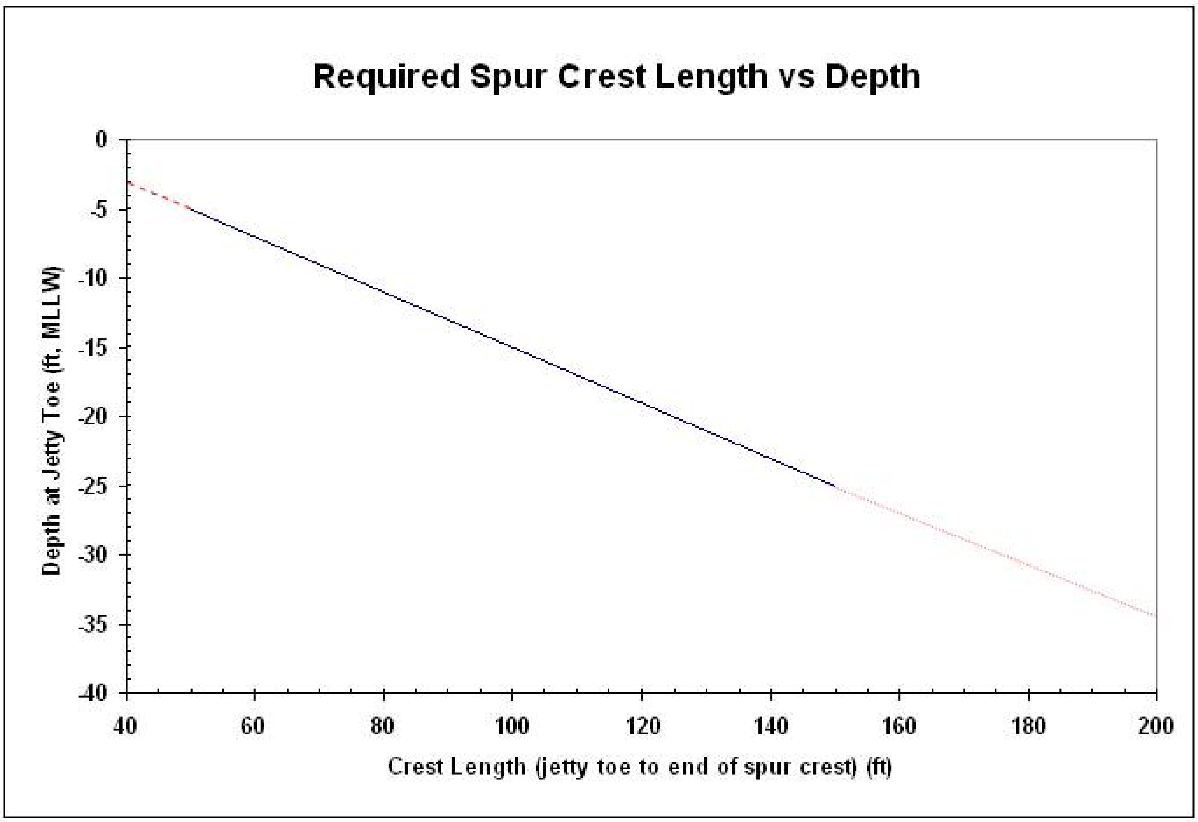


Figure A1- 205. Required Spur Length vs Depth

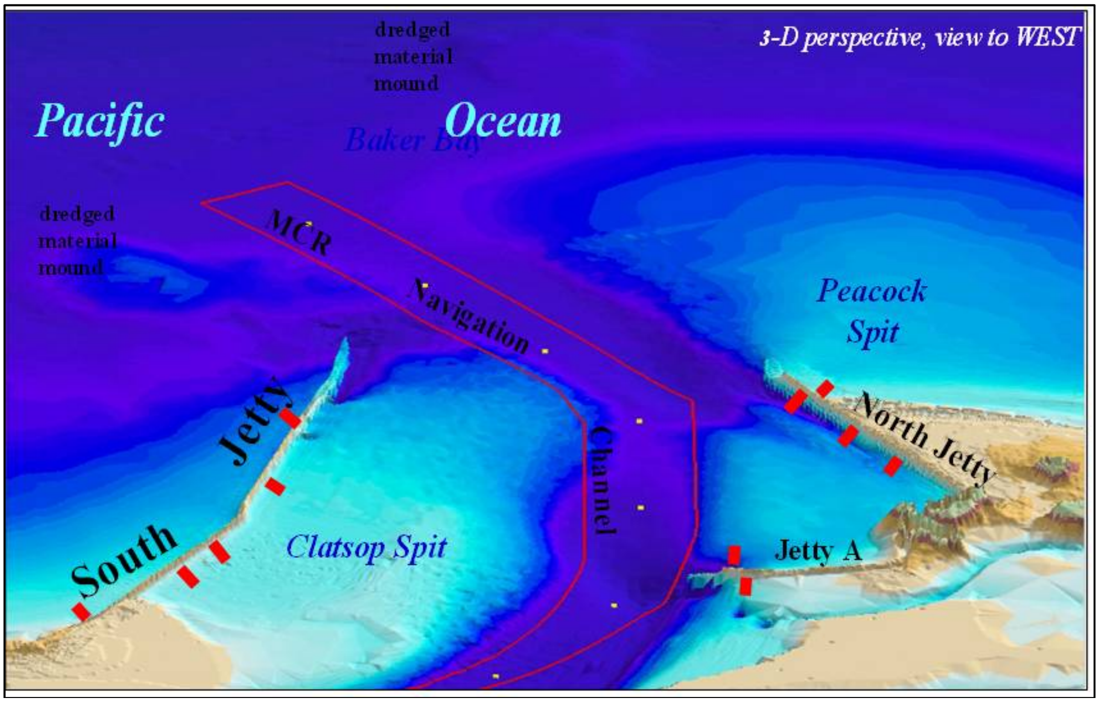


Figure A1- 206. Proposed Locations for Spur Groins

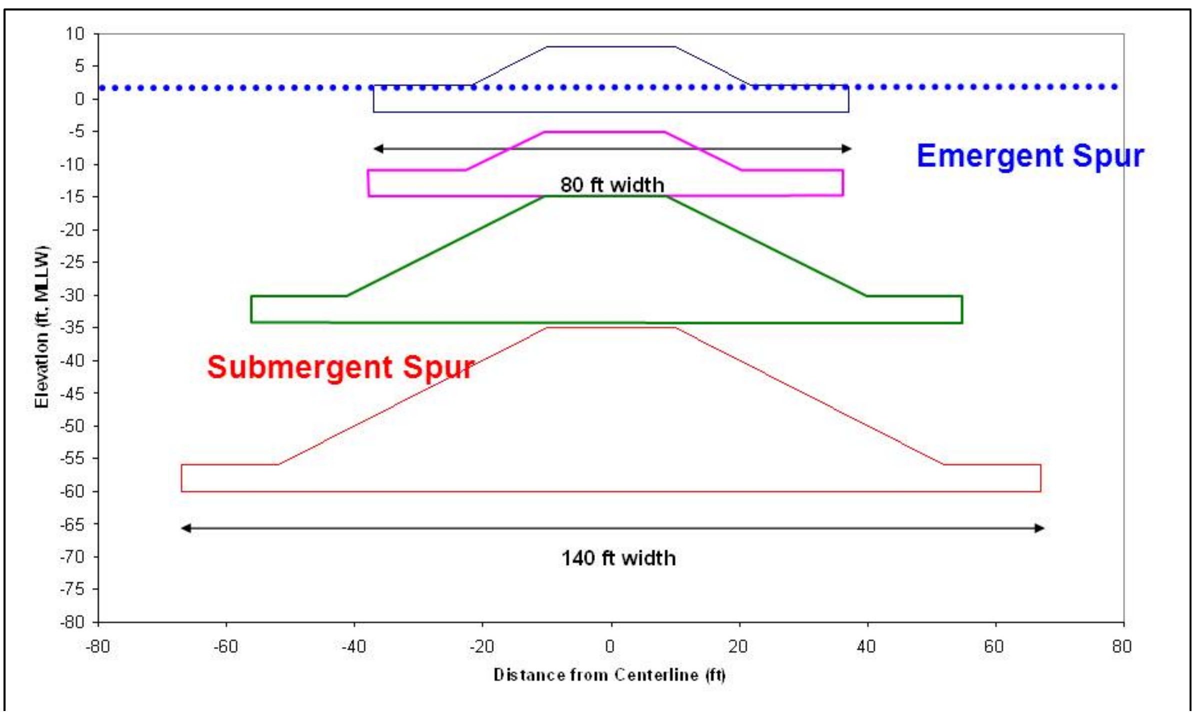
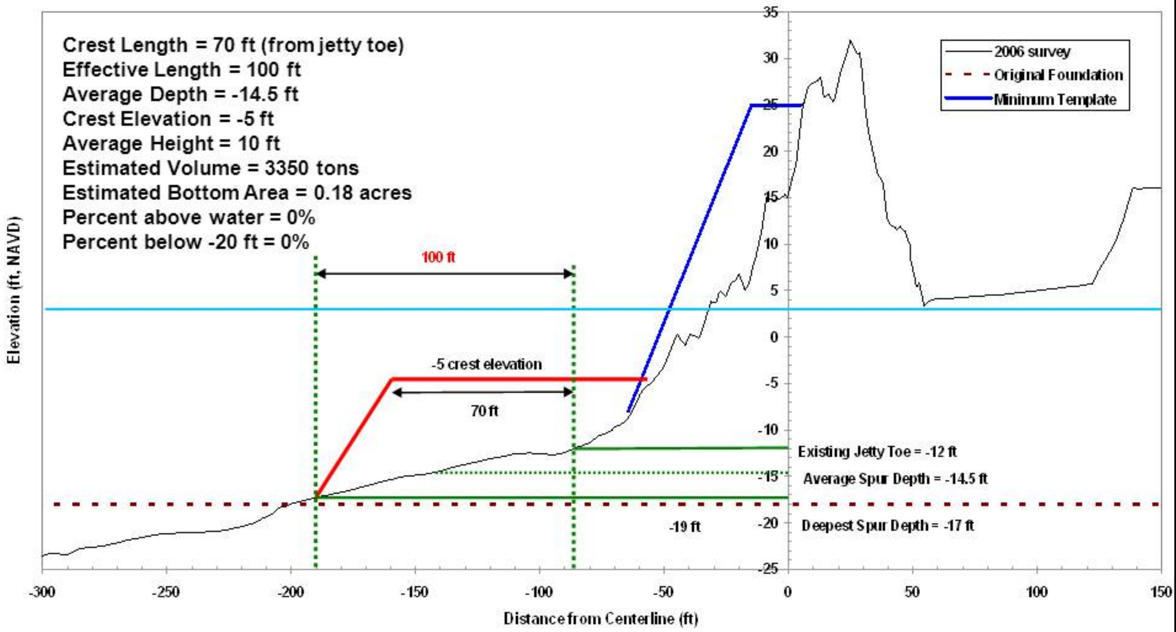


Figure A1- 207. Typical Spur Cross Section – Change with Depth



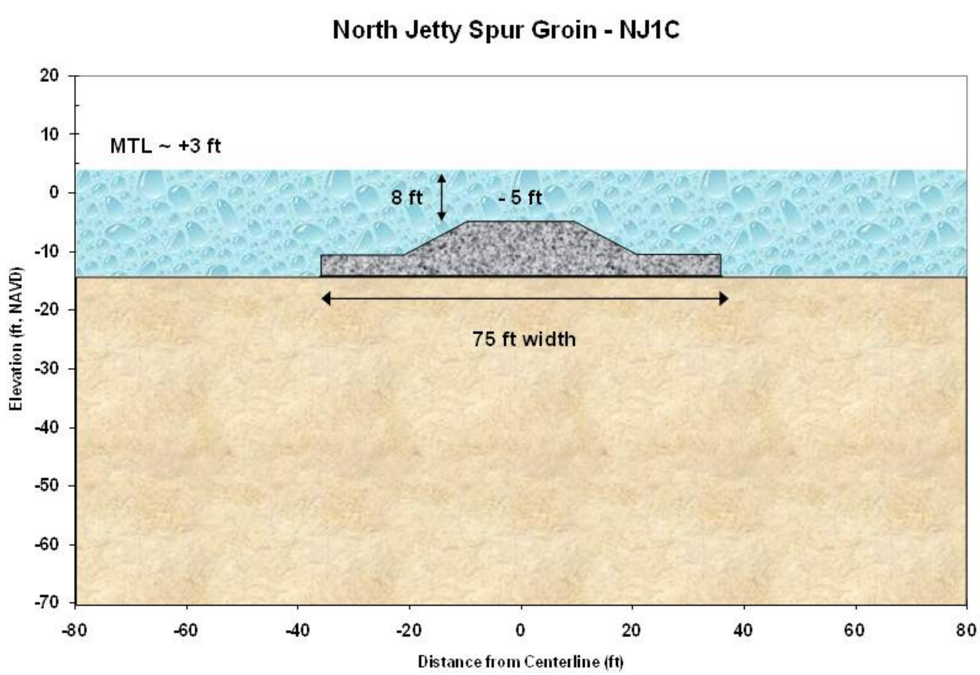


Figure A1- 208. North Jetty Proposed Spur Groin – NJ1C

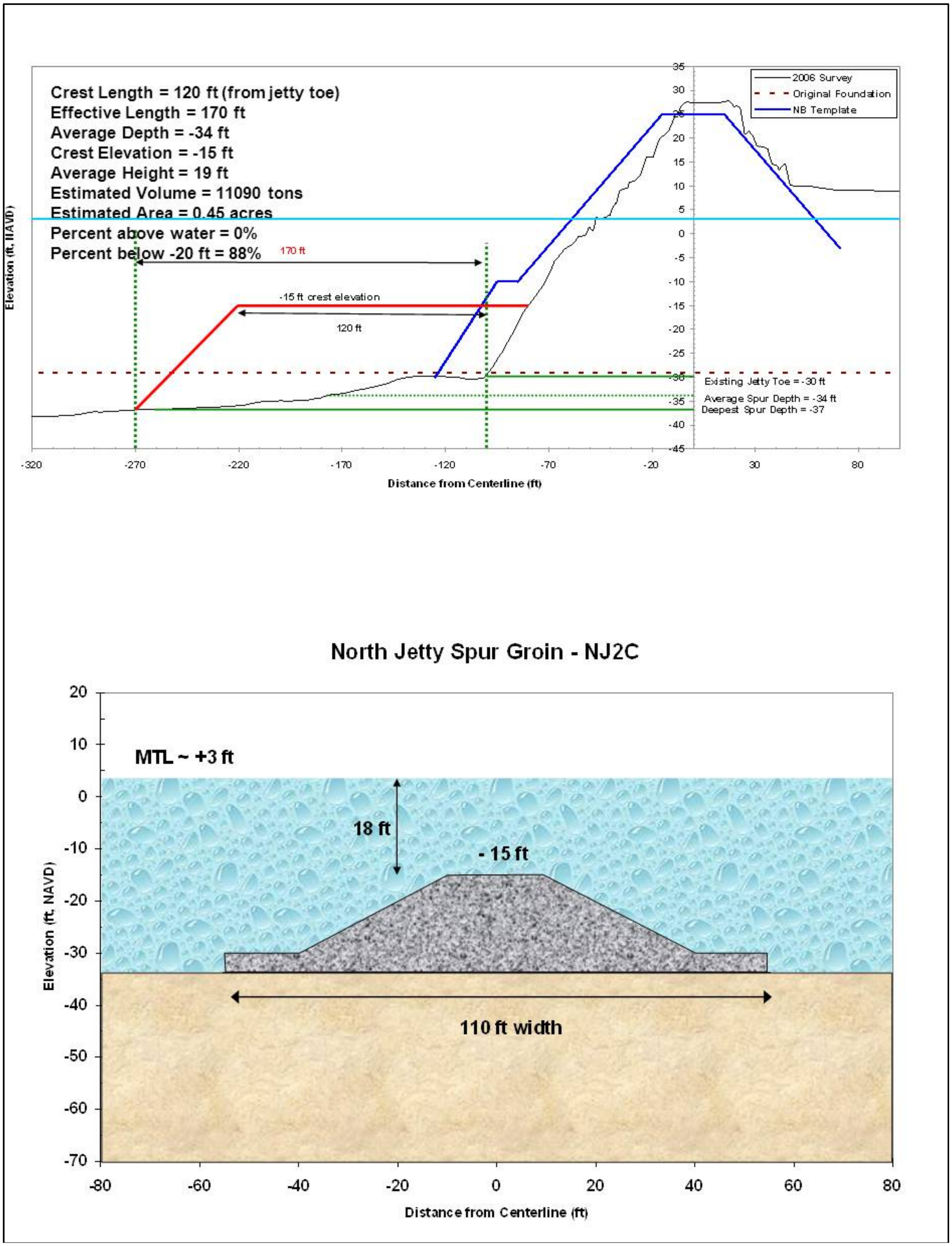


Figure A1- 209. North Jetty Proposed Spur Groing – NJ2C

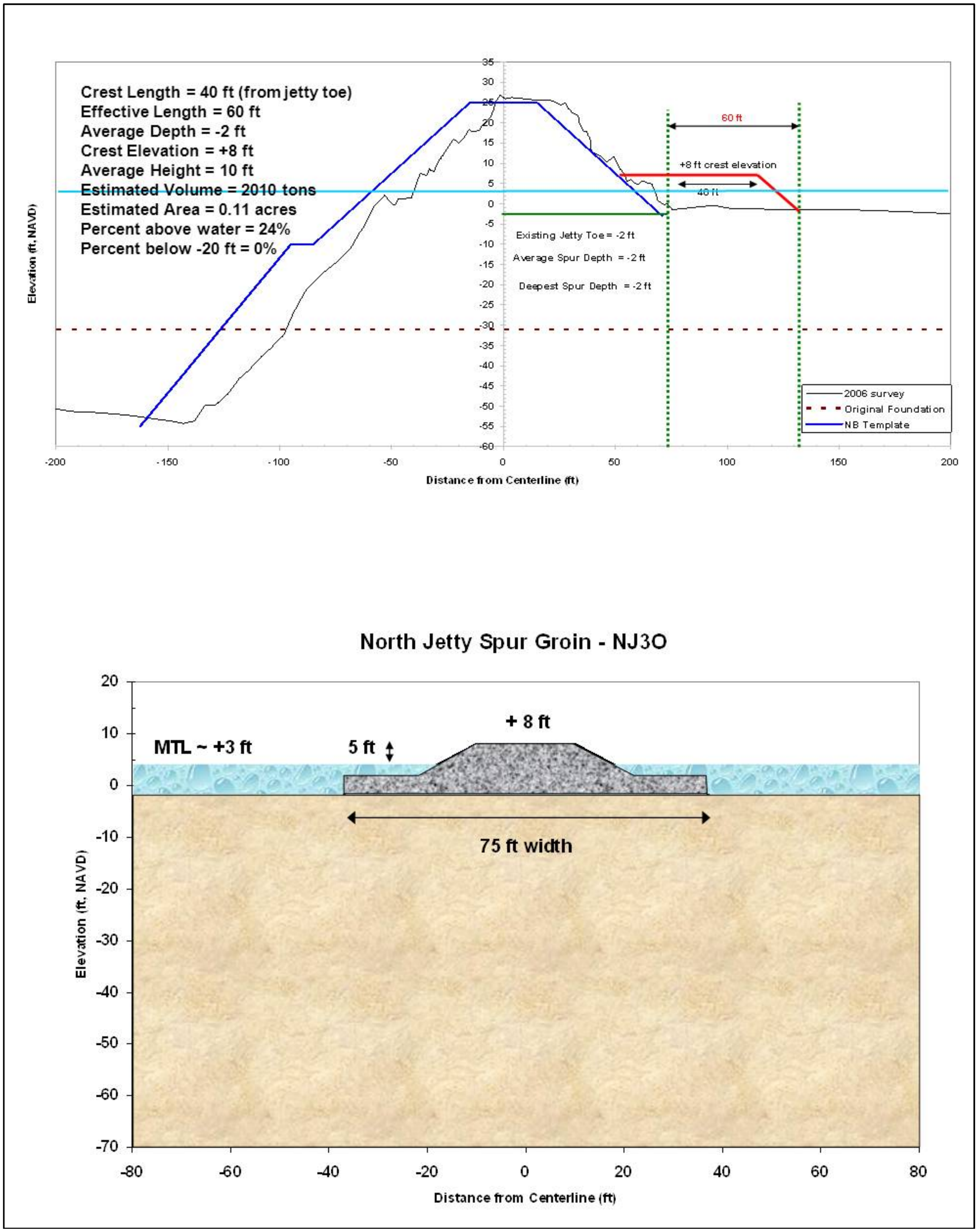


Figure A1- 210. North Jetty Proposed Spur Groing – NJ30

Proposed Locations for Spur Groins

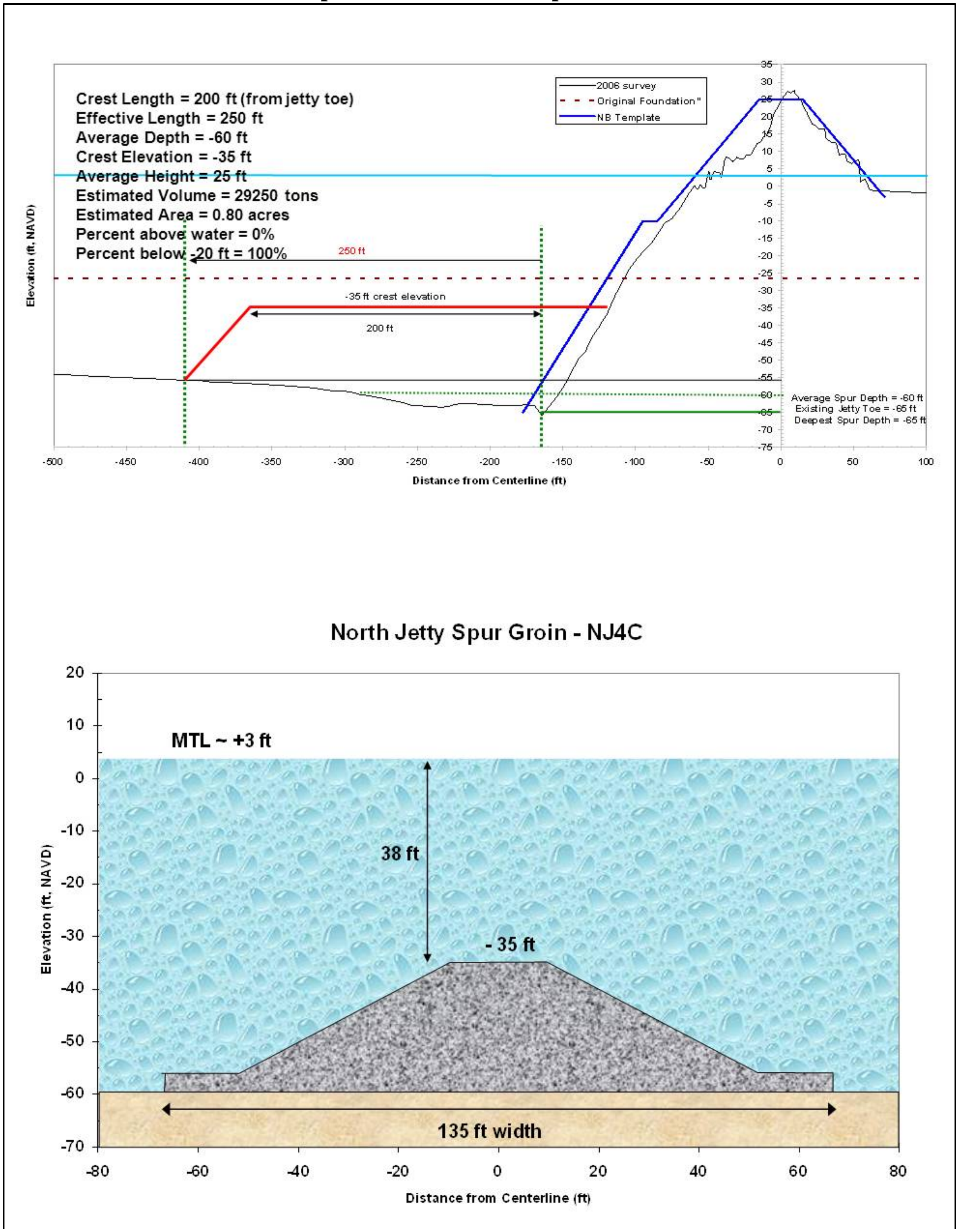


Figure A1- 211. North Jetty Proposed Spur Groing – NJ4C

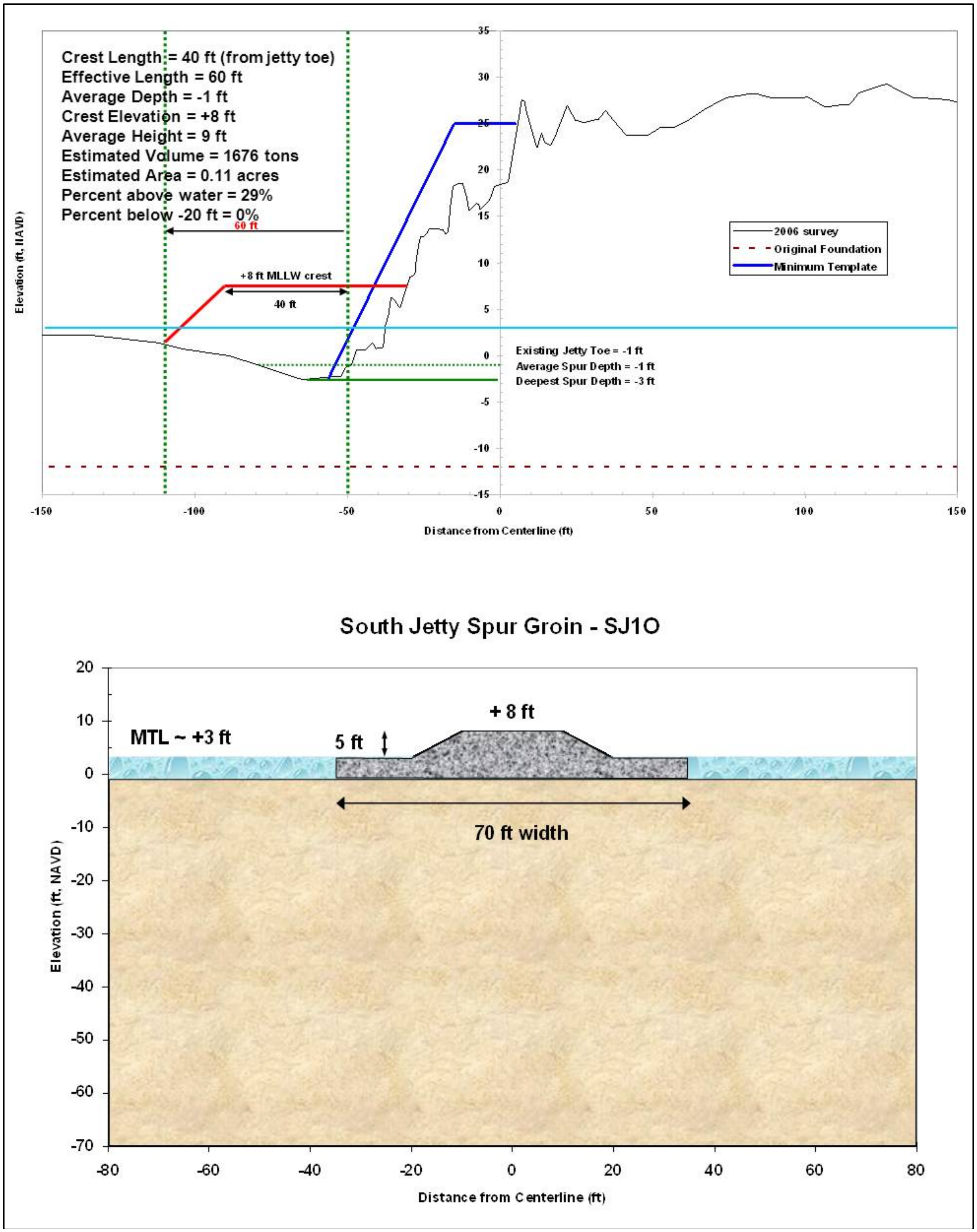


Figure A1- 212. South Jetty Proposed Spur Groing – SJ1O

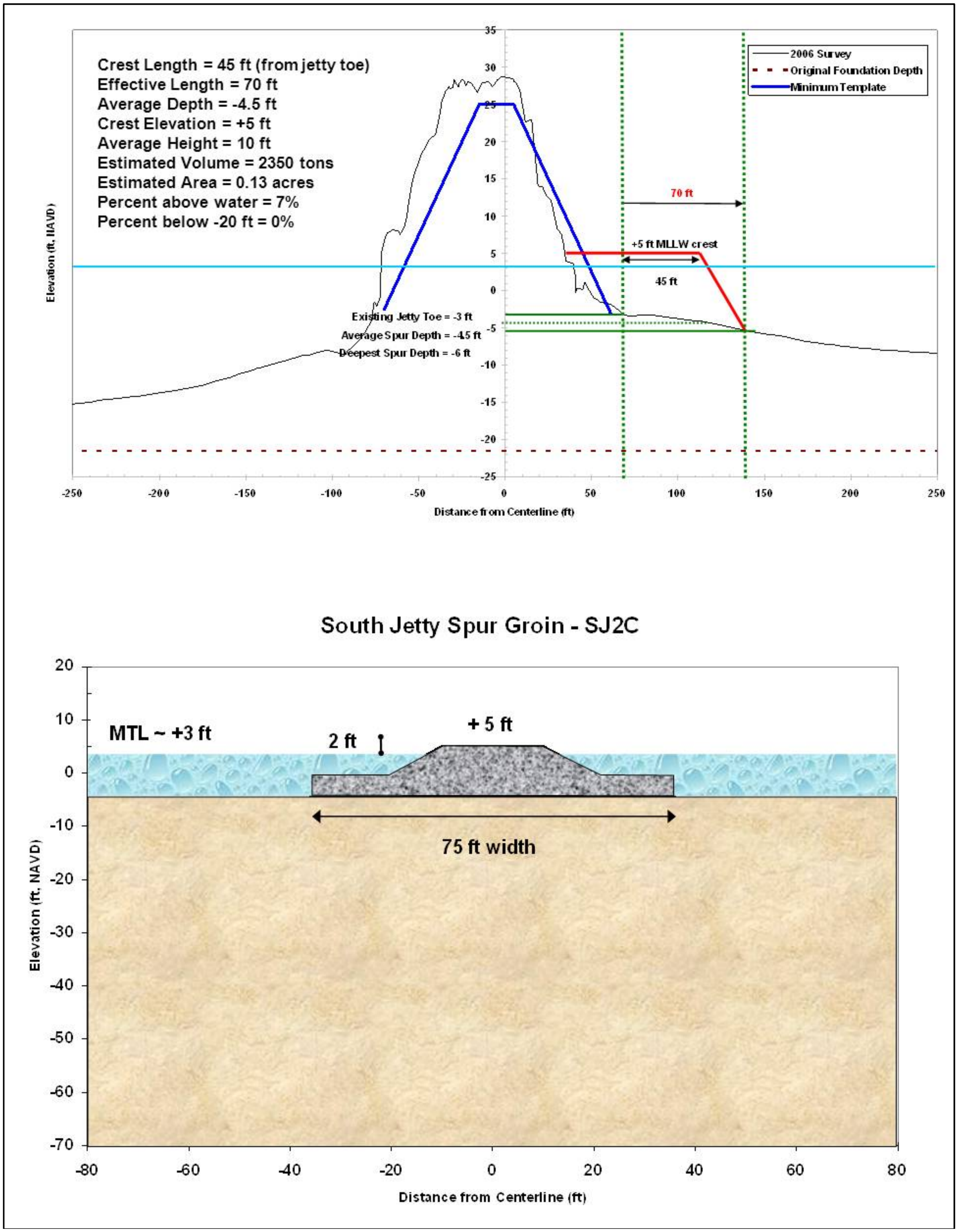


Figure A1- 213. South Jetty Proposed Spur Groing – SJ2C

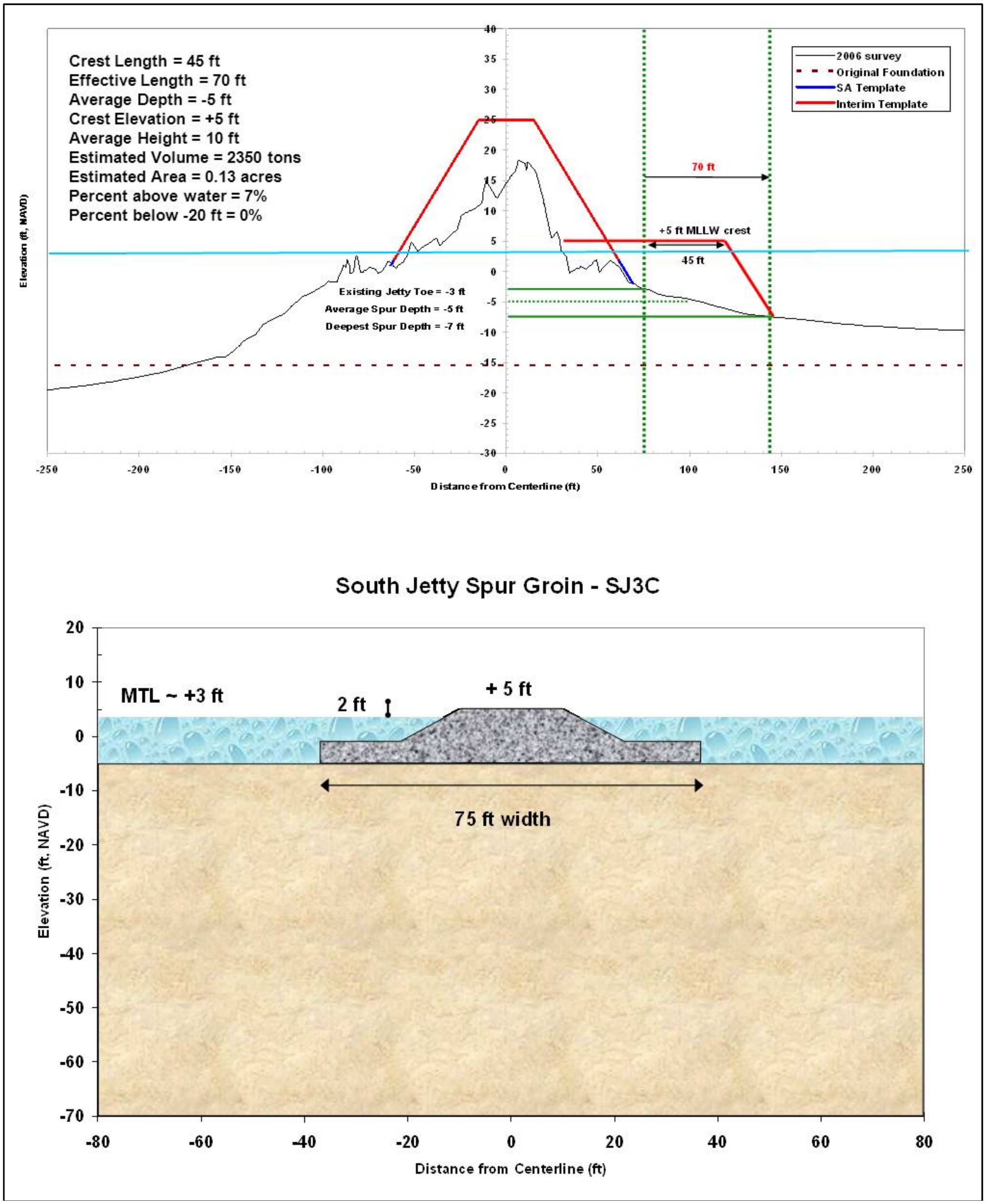


Figure A1- 214. South Jetty Proposed Spur Groing – SJ3C

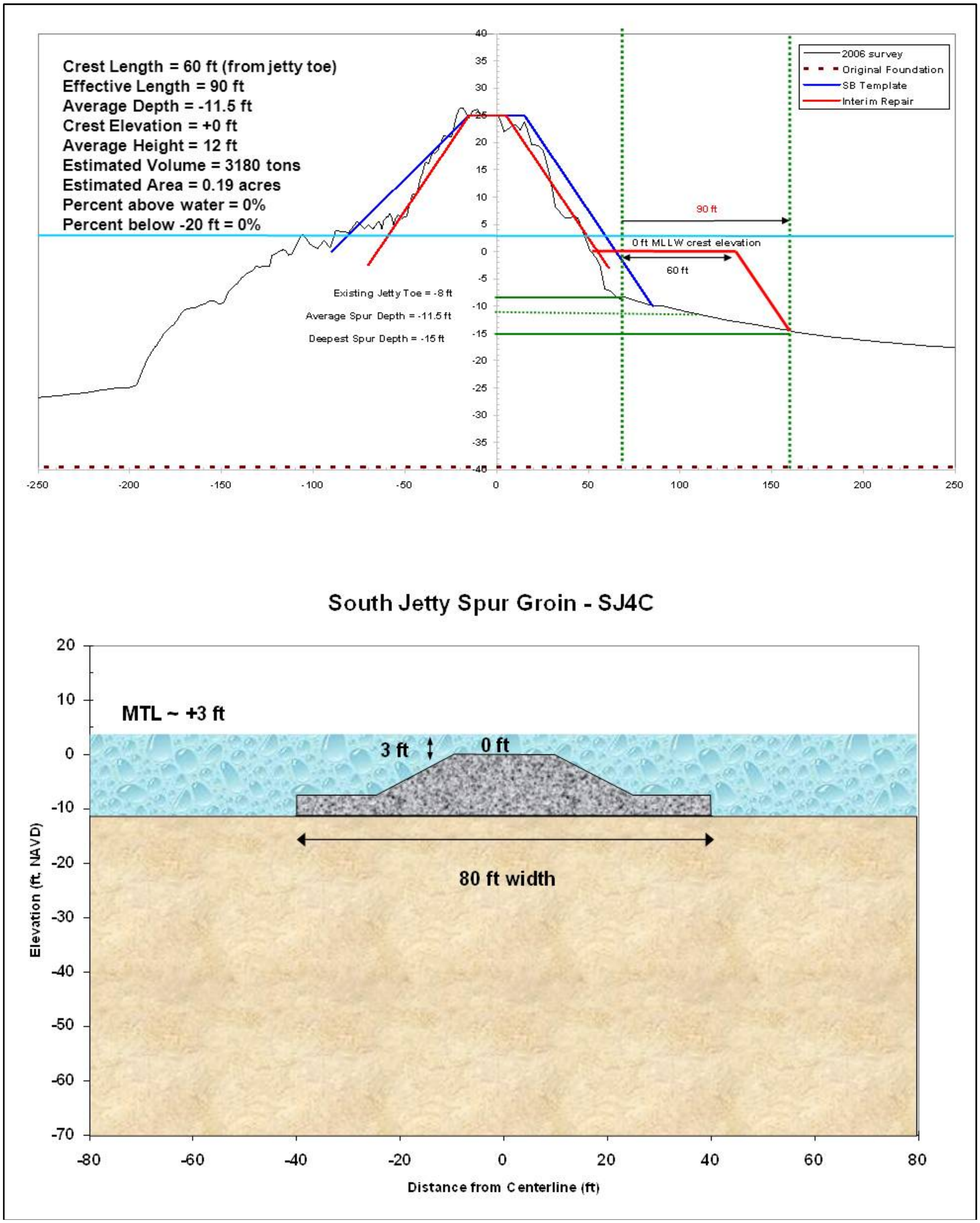
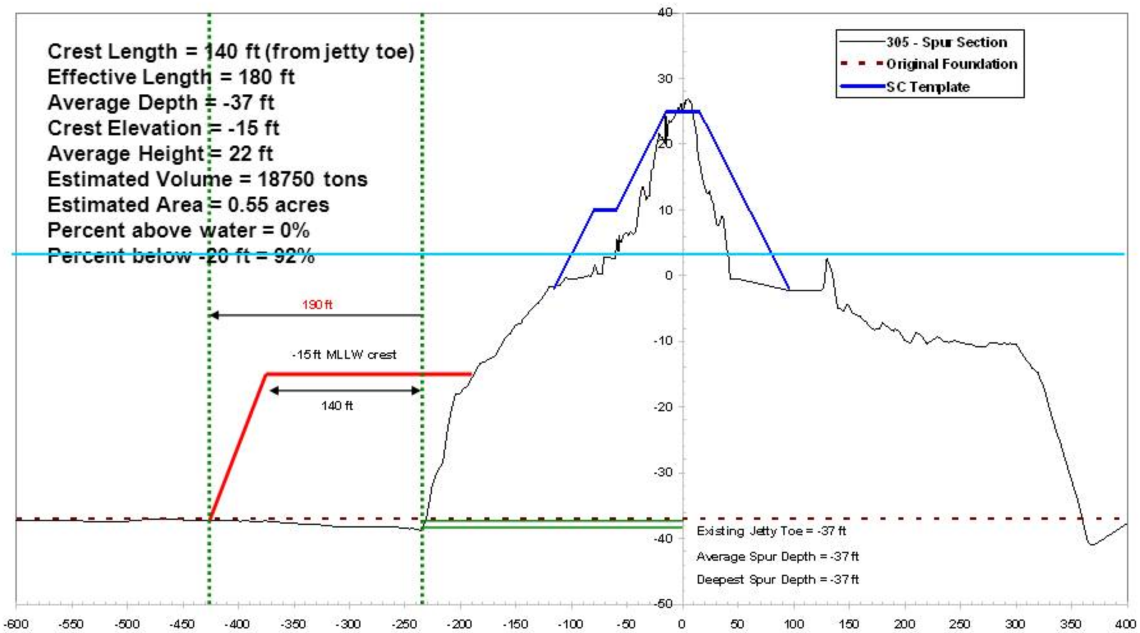


Figure A1- 215. South Jetty Proposed Spur Groing – SJ4C



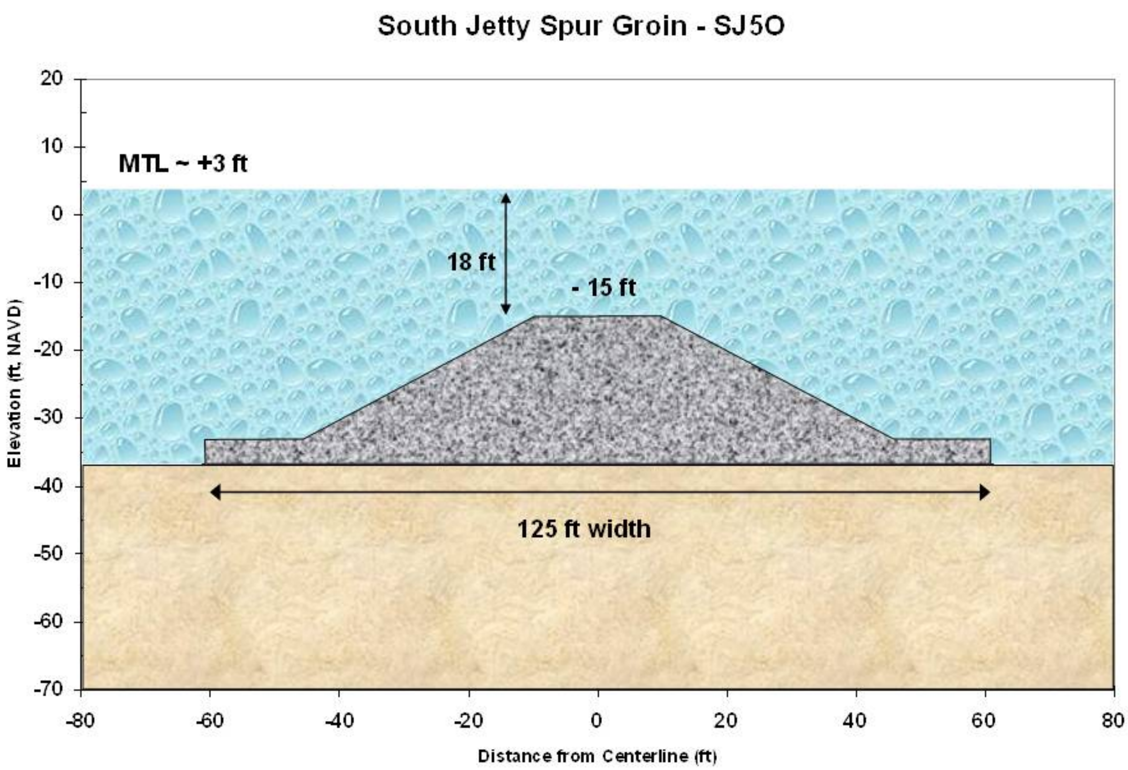


Figure A1- 216. South Jetty Proposed Spur Groing – SJ5O

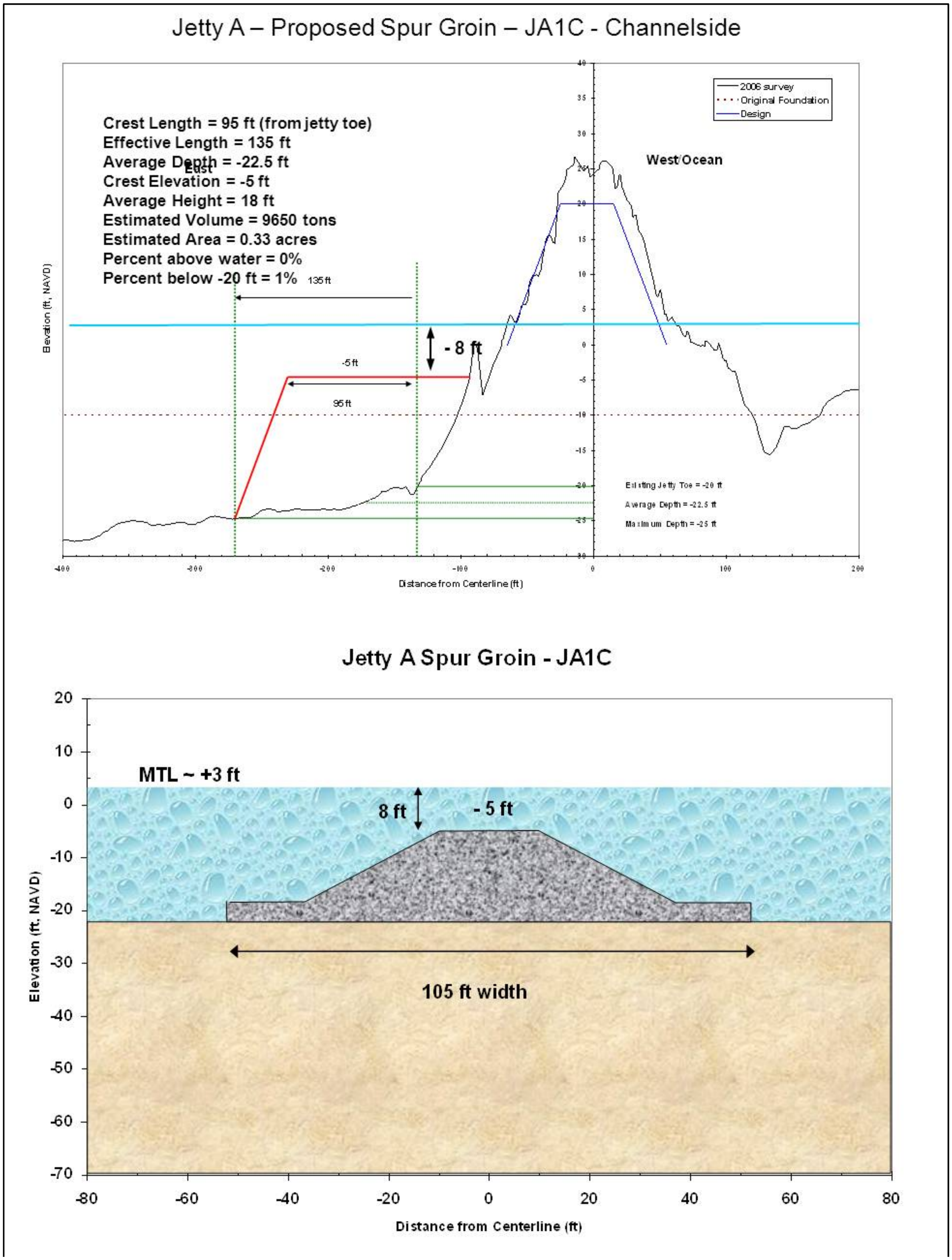


Figure A1- 217. Jetty A Proposed Spur Groin - JA1C

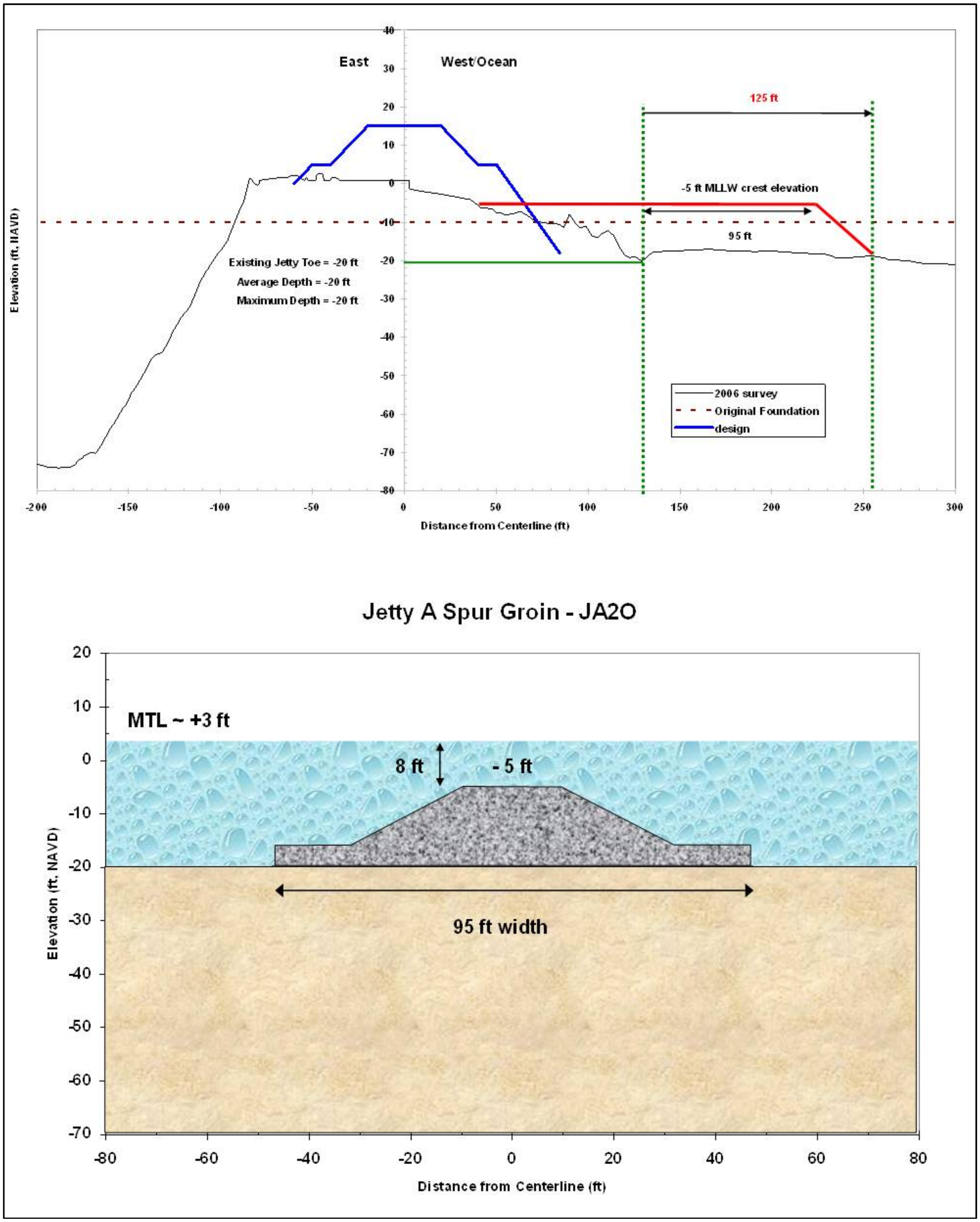


Figure A1- 218. Jetty A Proposed Spur Groin – JA2O

In areas where foundation scour threatens the overall stability of a jetty, spur groins will be constructed perpendicular to the jetty to facilitate stabilization via accumulation of sediment along the jetty foundation. Historical experience and numerical modeling were used to select the type, depth, and length of spur groin necessary to impact the processes causing increased scour at each jetty (e.g., rip currents, eddies). Each spur groin will have a 1V:2H side slope and crest width of approximately 20 feet and will be constructed using a 3- to 5-foot deep bedding layer composed of a mixture of gravel and rock that will then be covered with large stone sized for the location and exposure.

Two potential construction methods could be used for spur groin construction, either land-based or marine-based depending on location. Barges or similar equipment could be used to dump the bedding layer rock into place and a clamshell would be used to place larger stone on top of the bedding rock layer in locations with sufficient water depth. Or material could be placed using land-based equipment from on top of the jetty. Land-based construction might require a wide turnout crane placement with over-excavation down to grade as the crane walks back onto the main jetty axis. In addition, the emergent spur groins may be used as turnouts for construction equipment. The land-based construction method could be used for all but the deepest spur groin construction.

Figure A1- 219 shows percentage of time that the crests of spurs at 0 MLLW, +5 MLLW, and +8 MLLW would be exceeded (i.e. overtopped by water). Both spur groins with elevation +8 MLLW are not relevant to outmigration of fish because they are on the ocean side of the jetties. Spurs SJ2C and SJ3C on the South Jetty at an elevation of +5 MLLW would be above water 60% of the time for August-September and 55% for October-November. Spur SJ4C would be above water 5% of the time. It is expected that at some point on most ebb tides that spurs SJ2C and SJ3C would be above water, and that fish outmigrating within 70 feet of the South Jetty during that part of the ebb tide when the tops of these spur groins are exposed would have to swim around them. As noted earlier, sub-yearling Chinook tend to use nearshore areas, at least by the North Jetty, more than older juvenile salmonids and they typically go out of the MCR area over a period of more than one ebb tide. Table A1-8summarizes proposed spur groin characteristics for each jetty.

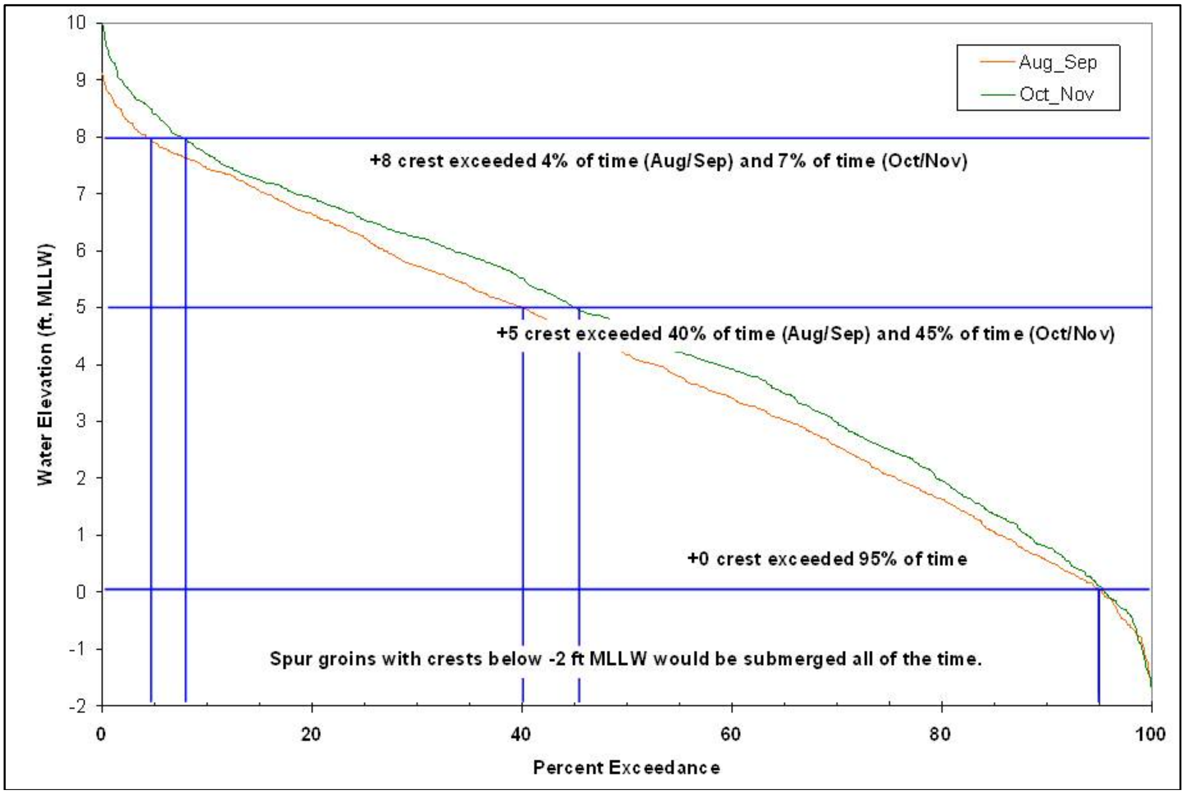


Figure A1- 219. Tidal Elevations at the MCR with Respect to Spur Groins

Table A1- 8. Proposed Spur Groin Characteristics

Spur Groin Feature	North Jetty	Jetty A	South Jetty
Number of spurs on channel side, or downstream for Jetty A.	3	1	3
Number of spurs on ocean side, or upstream for Jetty A.	1	1	2
Total rock volume per spur.	NJ1C: 3,350 tons NJ2C: 11,090 tons NJ3O: 2,010 tons NJ4C: 29,250 tons	JA1C: 9,650 tons JA2O: 7,330 tons	SJ1O: 1,680 tons SJ2C: 2,350 tons SJ3C: 2,350 tons SJ4C: 3,180 tons SJ5O: 18,750 tons
Total rock volume (all spurs)	45,700 tons	16,980 tons	28,310 tons
Area affected by each spur.	NJ1C: 0.18 acres NJ2C: 0.45 acres NJ3O: 0.11 acres NJ4C: 0.80 acres	JA1C: 0.33 acres JA2O: 0.29 acres	SJ1O: 0.11 acres SJ2C: 0.13 acres SJ3C: 0.13 acres SJ4C: 0.19 acres SJ5O: 0.55 acres
Total area affected (all spurs)	1.55 acres	0.61 acres	1.10 acres
Area of spurs above water.	NJ1C: 0% NJ2C: 0% NJ3O: 24% NJ4C: 0%	JA1C: 0% JA2O: 0%	SJ1O: 29% SJ2C: 7% SJ3C: 7% SJ4C: 0% SJ5O: 0%
Area of spurs below -20 MLLW.	NJ1C: 0% NJ2C: 88% NJ3O: 0% NJ4C: 100%	JA1C: 1% JA2O: 0%	SJ1O: 0% SJ2C: 0% SJ3C: 0% SJ4C: 0% SJ5O: 92%
Dimension of spurs: length x width x height (feet).	NJ1C: 100 x 80 x 10 NJ2C: 170 x 115 x 19 NJ3O: 60 x 80 x 10 NJ4C: 250 x 140 x 25	JA1C: 135 x 105x 18 JA2O: 125 x 100x 15	SJ1O: 60 x 80 x 9 SJ2C: 70 x 80 x 10 SJ3C: 70 x 80 x 10 SJ4C: 90 x 90 x 12 SJ5O: 190 x 125 x 22

c. Jetty Length Rebuild and Stabilization

Authorized lengths and original construction for the North, South, and Jetty A were 6200 ft, 2200 ft, and 900 ft longer than the existing 2010 jetty head positions. For most of those receded lengths, submerged relic stone features exist extending approximately up to the lower level of wave impact, approximately -15 ft to 0 ft MLLW. A typical submerged head feature can be seen on Figure A1- 93. Jetty recession history and rates for the three jetties are plotted in Figure A1- 220 through Figure A1- 222. Current recession rates are expected to range around 20 to 40 ft/yr, 5 to 20 ft/yr, and 5 to 20 ft/yr for the North, South, and Jetty A, respectively.

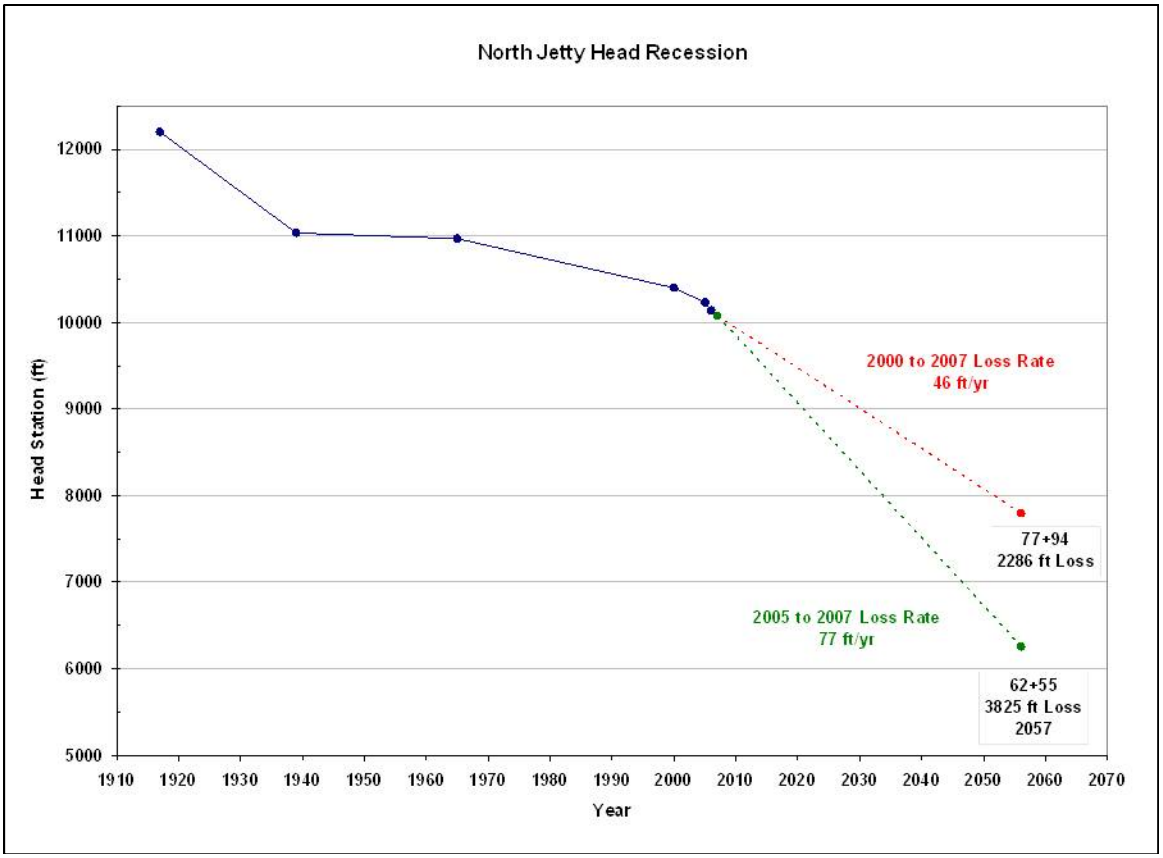


Figure A1- 220. North Jetty Head Recession

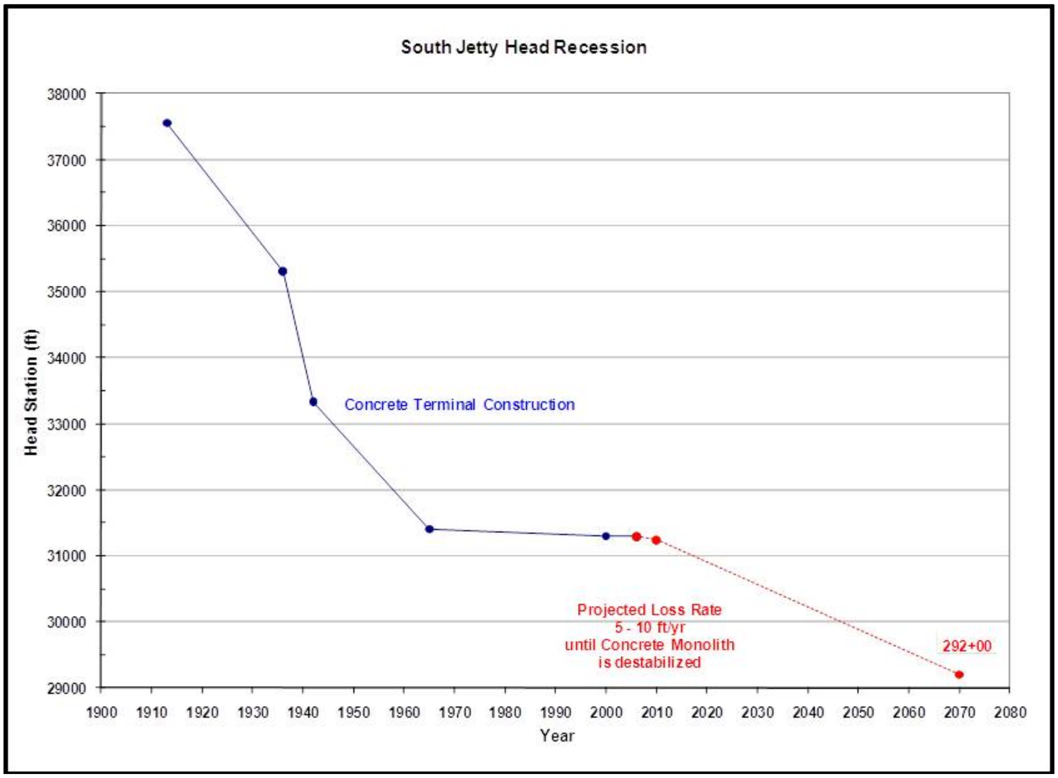


Figure A1- 221. South Jetty Head Recession

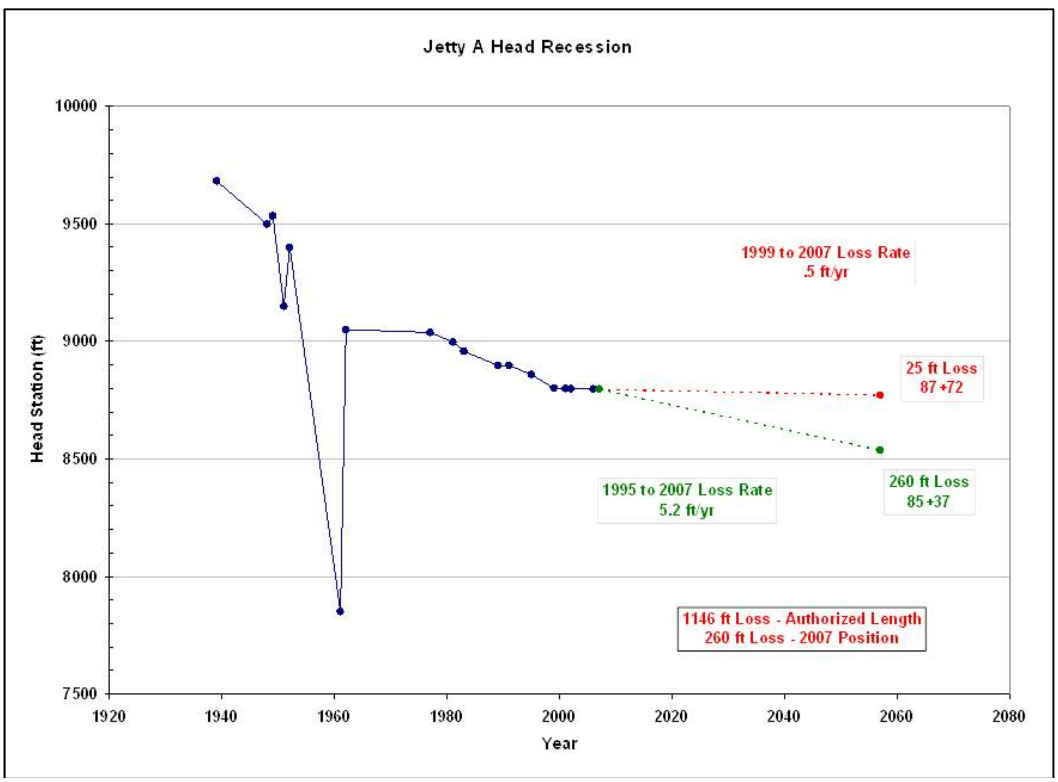


Figure A1- 222. Jetty A Head Recession

As stated earlier, jetty length recession has various consequences to the stability of the structures and the project including:

- Exposure of the weaker trunk of the jetty to wave action.
- Increased erosion of the ebb tidal and adjacent underwater shoals.
- Increased erosion of the adjacent shorelines.
- Increased depths along both sides of the jetties due to more effective wave penetration.
- Exposure of jetty foundation to greater forces.
- Greater sediment infill around the ends of the jetties into the navigation channel.

The circulation and stability of the present MCR inlet is tied to the condition of the inlet's morphology. This has been the case since jetty construction. In other words, the inlet's morphology is a function of the MCR jetties now in place. If the jetties change significantly over time (recession of jetty head or breach within jetty trunk), the inlet's morphology will respond accordingly. For example, if the head of the North Jetty recedes landward by 100 ft, the morphology adjacent to the North Jetty will adjust accordingly, with much of the mobilized sediment entering the MCR navigation channel. The offshore extent of the North Jetty acts to retain Peacock Spit and prevent its southward re-entry into the MCR inlet. The North Jetty acts to constrain current flow through the entrance to maintain a stable inlet.

The offshore extent of the South Jetty protects the MCR inlet from severe wave action and constrains destabilizing currents. The present condition of the South Jetty also acts to stabilize Clatsop Spit, and the shoreland south of the South Jetty. The South Jetty, in addition, serves to anchor the outer extent of portions of the ebb tidal shoal.

The offshore extent of Jetty A helps to reduce severe ebb tide circulation affecting the North Jetty, thereby protecting the North Jetty. Jetty A also protects Sand Island and Ilwaco channel from severe flood tide currents and storm wave action entering the inlet from the ocean. By effectively constraining currents within the inlet, Jetty A also reduces the likelihood of Clatsop Spit migrating northward into the inlet which would have a secondary effect of deepening channelside depths along the North Jetty. Continued head recession of any of the three jetties would increase the dredging requirement for the MCR channel.

Investigations examining the reconstruction of jetty length focused primarily on maintaining the underwater and adjacent shoals which have proven to be so critical to controlling the impinging wave climate and maintaining the current length to provide effective control of sediment movement into the navigation channel. Increased lengths were investigated to determine if those might provide a more sustainable project over the long term. South Jetty length rebuild was investigated out to Station 353+00, 4,000 ft seaward of the present location. North Jetty length rebuild was investigated out to Station 115+00, 1500 ft seaward of present location. Jetty A length rebuild was investigated out to Station 97+00, 900 ft seaward of the present location and equivalent to the original constructed length. Those lengths were still 2,200 ft and 700 ft short of the authorized lengths for the South Jetty and North Jetty, respectively, and are shown in Figure A1- 223 through Figure A1- 225.

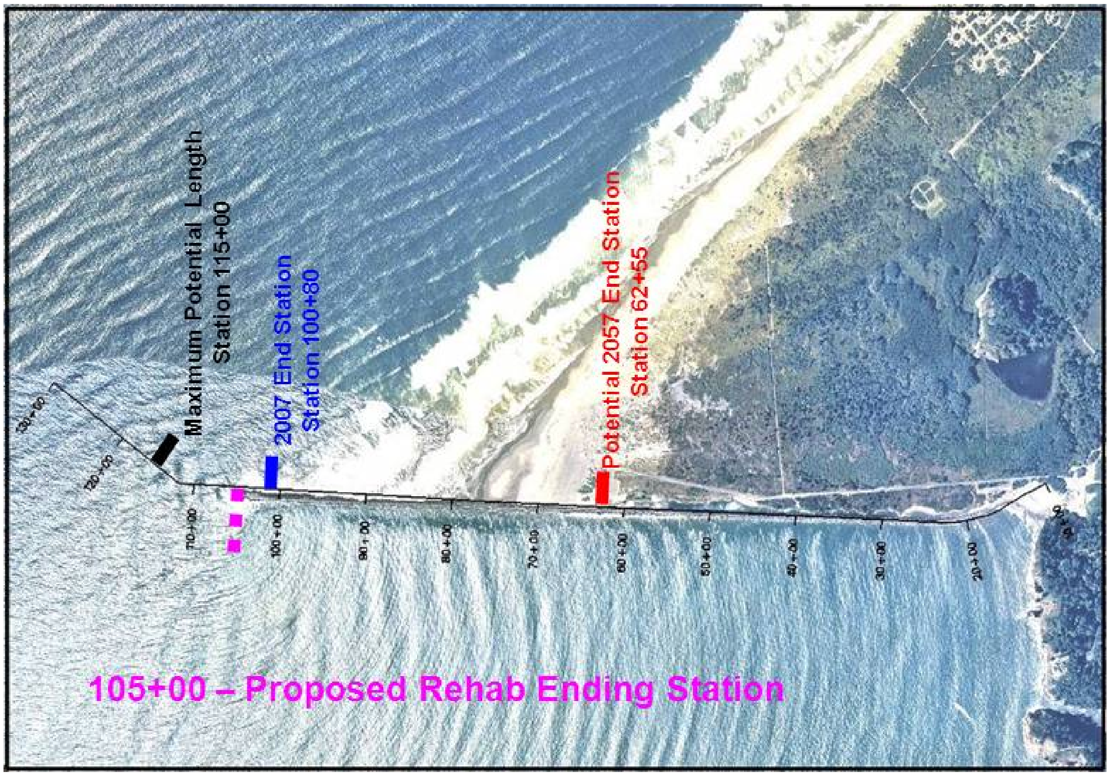


Figure A1- 223. ***North Jetty Proposed Rehab Ending Station***

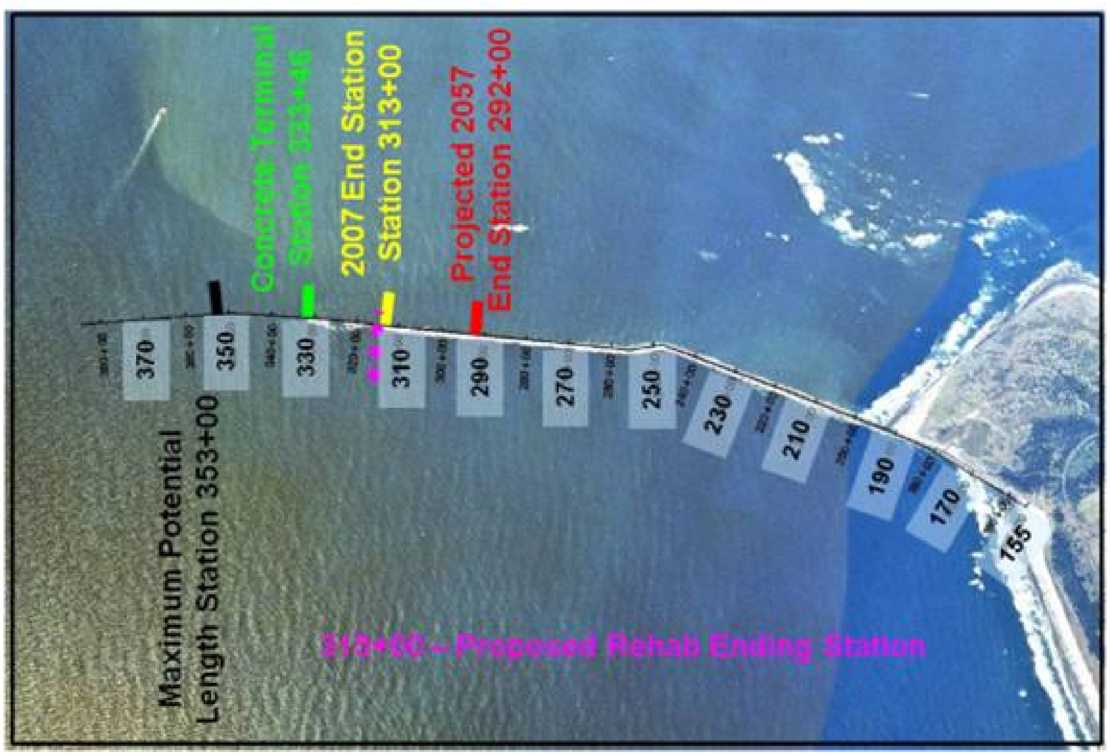


Figure A1- 224. ***South Jetty Proposed Rehab Ending Station***

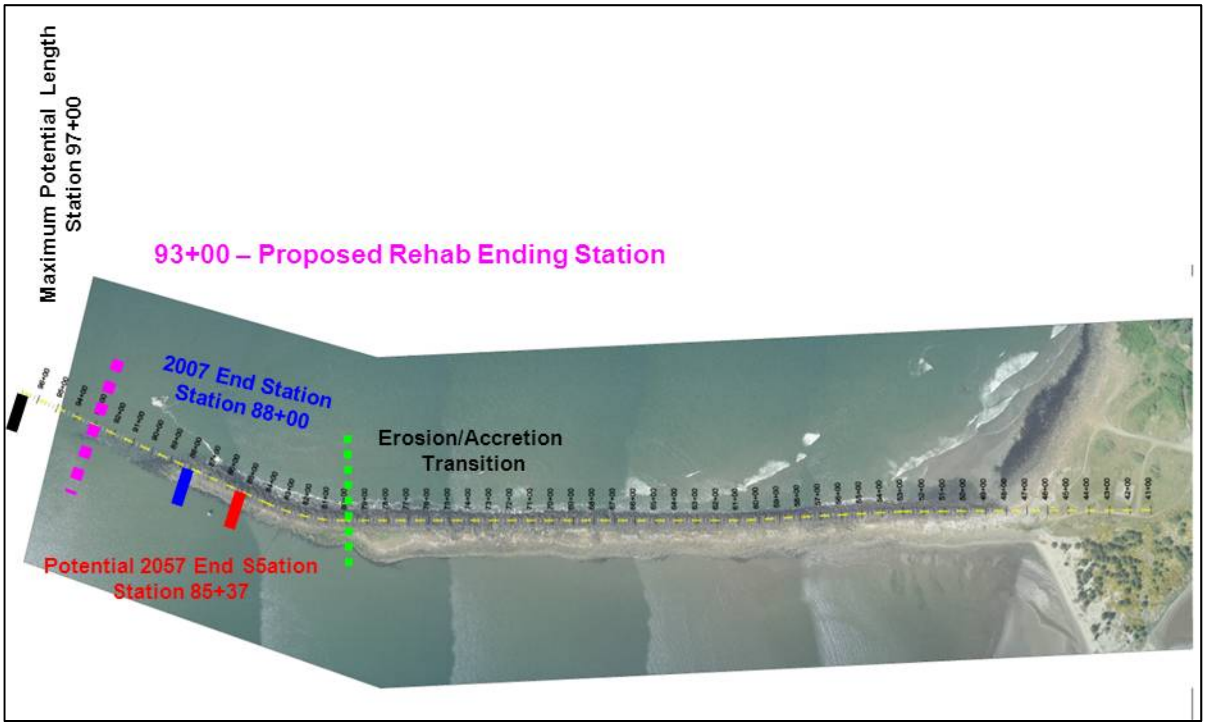


Figure A1- 225. Jetty A Proposed Rehab Ending Station

The USGS-Menlo Park assisted USACE with evaluating potential improvements and impacts of proposed jetty head rebuild for MCR. The USGS efforts focused on using the Delft-3D model to identify potential changes in circulation, salinity and sediment transport that could result from the offshore re-build of the three jetties. The Delft 3D model for MCR is the result of continual development supported through several regional initiatives, as sponsored by federal and state agencies. The model fully accounts for added circulation effects induced by waves and the baroclinic effect of the estuary (saltwater intrusion and related density driven circulation) and has been calibrated using the Mega-transect and CORIE data sets. The "baseline" model condition (no jetty re-extension) was based on 2006 bathymetry and attendant jetty configuration. The Delft 3D model was used to simulate the continuous circulation at the MCR during Aug-Sep 2005 and Oct-Dec 2001, for both the baseline condition and the condition featuring proposed re-extension of the jetties.

The October-November run was established for engineering purposes as this time period represents extreme conditions at the MCR. The model results (including all three jetty head rebuilds summarized above) show a limited response on the overall patterns of salinity flow, waves, and sediment transport on the MCR scale. For all jetty rehabilitation cases changes in residual salinity, velocity or sediment transport are small and mostly local at the rebuild location. Instantaneous velocities and salinities in the MCR show variations mainly due to small temporal shifts or spatial shifts rather than changes in e.g. maximum and minimum velocities or salinities. Outside the MCR, differences, small variations and fluctuations in position of the plume are observed. Most of these changes are generated at the jetty heads and advected seaward by the plume. Only the combined impact of rebuilding all the jetties shows a clear impact on sediment transport rates and morphology inside the entire MCR, with seaward transport and northward bypassing being enhanced (this plan was not carried forward).

In cases where the jetties have receded landward from their fully authorized offshore extent, evaluating the merits of jetty head rebuild is an important consideration for jetty rehabilitation. Due to the severe forcing environment of MCR, tremendous costs may be required to rebuild the jetties and re-establish a resilient jetty head section. An initial assessment of options for jetty rebuild, limited the considerations to partial jetty rebuild rather than considering rebuild to full authorized length. Added critical review determined that proposed options for rebuild of the head of a given jetty should be limited to conditions where the rebuilt jetty head could be placed within the relic stone footprint. These constraints were based on the need to balance the purpose of jetty rehabilitation with implementation cost.

Based on the above constraints, the rebuild of the South Jetty head (presently located 1,500 ft inshore of the concrete monolith) was not considered a viable rehab option. The head of the South Jetty was proposed to be stabilized at approximately its current location, Station 313 to 315. Maximum viable rebuild of the North Jetty head was determined to be Station 105, which would result in a re-established head position 1,700 ft inshore of the fully authorized length. Maximum viable re-extension of the head for Jetty A was determined to be Station 93, which is 500 ft seaward of its current position and 400 ft landward of its full authorized length. Jetty A length is important to controlling erosion along the North Jetty foundation; however, the substantial scour hole south of the Jetty A head limits a cost-effective head rebuild.

Figure A1- 223 through Figure A1- 225 illustrate the original length modeled as well as lengths and head positions of the proposed plan. Stabilizing the jetty heads can stop the loss of littoral sediment. Because the recommended project jetty lengths are approximately the same as existing jetty head locations (and significantly shorter than those modeled), it is not expected that the proposed project will have negative impacts on the hydrodynamics or sedimentation processes of the MCR inlet. It should be noted that a project plan which does not stabilize the jetty heads will more than likely have a significant negative impact on Clatsop and Peacock spits as well as the shoreline areas adjacent to both the North and South jetties.

d. Root Erosion Area Stabilization

There are two categories of erosion at the North and South Jetty roots. The erosion that is occurring on the adjacent shoreline on the oceanside is wave-driven and to some extent connected to the recession of the jetty head positions. Those erosion areas are being addressed through the jetty head stabilization as well as the spur groins proposed for those locations on the landward oceanside of both the North and South jetties. The second category of jetty root erosion occurs along approximately 50% of the North Jetty length. A depressed area behind the jetty root has been created over time due to a combination of factors including overland flow channeled toward the jetty root, erosion on the channelside of the North Jetty root, and tidal flow combined with wave transmission and overtopping into the lagoon area.

The continual hydraulic flow through the jetty root/trunk cross section undermines the foundation of the structure. An added concern is the shoreward retreat of Benson Beach toward the lagoon area generating the possibility that an ocean/lagoon connection may be eventually created, increasing exposure of the North Jetty and decreasing its long-term stability. The engineering feature which is proposed to stabilize the North Jetty root is a combination of re-directing the overland flow away from the lagoon area and placement of gravel and sand on the landward side of the jetty in order to eliminate the tidal flow through the jetty which is destabilizing the foundation. Table A1- 9 provides summary information on the proposed lagoon fill characteristics.

Table A1- 9. Lagoon Fill Characteristics

Lagoon Fill Features	North Jetty
Timing of construction	2012
Material used for fill	Sand, gravel, quarry stone
Short-term and long-term use	Stockpile area, long-term stabilization of root
De-watering	Culvert feeding into area will be re-directed
Impact on wetlands	1.78 acres
Impact on Section 404 waters	4.71 acres

12. Hydrodynamic Modeling of MCR Entrance

The USGS was contracted to apply the existing Delft3D model of the Columbia River estuary and adjacent coast to examine the effects of rebuilding the MCR jetties length on the circulation, sediment transport, and salinity field near the entrance. The modeling objective was to evaluate the functional performance of the proposed jetty rebuild extensions and potential effects which could impact out-migrating juvenile Salmon. To achieve this objective, the following questions were addressed:

1. What is the normal variation of circulation at MCR (without jetty modification) for each model time period?
2. How do the proposed jetty modifications affect the variation of circulation at MCR?
3. How far do changes in the above parameters extend away from the reconstructed jetty alternatives (i.e., will salinity or sedimentation be affected nearby the jetties, within the MCR, or within the estuary)?

The results of the jetty rehabilitation runs are based on model simulations using the refined model described in this section. Simulations have been made for both the summer (Base Case and Case E, all jetties rebuild), and winter conditions (Base Case and all jetty cases, A to F). Separate analyses for the effects of filling in the South Jetty low-crested section and rebuilding the jetty lengths were presented. For waves, salinity, flow, sediment transport and morphology overview maps are presented showing the reference simulation and the difference between the various alternatives compared to the reference simulation. In this section Case B, low-crested section rebuild but with existing jetty lengths, is used as a reference to minimize the change of instabilities during the model simulations. Figure A1- 226 shows the model bathymetry used for the modeling. Figure A1- 227 shows the model schematizations for the South, North, and Jetty A modeling. Various results from the model are illustrated in Figure A1- 228 through Figure A1- 248.

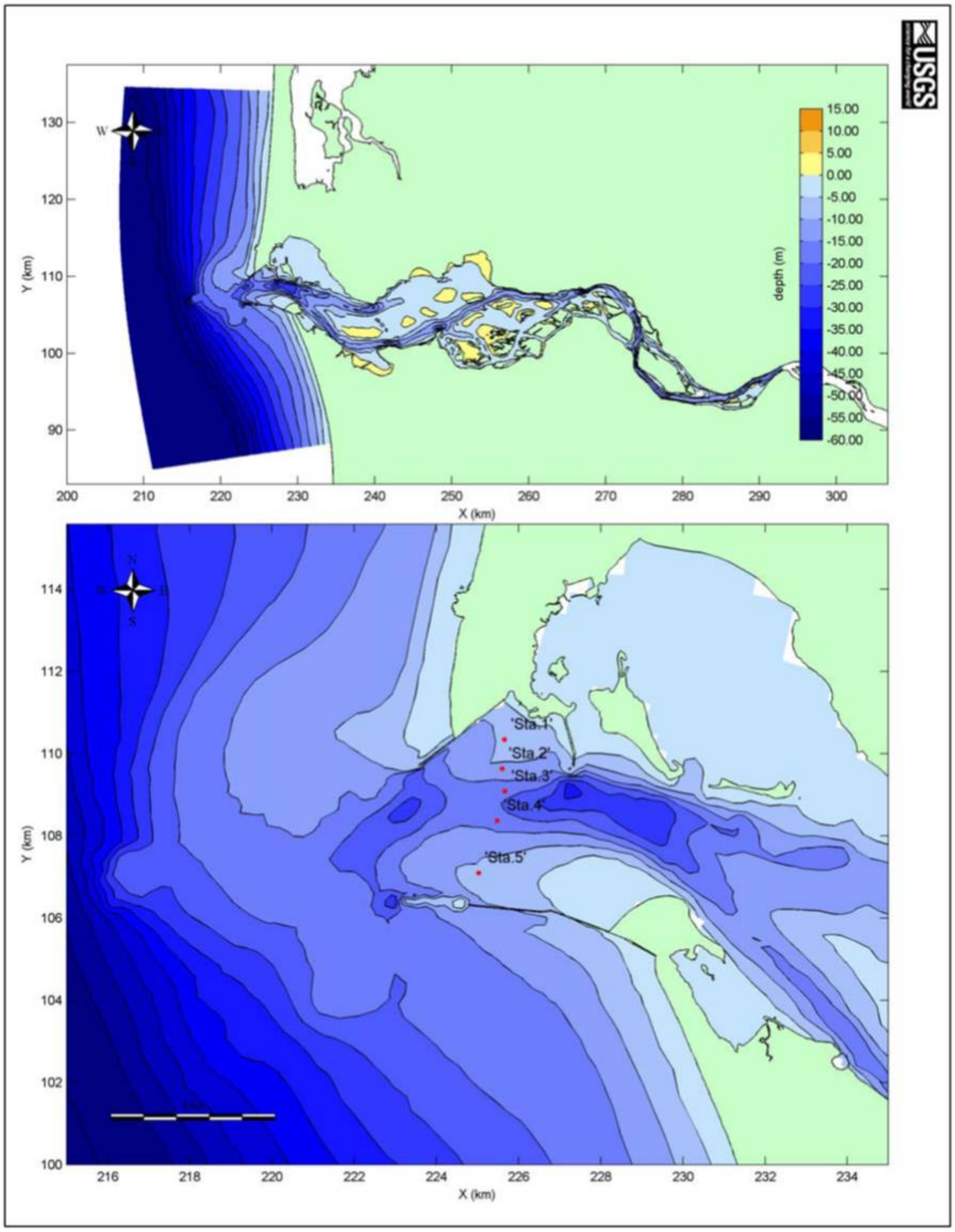


Figure A1- 226. Overview of the MCR model bathymetry for the complete domain (top) and the MCR in detail (bottom panel).

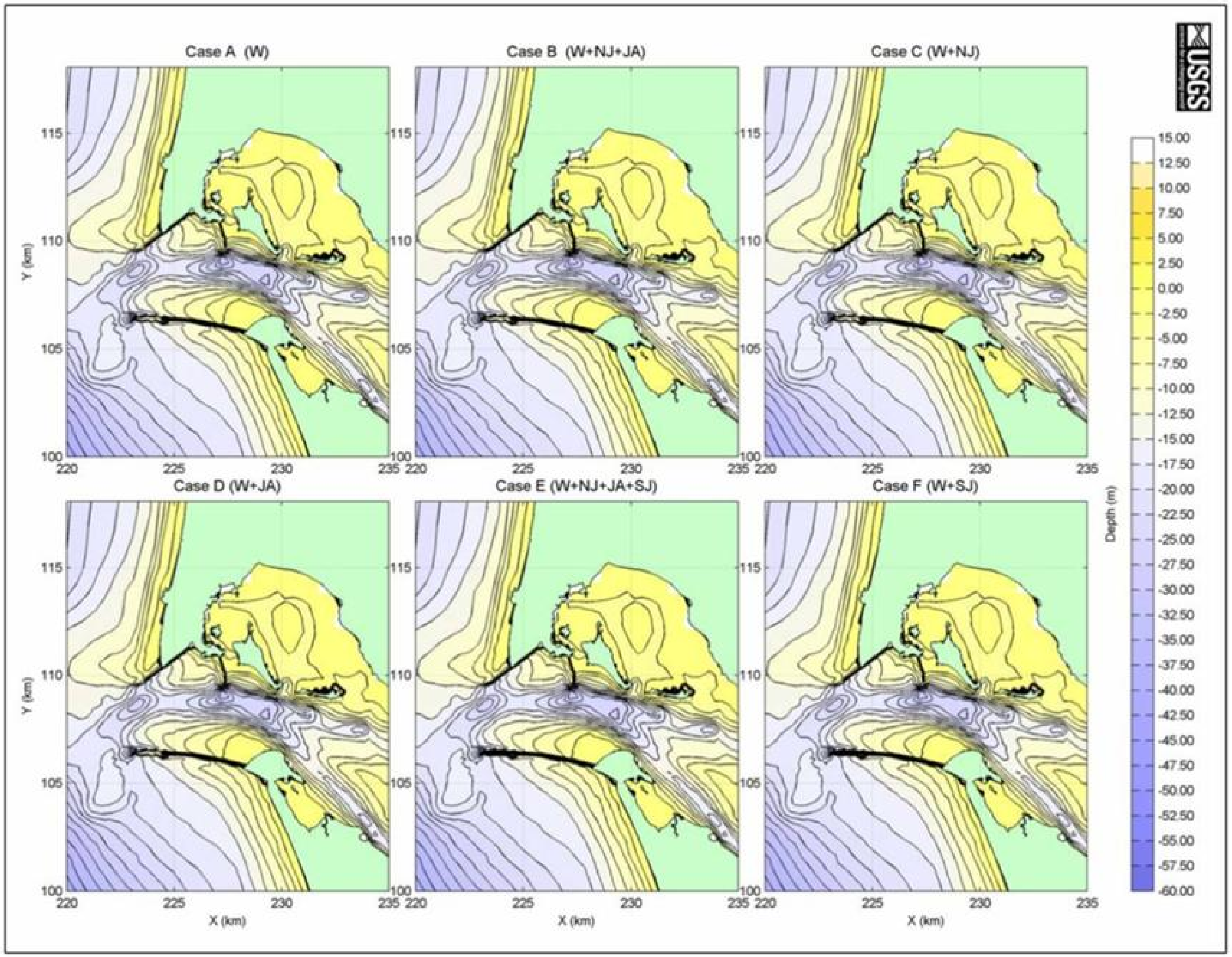


Figure A1- 227. Model schematizations for Low-Crested Section (W), North Jetty (NJ), South Jetty (SJ) and Jetty A (JA) as used in the MCR jetty rehabilitation cases A to F.

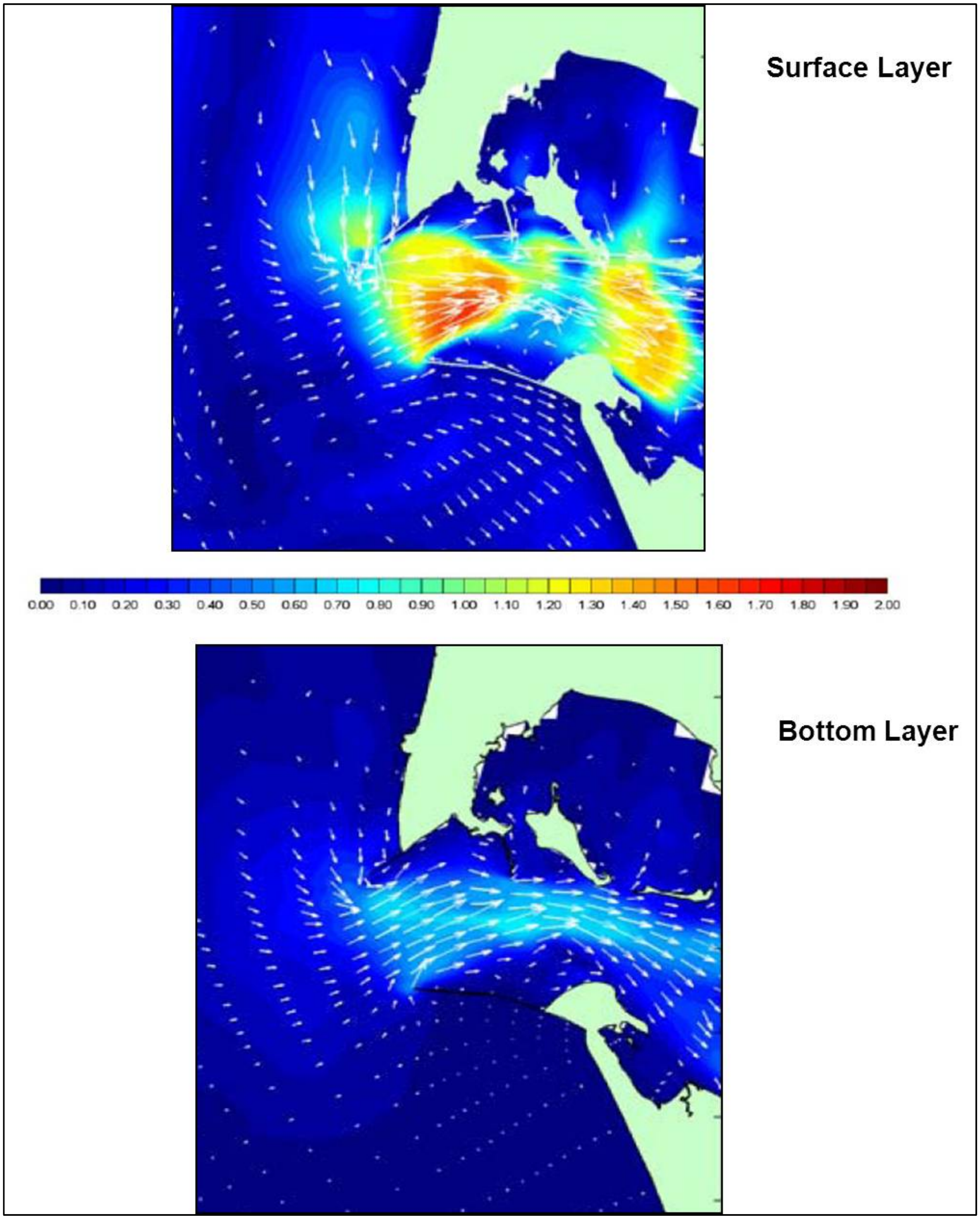


Figure A1- 228. Snapshots of the velocity field during a single tide cycle – Maximum Flood

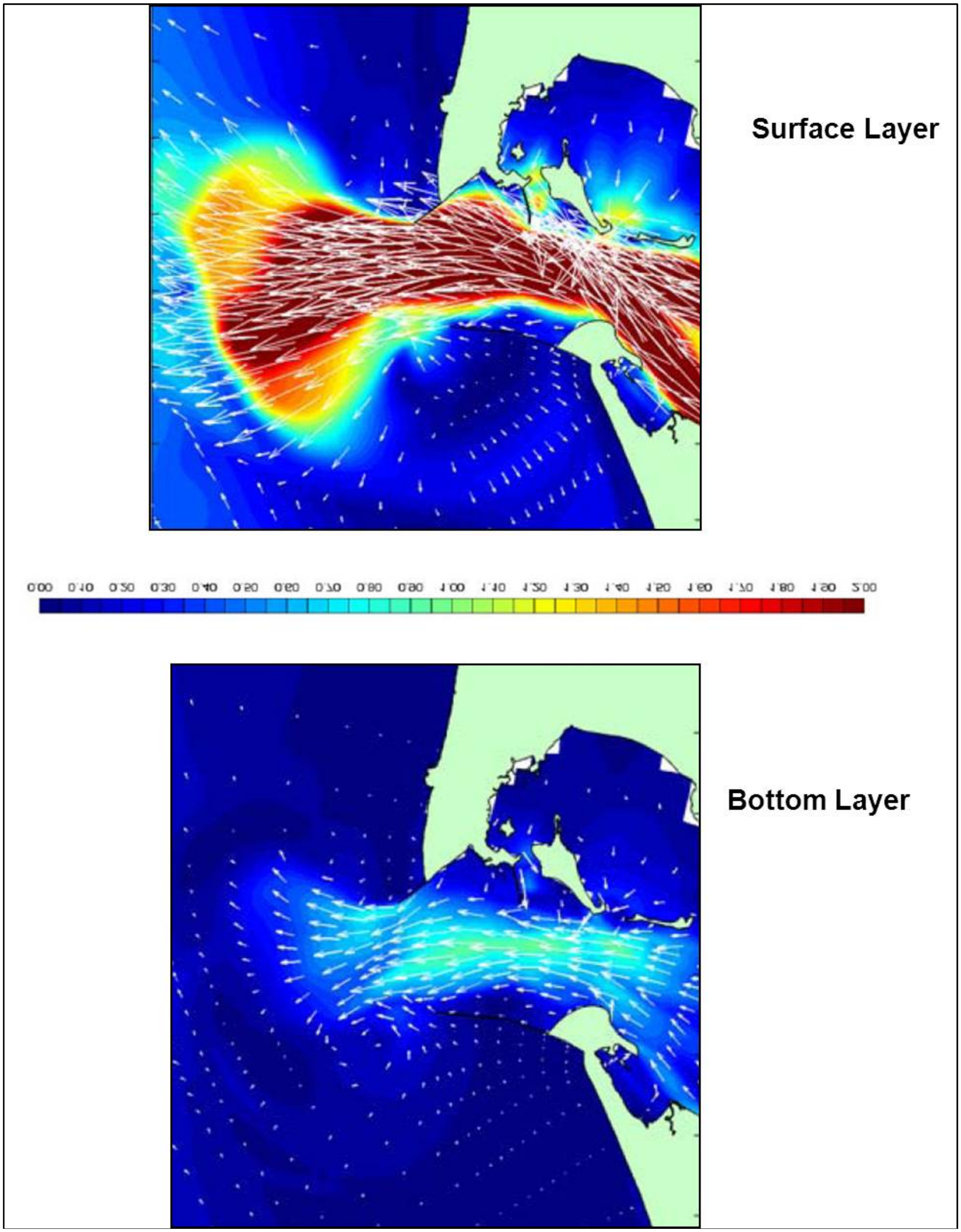


Figure A1- 229. Snapshots of the velocity field during a single tide cycle – Maximum Ebb

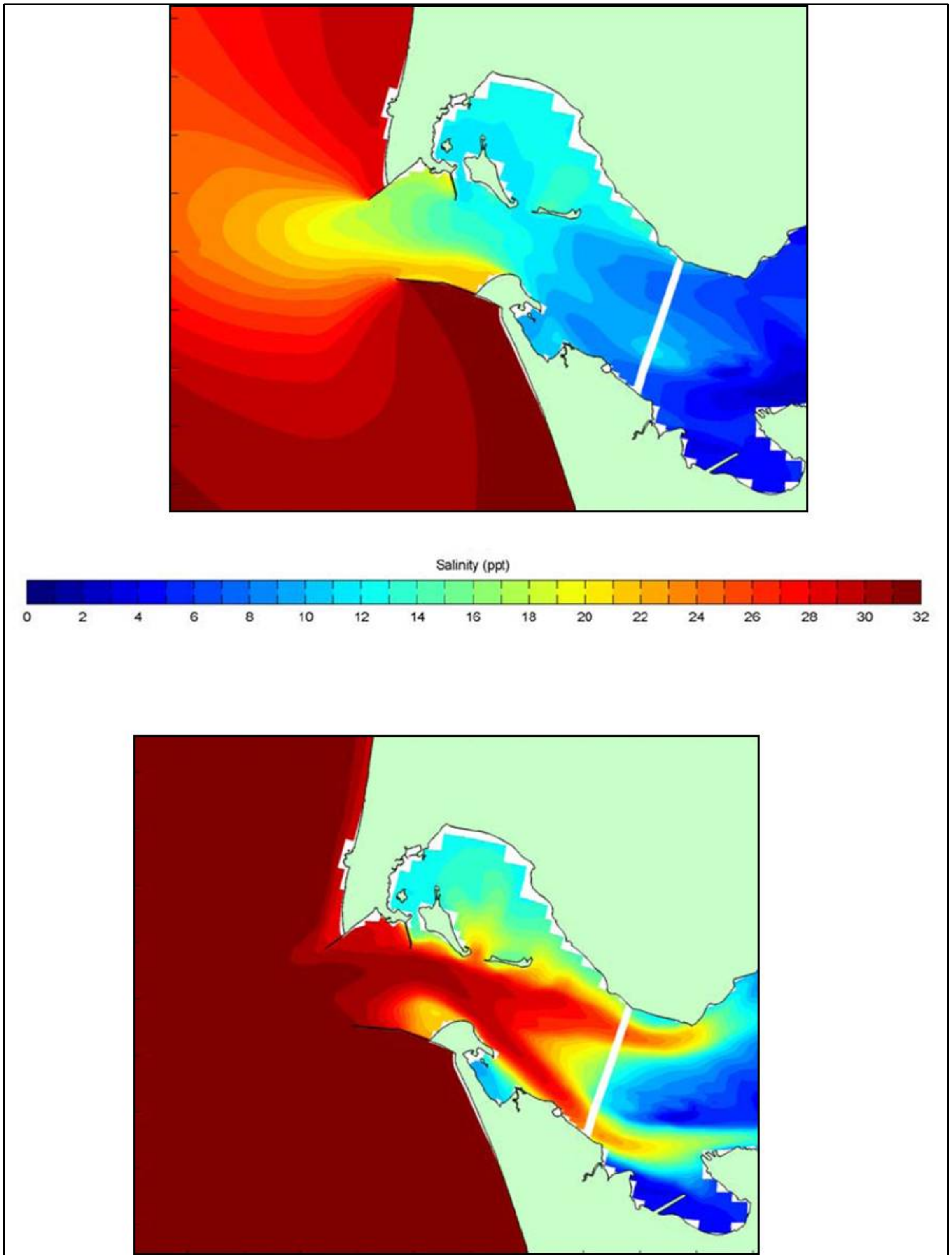


Figure A1- 230. Mean Salinity for Surface and Bed Layers

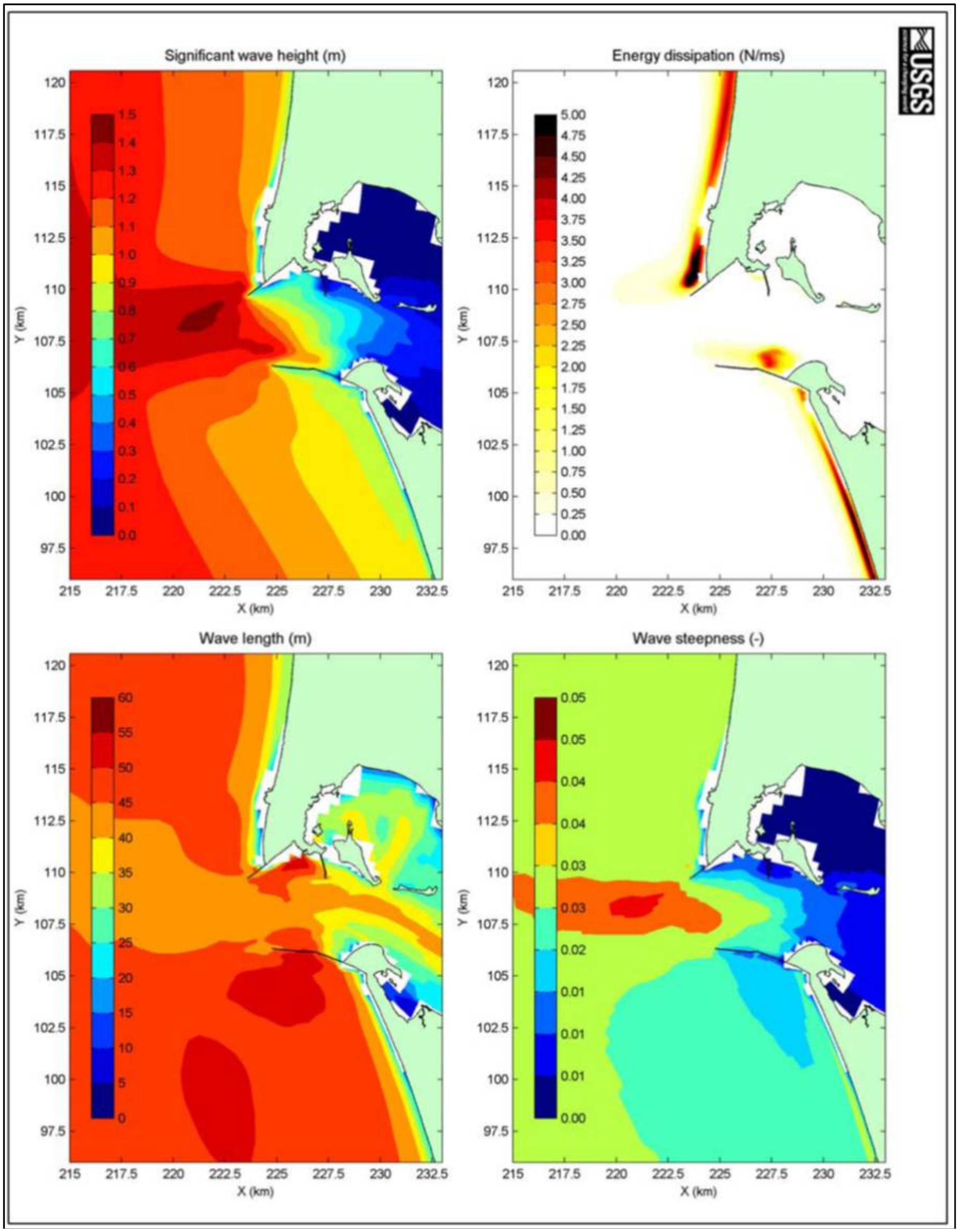


Figure A1- 231. Significant wave height, energy dissipation, wave length and wave steepness averaged over the summer campaign (August-September 2005).

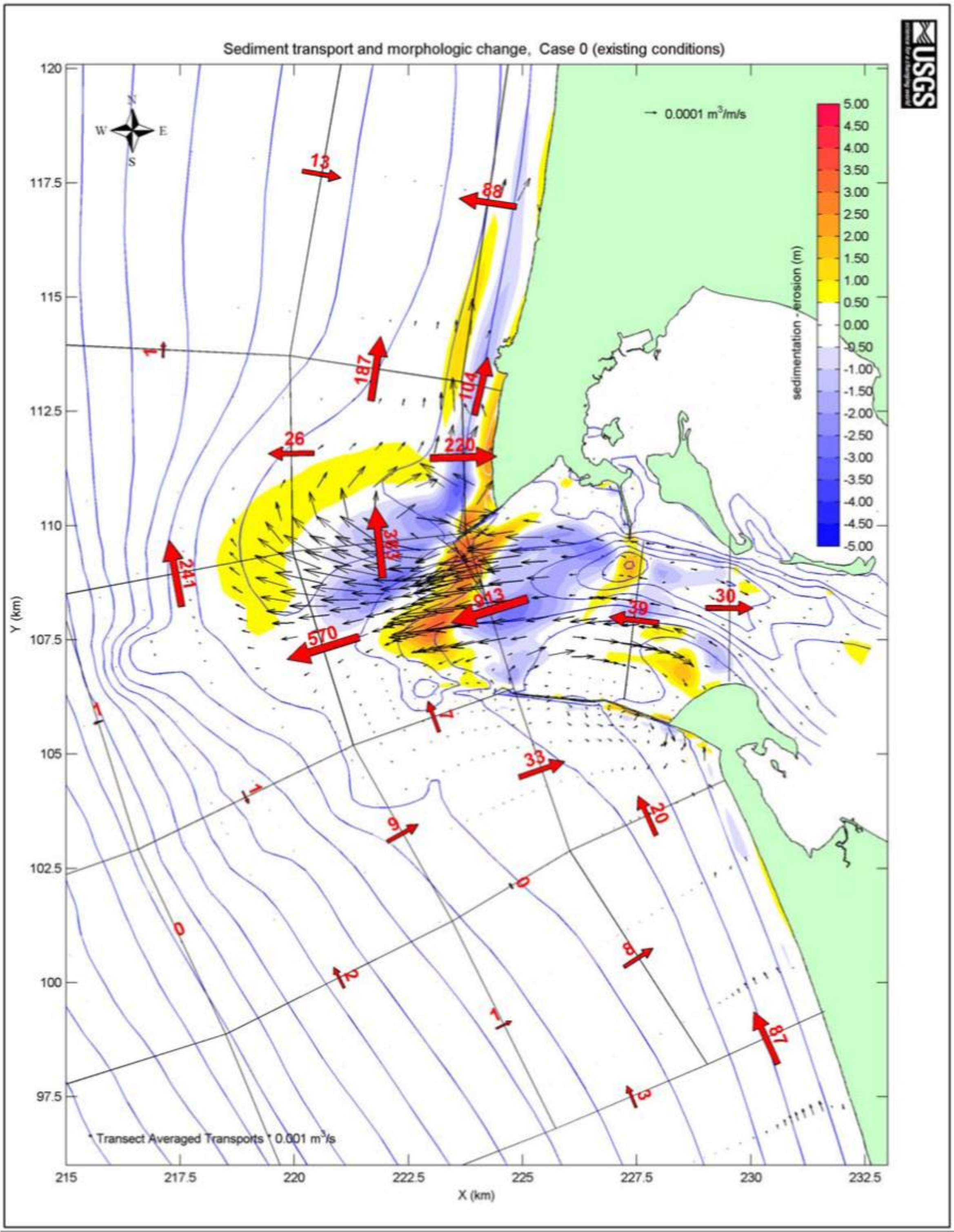


Figure A1- 232. Sedimentation – Erosion Patterns (m), Mean Total Transport (m3/m/s) and Transect-Averaged Sediment Transport (0.001 m3/s)

October - December 2001 quasi-real time simulation (includes tides, fresh-water discharge, wind and waves)

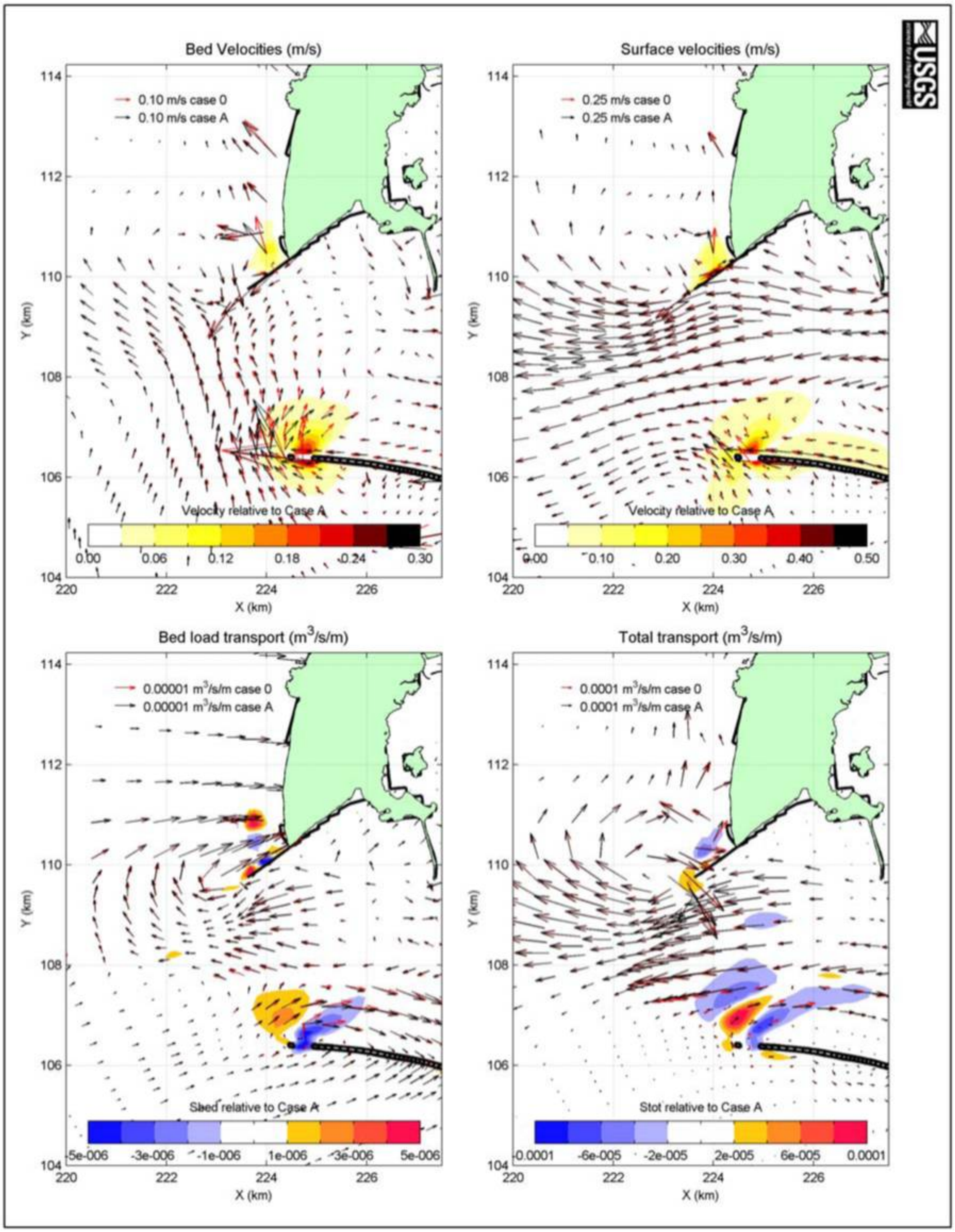


Figure A1- 233. Modeled Residual Velocities (top) and Residual Transports (Bottom)

Overview modeled residual velocities (top) and residual transports (bottom) for Case 0 (existing conditions including low-crested section) and Case A (low-crested section filled). In the top panels colors represent the magnitude of the residual vector, in the bottom panels colors represent difference between the transport magnitudes.

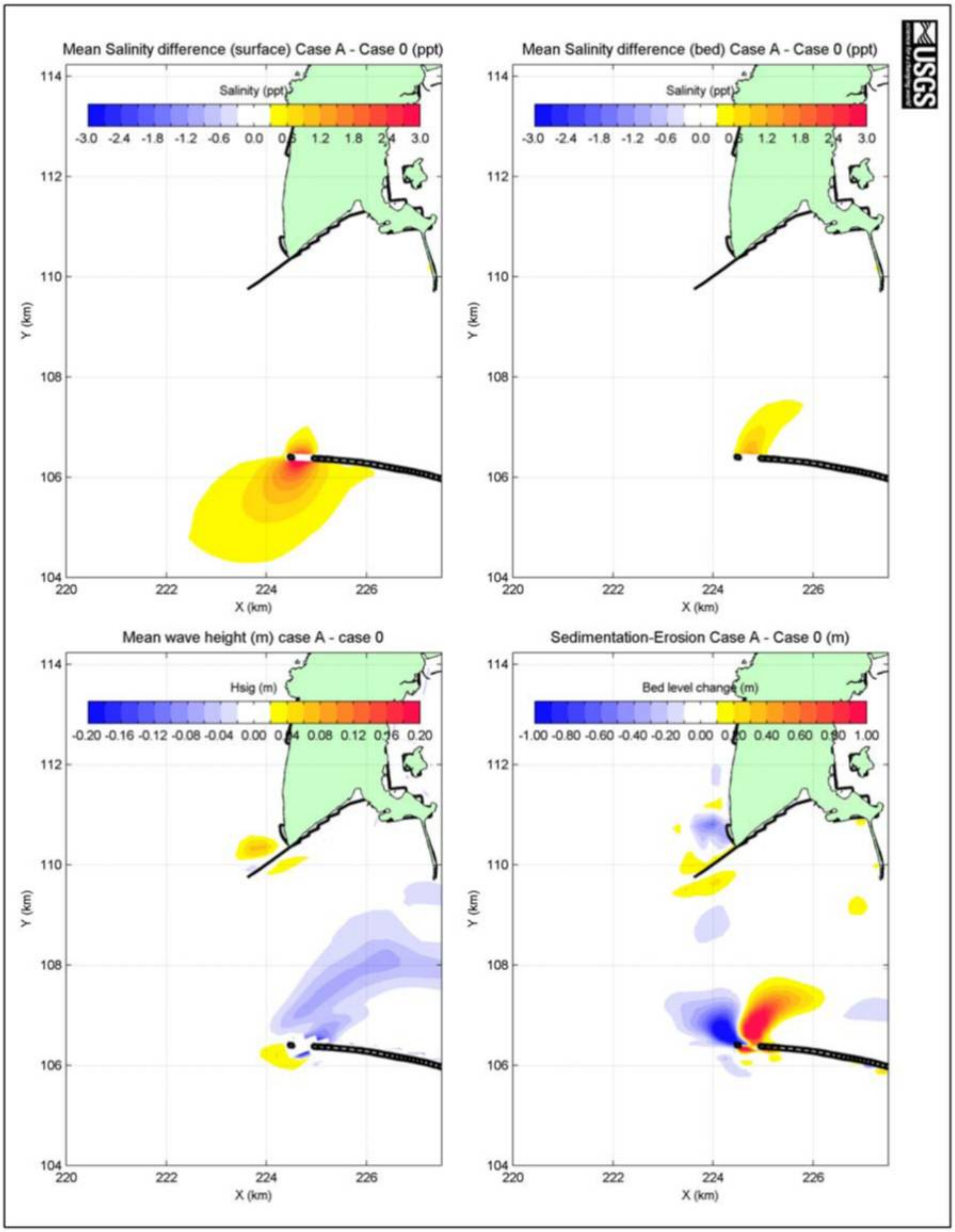


Figure A1- 234. Modeled Differences in Mean Salinity, Magnitude of Surface and Bed Layer, and Difference in Magnitude of Mean Wave Height and Sedimentation/Erosion

Overview modeled differences in mean salinity magnitude of surface and bed layer (upper left and right), and difference in magnitudes of the mean wave height and sedimentation/erosion (lower left and right) for Case 0 (existing conditions including low-crested section) and Case A (weir filled).

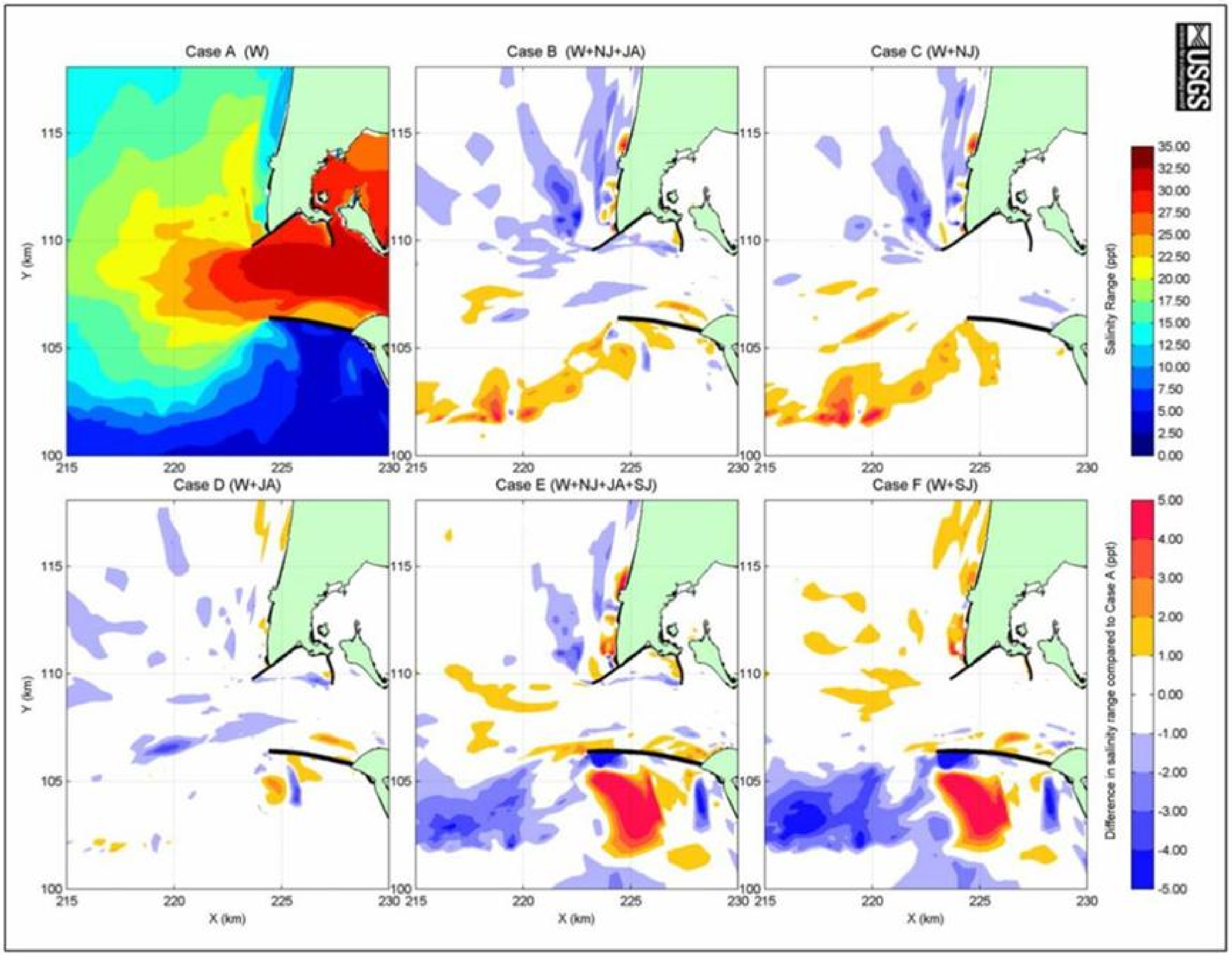


Figure A1- 235. Modeled Salinity Range (max – min salinity) in the Surface Layer for Case A (bottom left) and the Differences in Salinity Range due to Jetty Rehabilitation Cases B to F Relative to case A

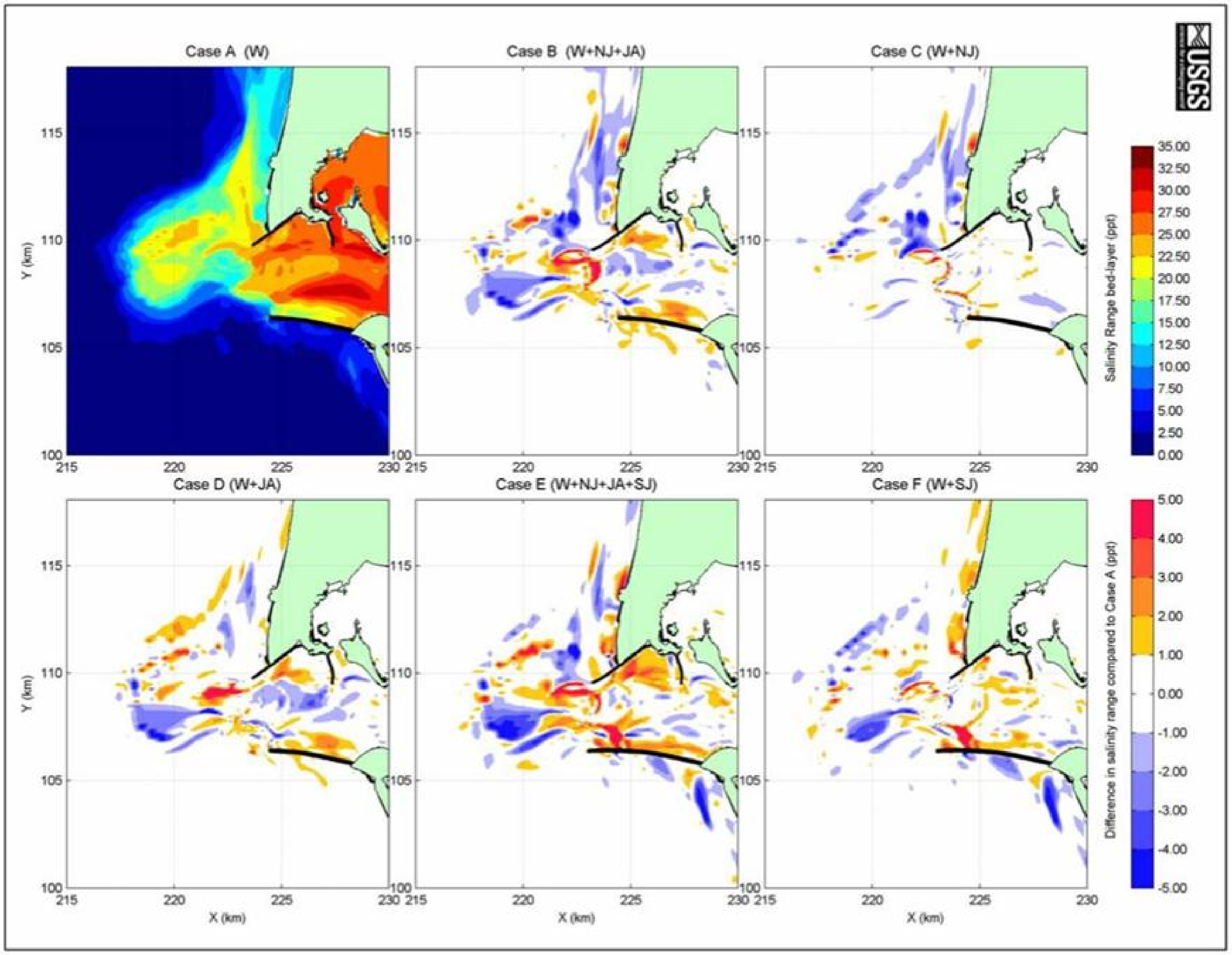


Figure A1- 236. Modeled salinity range (max – min salinity) in the bed layer for Case A (bottom left) and the differences in salinity range due to Jetty Rehabilitation of cases B to F relative to case

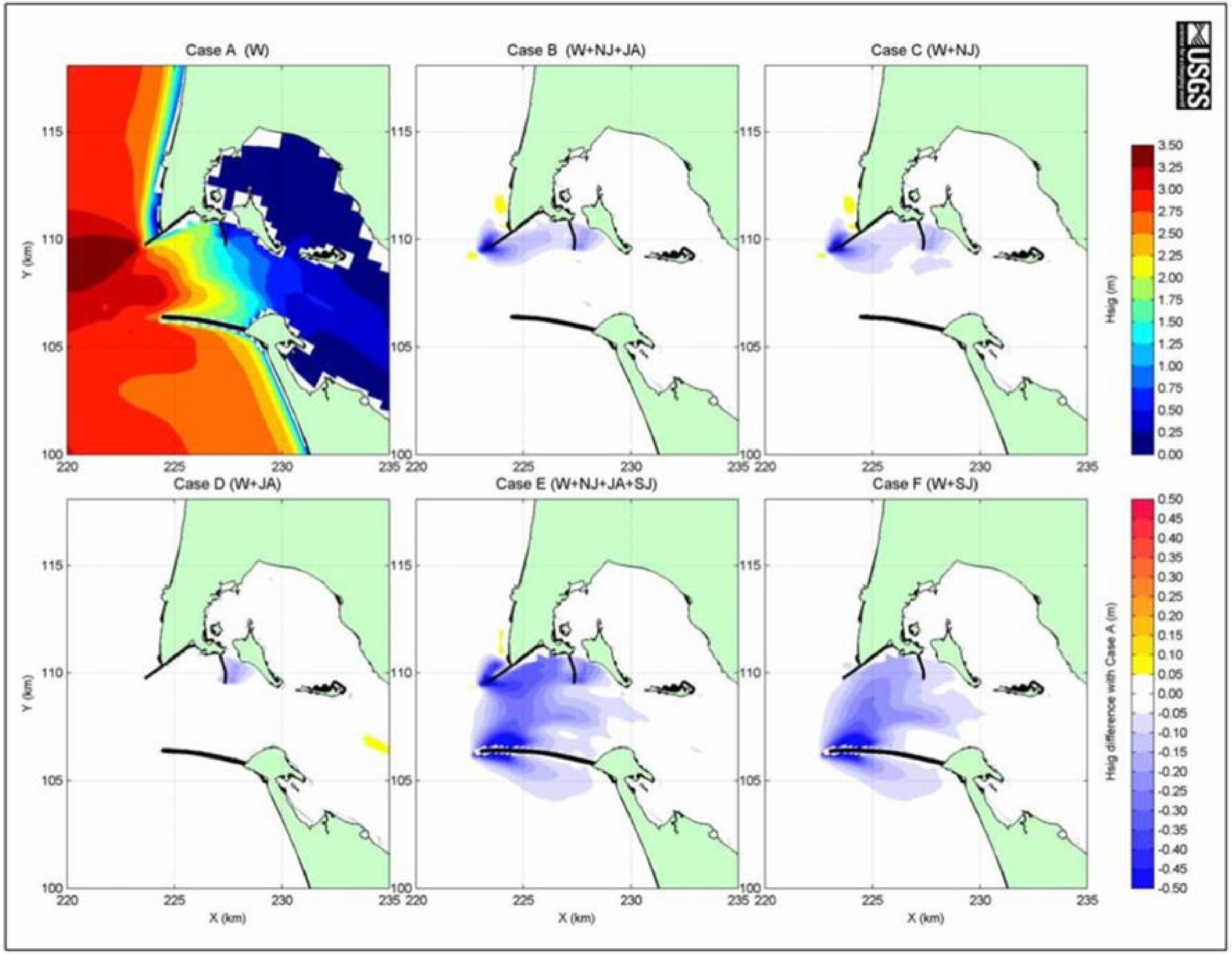


Figure A1- 237. Modeled mean wave height for Case A (bottom left) and the differences in mean wave height due to Jetty Rehabilitation of cases B to F relative to case A.

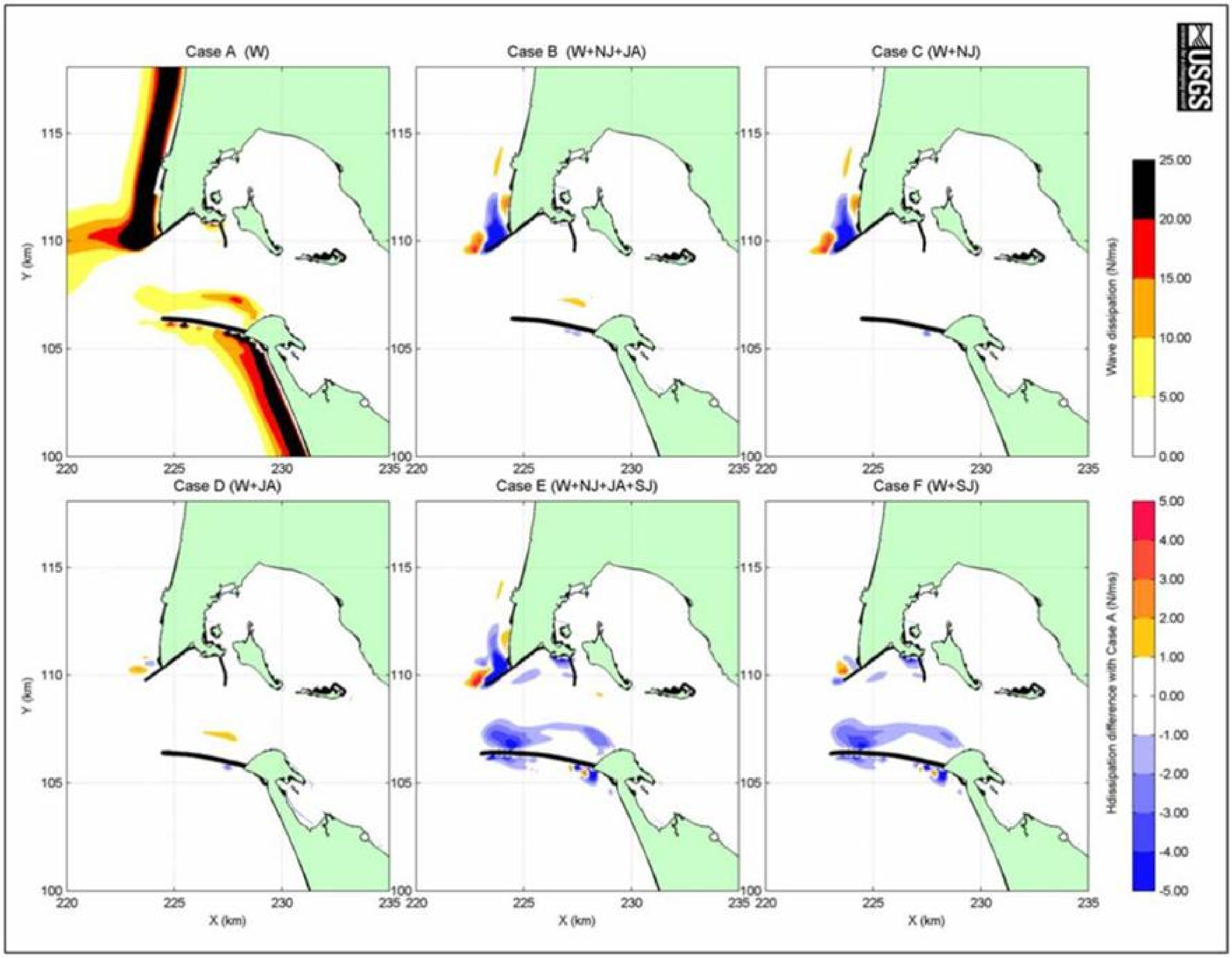


Figure A1- 238. Modeled mean wave dissipation for Case A (bottom left) and the differences in mean wave dissipation due to Jetty Rehabilitation of cases B to F relative to case A.

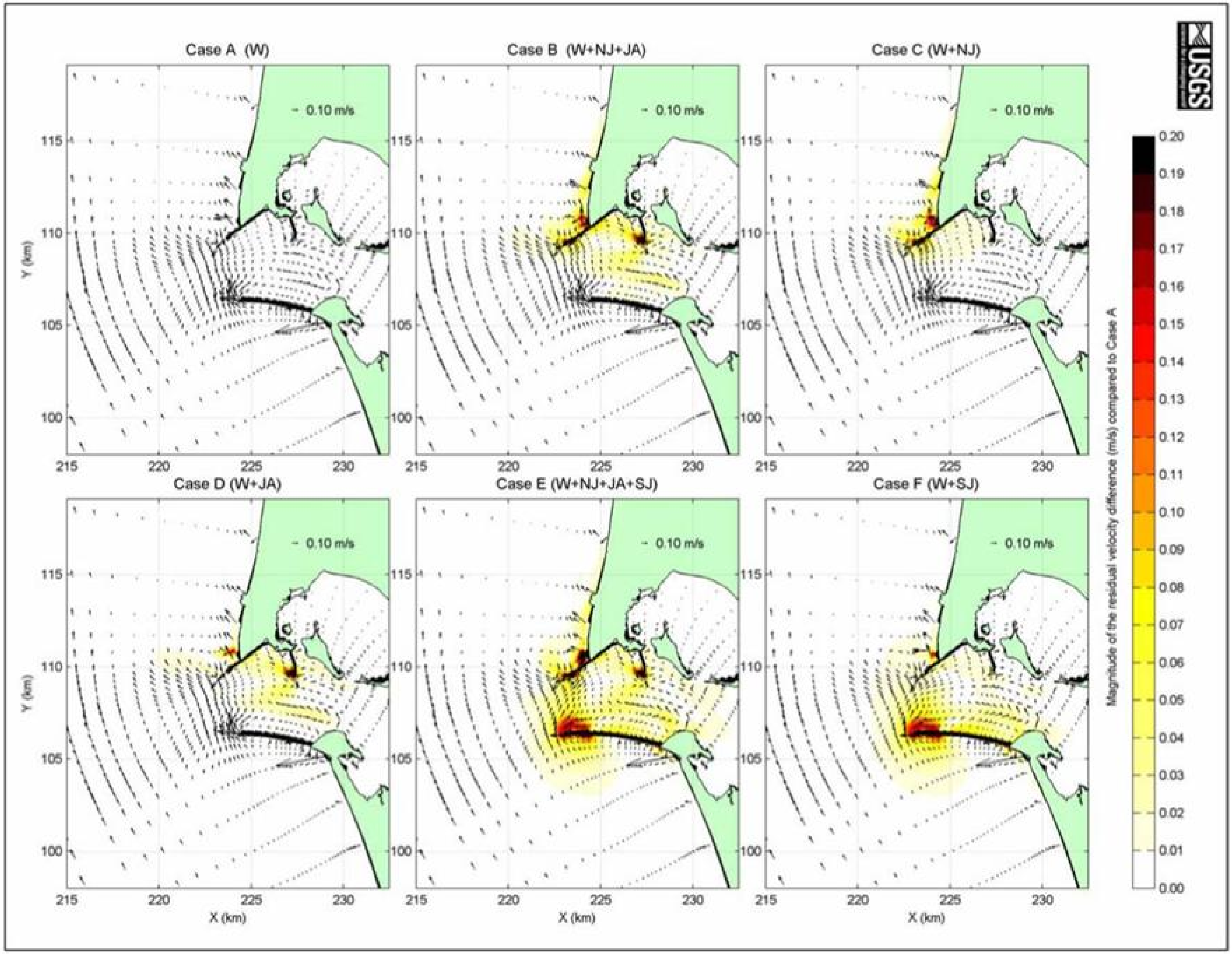


Figure A1- 239. ***Modeled residual surface flow vectors for Cases A to F. Colors indicate the magnitude of the difference vectors relative to Case A.***

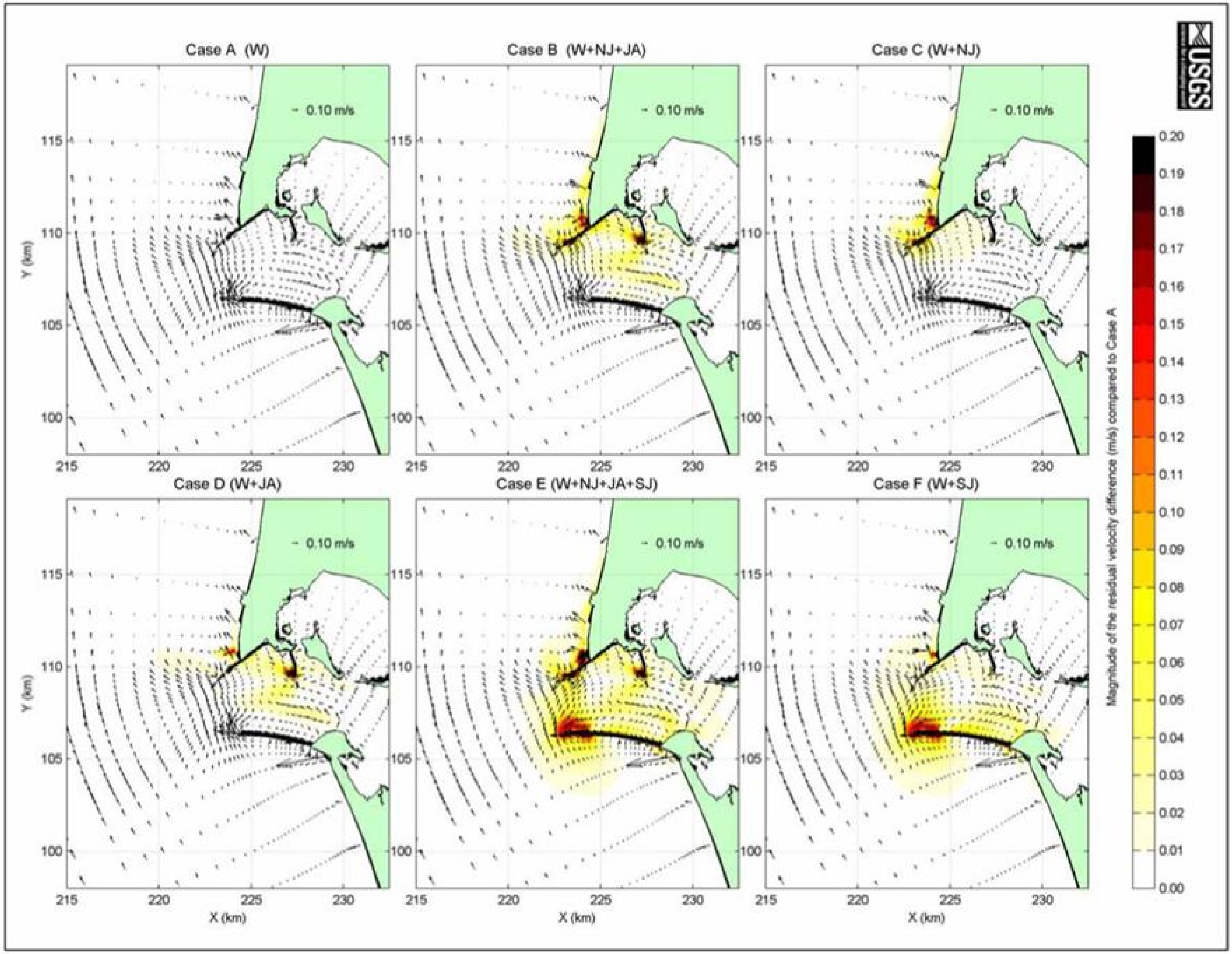


Figure A1- 240.** **Modeled residual bed flow vectors for Cases A to F. Colors indicate the magnitude of the difference vectors relative to Case A.

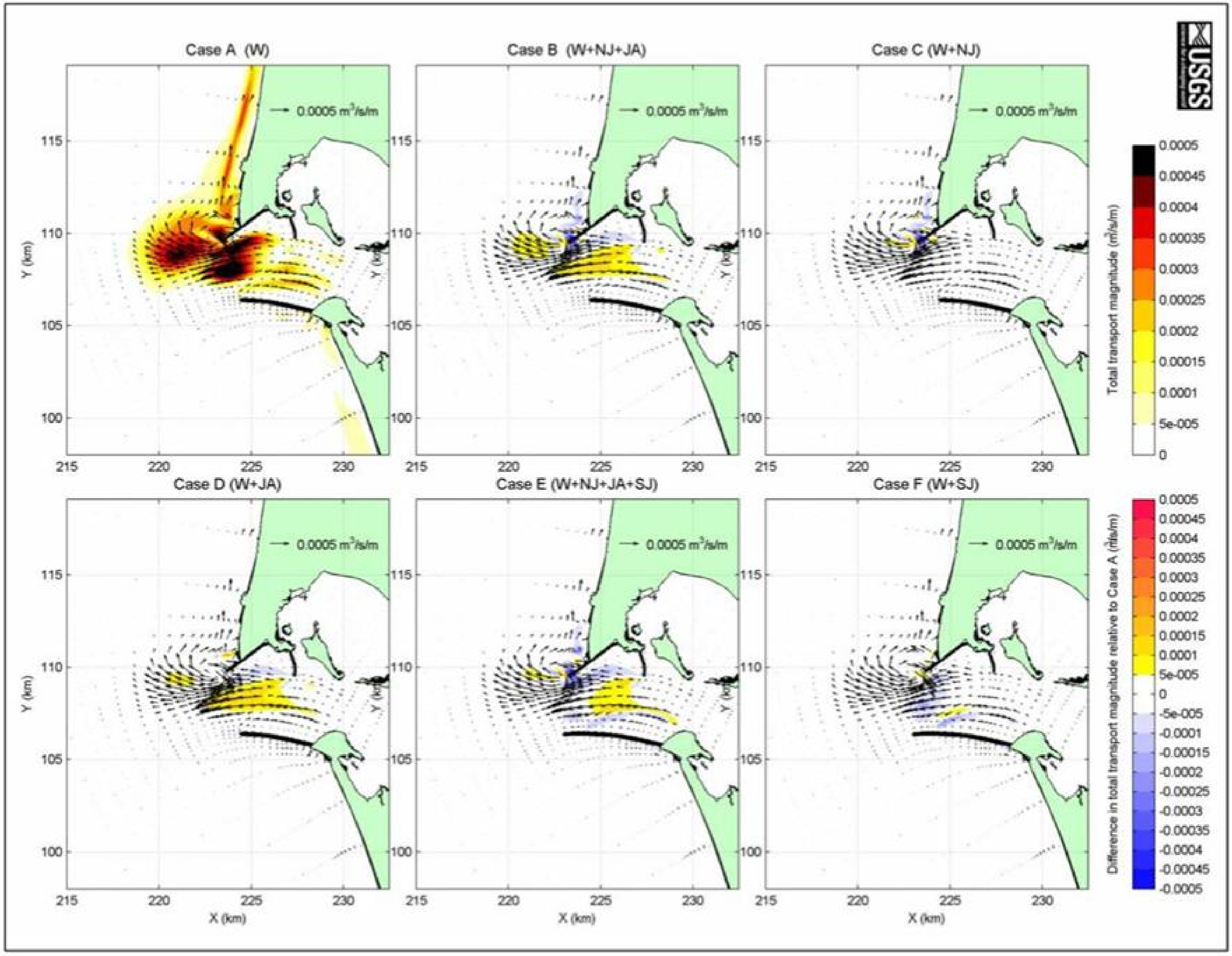


Figure A1- 241. Modeled residual total-load sediment transport vectors for Cases A to F. Colors (B to F) indicate the difference in transport magnitude relative to Case A.

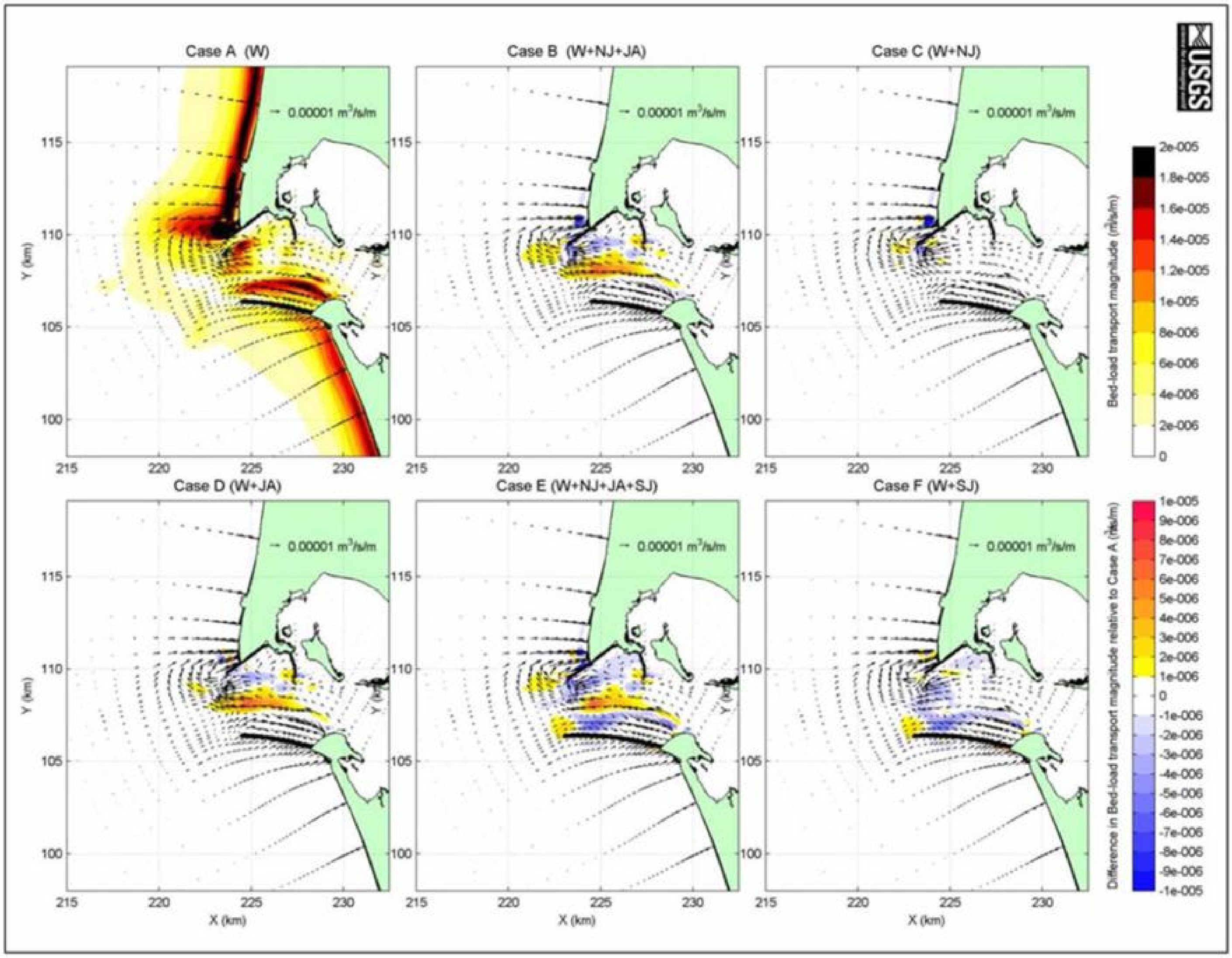


Figure A1- 242. Modeled residual bed-load sediment transport vectors for Cases A to F. Colors (B to F) indicate the difference in transport magnitude relative to Case A.

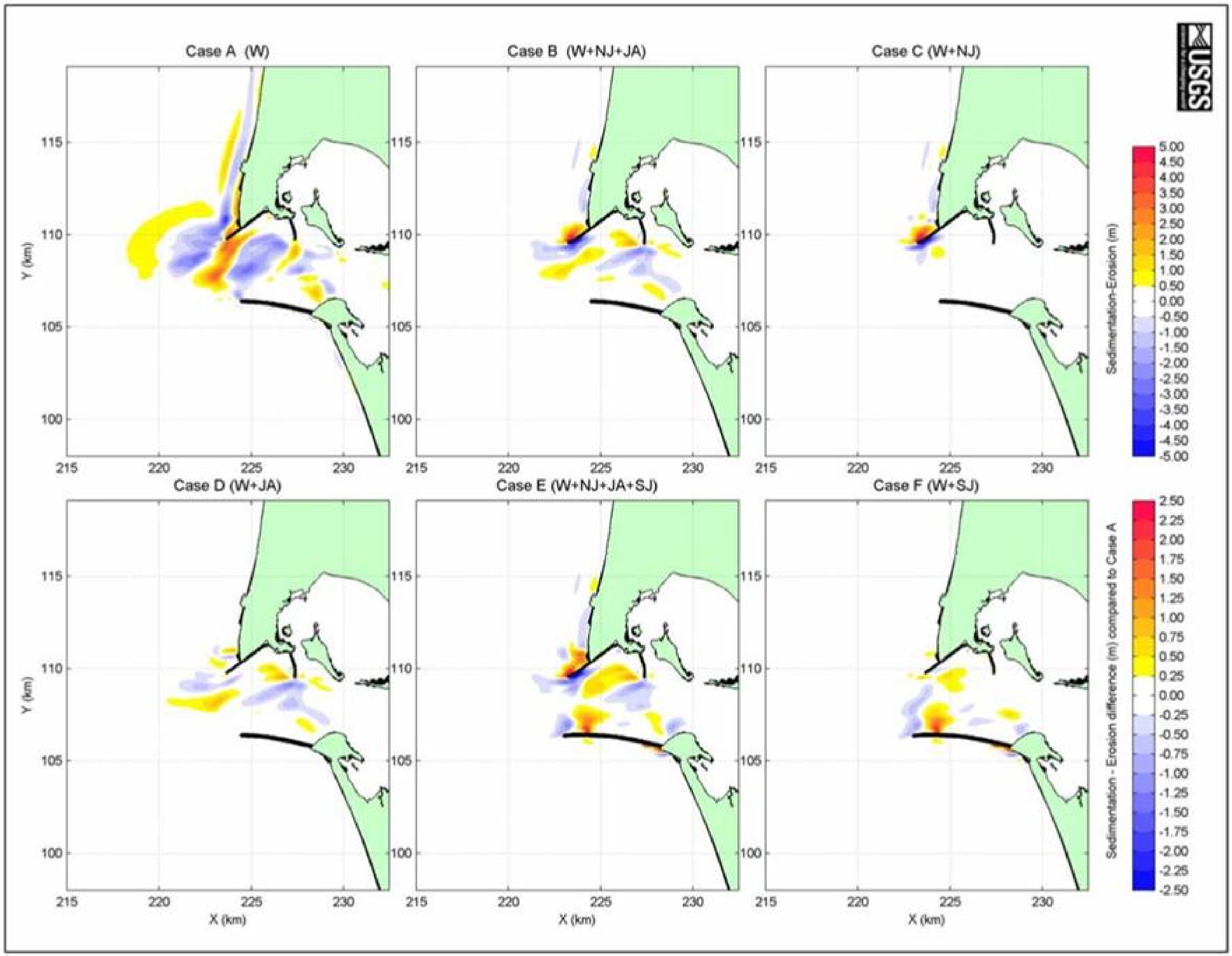


Figure A1- 243. Modeled sedimentation-erosion pattern for Case A (bottom left) and the differences in sedimentation-erosion relative due to Jetty Rehabilitation of cases B to F relative to case A.

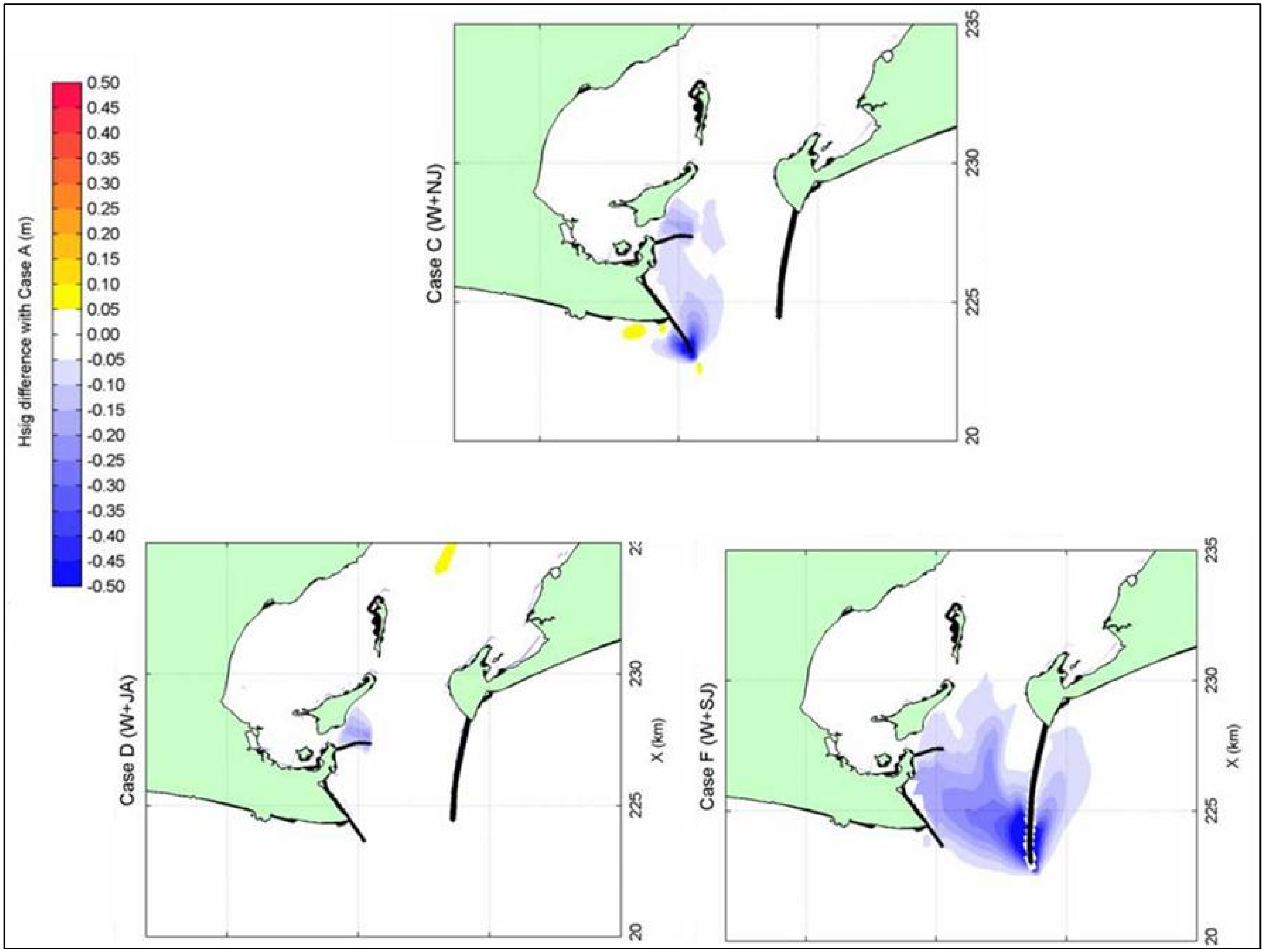


Figure A1- 244. Modeled Mean Wave Height Difference

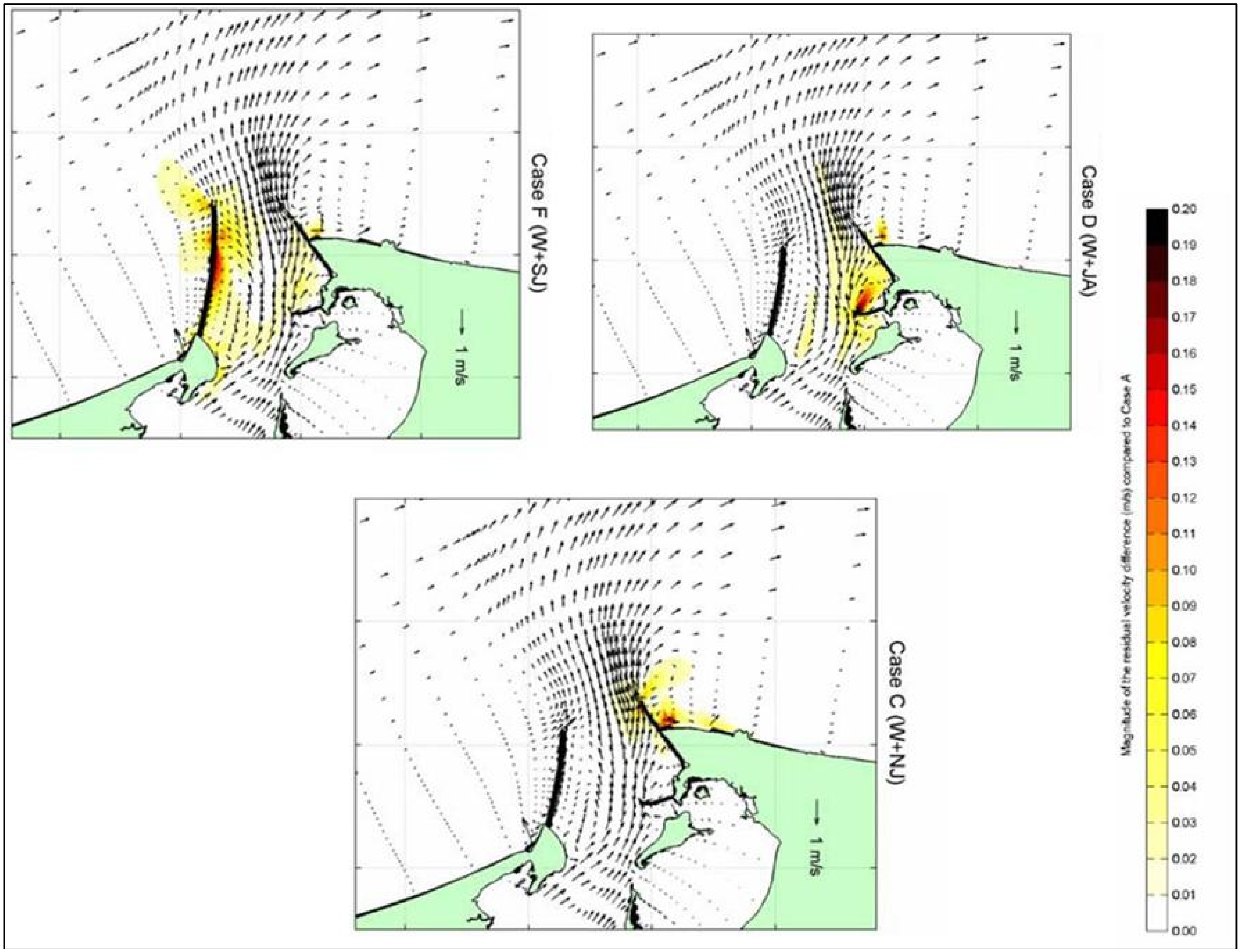


Figure A1- 245. Modeled Residual Surface Flow Velocity Vectors

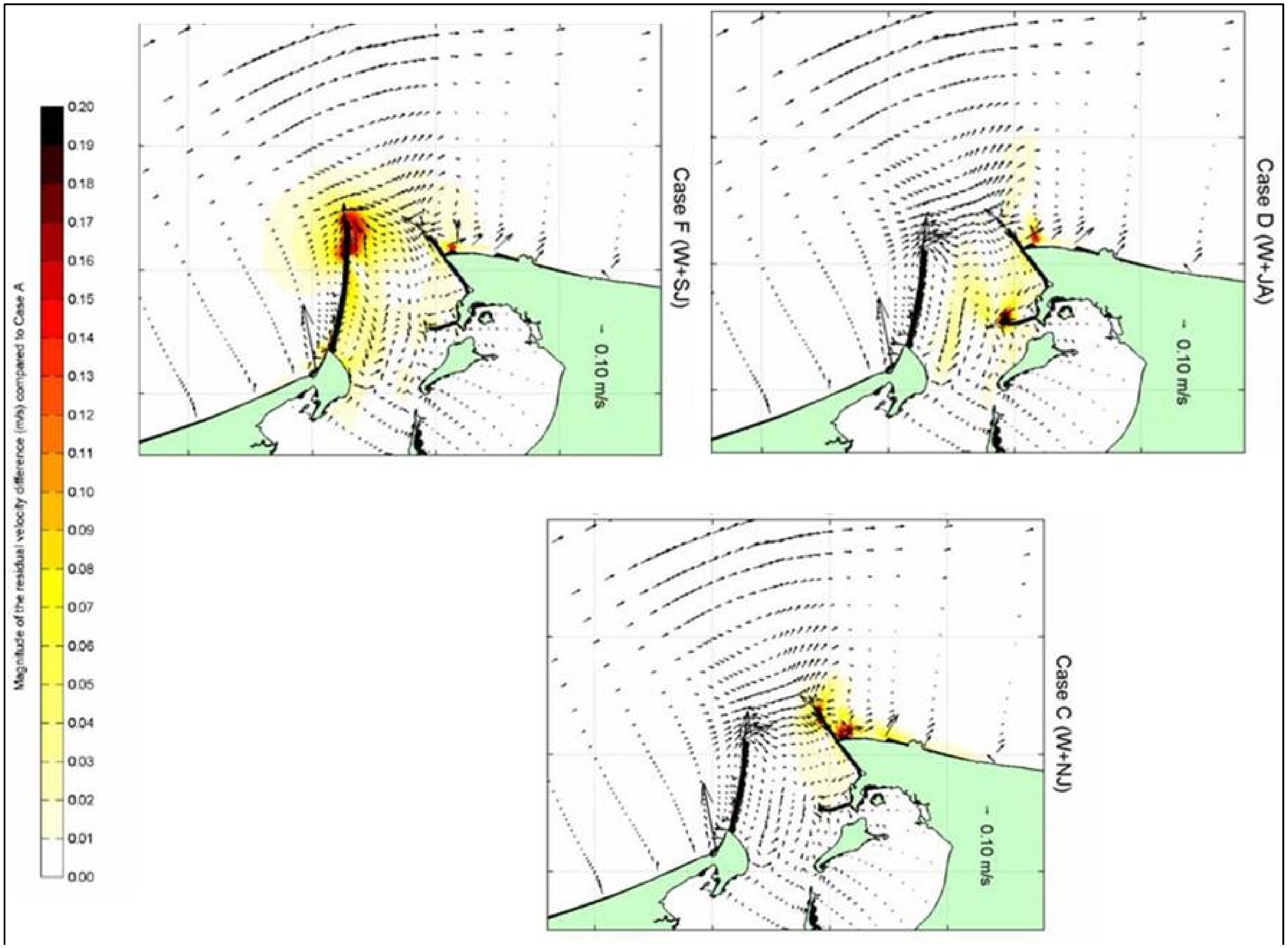


Figure A1- 246. Modeled Residual Bed Flow Velocity Vectors

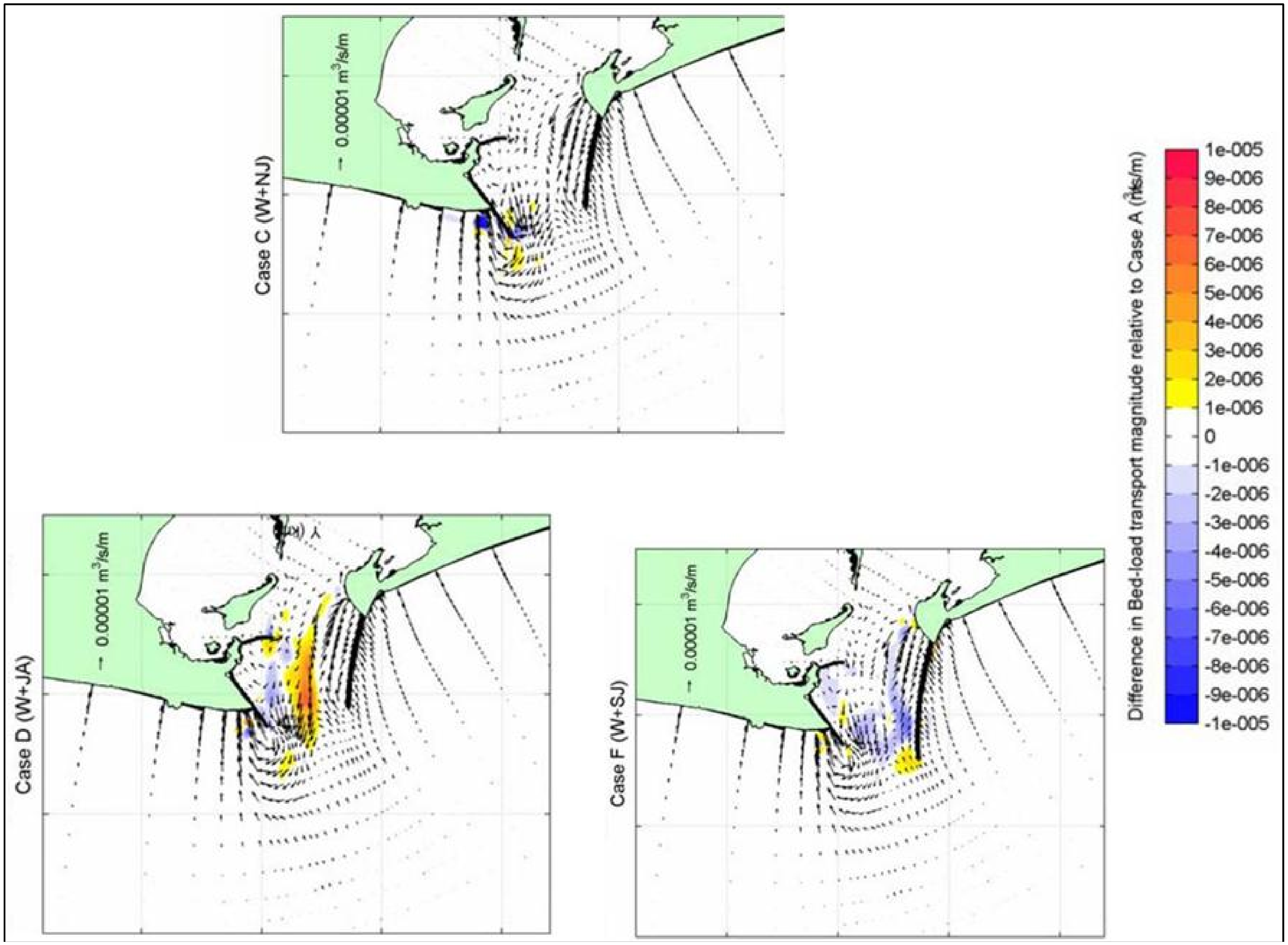


Figure A1- 247. Modeled Bed Load Transport Difference

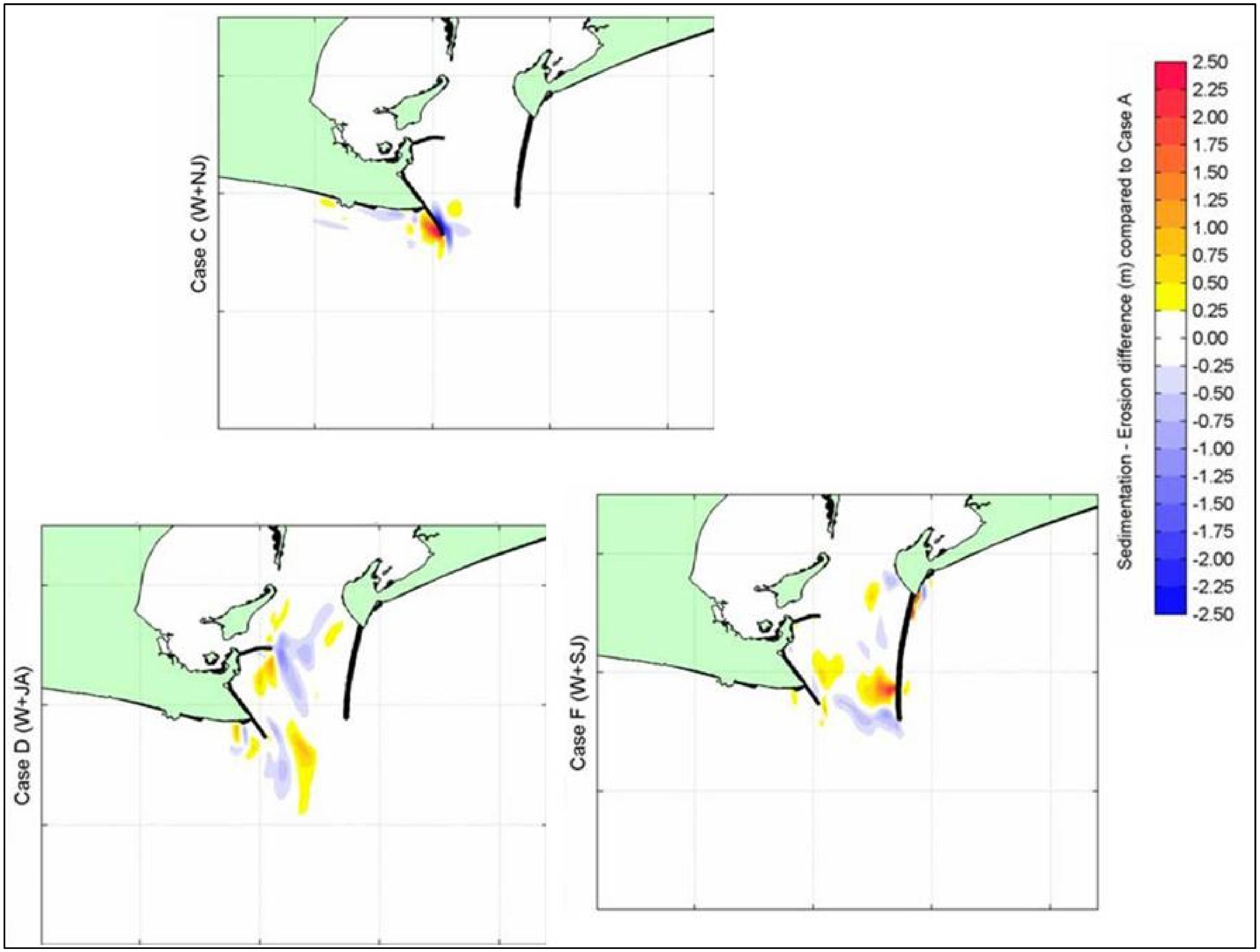


Figure A1- 248. Modeled Sediment – Erosion Patterns (blue = erosion, yellow = accretion)

Analysis of the results shows limited influence of the jetty alternatives on flow, salinity and sediment transport outside the sea model domain. Therefore, the overview maps presented in this report are mainly focused on the MCR part of the sea domain.

a. Analysis of Rebuilding South Jetty Low-crested Section Seaward of Head

Local effects of filling in the South Jetty low-crested section seaward of the existing head were observed in the salinity, waves, flow and sediment transports. Rebuilding the height of the South Jetty induces differences in mean salinity for both the bed and surface layer but the differences are minor (less then 1ppt) and focused at the low-crested section location. Wave heights show a minor increase at the south side of the low-crested section and small decrease in the MCR (variations < 0.15 m). Changes in the residual surface flow patterns focus around the low-crested section and jetty head. Local velocities in and directly adjacent to the low-crested section reduce strongly as the closed off low-crested section eliminates flow. The residual velocity around the jetty head shows a small increase resulting in larger net sediment transports. The changes in residual velocity fields are focused mainly at the jetty head, but small deviations in the residual velocity magnitude and direction are observed in the entire MCR entrance. An interesting feature is the reduced return flows along the northern side of South Jetty. The slightly changed flow distributions are reflected in the relative sedimentation-erosion patterns and rates. With the low-crested section filled, less sediments are eroded at the location of the low-crested section but more sediments are eroded at the jetty head. Effects on sediment transport outside the sphere of low-crested section influence are minor.

b. Analysis of Restoring Jetty Lengths

Effects on Salinity. The effect of jetty rebuilds on salinity are visualized by plotting the maximum salinity range (defined as = maximum observed – minimum observed salinity) during the simulation, mean salinities, and time series of salinity in the mega transect. Inside the MCR, the change in salinity range is limited. In the surface layer, the central part of the MCR and along North Jetty shows up to a 1 ppt decrease in salinity range. Along the South Jetty an increase of 1 to 2 ppt is observed. In the bed layer changes have a wider spatial variation. Extension of Jetty A (to 97+00) tends to increase the salinity range by 1-2 ppt along the jetties, while the central part slightly (1 ppt) decreases. Extension of South Jetty shows an opposite behavior with an up to 1 ppt increase in the channel. North Jetty extension has limited effect.

Most pronounced changes are observed outside the MCR. Relative large fluctuations in maximum range (over 5 ppt) are observed along the South Jetty and along the edges of the plume. These relative large changes are due to small changes in the plume that affect areas that are normally completely saline. Since the maximum that is recorded is tracked, it becomes visible in the plot. Averaged over the month the effect of the jetty rebuilds shows only local changes near the rebuild jetty heads with the largest impact on mean salinities in the surface layer due to the South Jetty rebuild.

Detailed analysis of the salinity time series for mega transect Stations 3 and 5 illustrate only limited changes in salinity values. In the main channel (Station 3) over 10 ppt differences are observed sporadically due to small temporal shifts of the signal. Larger variations occur at Station 5, closer to the South Jetty. The overall maximum and minimum values do not change distinctively.

Effects on Waves. The 2001 October-December winter simulation is governed by a sequence of storm events. Wave heights over 8.5 m are observed on the open sea. Wave heights decrease significantly towards the coast due to refraction and bottom friction, with the majority of the energy dissipation occurring along the coastlines due to depth-induced breaking in the surf zone, and on the northwestern part of the ebb-delta facing the North Jetty. Inside the MCR a dissipation hotspot occurs on the shoals along the South Jetty.

The effect of jetty length rebuilds on the wave heights at MCR is visualized by plotting the mean wave height and mean wave dissipation over the October-December runs. The North and South Jetty rebuilds further reduce wave-heights inside the MCR to mean values below 1.0 m towards the estuary. The South Jetty extension is most effective in reducing the maximum and mean wave heights in the MCR. At the location of the mega transect the mean wave height reduces up to 15%.

Detailed analysis of the wave time series at the mega-transect stations show that the largest reductions occur during the major storm events when waves significantly exceed 2 meters. Only minor change is observed for lower wave cases. Rebuilding North Jetty and Jetty A only induces limited local effects in the MCR. However, the longer North Jetty might have a positive effect on the stability of Peacock Spit, between North Jetty and North Head, due to increased seaward energy dissipation rates around the new jetty head.

Effects on Flow. Analysis of the effects of jetty rehabilitation on flow velocities is based on animations of the velocity vectors and magnitude (differences), and residual flow plots. As a result of rebuilding the jetties, changes in the flow vectors (magnitude and direction) can be observed in the MCR and in the ebb-jet area; largest differences occur during peak ebb and flood (see snapshots of the flow at maximum flood and maximum ebb). The differences in the flow magnitudes mainly result from a slight spatial or temporal shift of the flow vectors rather than a strong increase (or decrease) of the overall velocities. In the central part of MCR at the location of mega transect locations differences between maximum and minimum observed velocities of the different alternatives are mostly small (<10%) compared to the original signal. At the boundary Stations (1 and 5) for some alternatives, differences from the base case are larger due to the direct influence of the jetty alteration (B72-73).

The changes in residual flow field are a good indicator for the longer-term (month-averaged) effects of the Jetty Rehabilitation alternatives on the flow at MCR. The residual flow field is obtained by summation of the Eulerian velocities over the simulation period (20 October – 9 December 2001). Figure A1- 246 and Figure A1- 247 illustrate the residual vectors for surface and bed layer respectively. The colors indicate the magnitude of the change in residual flow vector compared to case A (no distinction in increase or decrease is made).

Comparable residual flow patterns can be observed for the different alternatives. Residual flow in the MCR exceeds the flow along the adjacent coastal sections and is ebb-dominant due to the fresh-water influx. The various jetty rebuilds mostly induce local changes along the jetties. Rebuilding the North Jetty mainly impacts the velocities north of the jetty. In this area two opposite rotating eddies are observed in the surface layer. At the jetty head a residual clockwise rotating eddy forms. Landward a secondary anticlockwise rotating eddy determines the residual velocities along the jetty foot and coast. The changes in this secondary eddy might influence the sediment transports and morphology along the jetty and coast. South of the jetty, inside MCR, effects are negligible. Extension of Jetty A has a larger effect on the overall flow patterns inside the MCR as this jetty extends into the main channel. Changes in the residual eddy forming along the sheltered, downstream side of the jetty dominate the overall picture. In general the residual velocities towards the Peacock Spit coast tend to decrease and are more landward directed. Locally, at the jetty head, velocities increase due to contraction of flow and increased residual velocities extend seaward. Rebuilding the South Jetty reduces the residual return flow along the jetty. Main differences occur around the jetty head due to the different location of flow acceleration. Along the North Jetty and Jetty A, a minor increase in residual velocities is observed. Rebuilding all jetty heads results in a summation of all above mentioned effects, with the largest changes occurring inside the MCR and along the North and South jetties. Changes in the far-field area, outside the sphere of direct ebb-jet influence, along the adjacent coasts are minor.

Effects on Bed Layer. Residual velocities in the bed layer show a more complex spatial distribution compared to the reasonable uniform seaward flow in the surface layer. Nevertheless the effects of the jetty rehabilitations are limited to the jetties, with largest changes at the jetty heads. Rebuilding the North Jetty mainly impacts the velocities north of the jetty. Similar to the surface layer two opposite rotating eddies are observed, with augmented residual flow towards the coast due to the North Jetty extension. The increased length of Jetty A mainly increases the near-bed residual velocities between the coast and jetty. The South Jetty rebuild modifies the net inflow into the MCR. Minor changes in flow magnitude and direction can be observed in the entire MCR area. The largest alterations occur directly at the jetty tip. Along the jetty the residual seaward transport is reduced, while landward transports towards the channel increase.

Effects on Sediment Transport. Sediment transport along the coast is largest in the surf zone area due to wave-breaking induced currents. Residual transport rates are small compared to the large changes in the direct vicinity of the MCR. Wave breaking on the ebb-delta front contributes to the sediment transports directly by wave-driven currents, while wave stirring increases the amount of sediments available for transport by the ambient (tidal) flow. Inside the MCR, both waves and tides play a key role for sediment transport. Residual sediment transports peak at spring tide when velocity asymmetry is largest.

The reasonable small, local alterations of the tide, wave and salinity fields result in alterations of the sediment transport patterns and magnitudes in the direct vicinity of MCR. No clear change in sediment transports can be observed along the Oregon coast south of the inlet and along Long Beach north of North Head.

The bed-load and total-load show comparable differences in sediment transport rates due to the jetty rebuilds. In the entrance channel sediment transports are generally seaward directed. Extension of Jetty A slightly modifies and increases the flow in the central part of the main channel, increasing seaward sediment transport, while along Clatsop spit flow and transports are slightly reduced. Effects of the North Jetty rebuild are local with largest changes at the tip of the jetty and a reduction of sediment transport between North Jetty and North Head. Near the North Jetty, transports are more shoreward directed. Rebuilding the South Jetty mainly decreases the residual sediment transports at MCR. On the shoals along the South Jetty (where wave energy dissipation is large) a landward sediment flux prevails. The extension of the South Jetty reduces the residual seaward transports over the shoal due to a dominant decrease of the flood transports. The jetty rebuilds have minor effect on the seaward extension of the transports onto the ebb-delta.

Effects on Morphology. Morphologic change shows patches of alternating sedimentation and erosion. Changes in the MCR and near-field ebb delta are relative large. On the ebb-delta we observe a seaward (north-westward) migration of the delta frond. The MCR is governed by local re-deposition of sediments; erosion between Jetty A and the seaward tips of North and South Jetty, and accretion seaward.

The jetty rebuilds slightly alter the sedimentation erosion patterns. Jetty A predominantly induces changes in the central part of MCR. Rebuilding the North Jetty reduces the accretion at its southern margin while increasing accretion (less erosion) north of the jetty. The South Jetty rebuild reduces the sediment redistribution between the North and South jetties.

Limited changes occur in the overall transport rates due to the single jetty rebuilds. North Jetty locally increases Northward bypassing rates at the Jetty head, but no significant change in the longshore and cross-shore transports along the Washington coast is observed. Jetty A mainly impacts the transport rates in the channel. Increasing seaward transports show the potential of this alternative for reducing channel dredging volumes. The South Jetty rebuild causes the largest change in transport rates in the MCR. Seaward transport in the mouth is reduced. An interesting feature is the change in sediment direction bypassing the tip of the South Jetty from northward to southward (although magnitudes are very small).

Despite limited effects of the separate jetty rebuilds, the cumulative effect of all jetty rebuilds does show a clear initial signal. Seaward transport in the MCR and northward bypassing on the ebb-delta is enhanced. Along the adjacent coasts however no clear changes occur. Note that this analysis is based on short-term runs. For morphology it is necessary to do longer simulations to distinguish between initial effects and long term trends.

c. Hydrodynamic Modeling Conclusions

The state of the art Delft 3D online morphology model has been used to calculate flow, sediment transport and bathymetric change at the MCR. Simulations were made for two time frames. The August-September summer computation (25 July - 9 October 2005) is based on the time frame when the mega transect experiment was performed and is representative of typical mild summer conditions. Hydrodynamic validation of the model results with the mega transect observations showed that the model is able to simulate the dominant features in the tidal flow, salinity and wave field. Absence of sediment transport data did not allow for morphodynamic validations. Sensitivity analysis shows the strong influence by tides, waves and density differences for sediment transports at MCR. A near-balance between the tidal and non-tidal (density-driven) contributions exists; tides only, in the absence of salinity gradients, induces a large sediment export in the entrance as both the tidal residual and tidal asymmetry driven component are ebb-dominant. Including salinity has shown to affect the (near-bed) residual flow considerably, and as a result of the changes in vertical flow distribution with reversed residual bed velocities, sediment export at the entrance reduces to near zero. Loss of momentum and dissipation of wave energy due to wave-breaking generates wave driven currents and sediment transports outside the MCR.

Using the model settings of the mega transect experiment, a second period of winter (storm) conditions was modeled (20 October - 9 December 2001) that illustrates the large sediment transports and morphological change associated with waves. Sediment transport rates along the coast are still small compared to the large changes in and around the MCR. The winter campaign has been used to evaluate the functional performance of different jetty rehabilitation schemes on circulation changes in salinity, flow and sediment transport. The model results show a limited response on the overall patterns of salinity flow, waves, and sediment transport on MCR scale. For all jetty rehabilitation cases changes in residual salinity, velocity or sediment transport are small and mostly local at the rebuild location. Instantaneous velocities and salinities in the MCR show variations mainly due to small temporal shifts or spatial shifts rather than changes in e.g. maximum and minimum velocities or salinities. Outside the MCR, small variations and fluctuations in position of the plume are observed. Most of these changes are generated at the jetty heads and advected seaward by the plume.

Only the combined impact of rebuilding all jetties to the full rebuild position (South Jetty at Station 353, North Jetty at Station 115, Jetty A at Station 97) shows a clear impact on sediment transport rates and morphology inside the entire MCR, with seaward transport and northward bypassing being enhanced.

Even though the single jetty rebuilds only show limited change in the hydrodynamic and morphodynamic regime of MCR, there is a potential for locally affecting flow and sediment transport. In general the North Jetty rebuild has minor effect on MCR processes. Changes in flow and sediment transport are observed at the jetty head and on the north side of the jetty that could benefit the Peacock Spit shoreline due to wave-energy reduction. Jetty A impacts the flow in the central part of the MCR enlarging velocities, possibly decreasing channel sedimentation and reducing dredging, while reduced residual flow might favor the Peacock spit shoreline between North Head and Jetty A. South Jetty shows most widespread effects in the MCR, probably due to reduction of the wave climate during extreme wave conditions. Only little effects are visible south of the jetty.

The model results described are based on the re-extension of the Jetty A (900 ft) to its fully authorized length and North Jetty partial re-extension to 115+00. After the USGS modeling was completed, and in consideration of the model results and added evaluation based on functional assessments, the USACE determined that the candidate re-extension options for each jetty be revised. The present consideration for maximum seaward North Jetty rebuild has the reconstructed jetty head terminating at Station 105 (300 ft from the 2006 position). The present consideration for maximum seaward South Jetty re-build is Station 315+00. The present consideration for maximum seaward Jetty A re-build is Station 93+00. It should be noted that the Delft 3D model results described above are based on longer jetty rebuilds than those currently proposed.

Modeling the proposed post-construction condition predicted a negligible increase in velocity in waters in the vicinity of Jetty A; differences were less than 0.1 meter/second (0.33 feet/second). Surface current direction was predicted to change slightly toward the north as water flows around Jetty A, forming a more pronounced clockwise eddying effect west of Jetty A and tending to force water more directly toward the North Jetty. Residual velocities toward the North Jetty are predicted to decrease, however, and this effect will act to protect the North Jetty. Changes to current direction and velocities were found to be negligible in the vicinity of the South Jetty.

Salinity. Salinity distribution is determined by the circulation patterns and the mixing process driven by tidal currents. In surface waters near the North Jetty salinity naturally varies with tides to about 20 parts per thousand (ppt) during October-November. Modeling the post-construction condition predicted minor local changes to mean salinity. Changes to bed layer salinity are predicted in waters between Jetty A and the North Jetty. An increase in mean salinity of about 0 to 4 ppt (from 26-28 ppt to 28-30 ppt) was predicted to occur over some of this area. A similar but less extensive salinity pattern was predicted for the near surface layer in waters between Jetty A and the North Jetty. A decrease in mean salinity of 0 to 4 ppt (from about 12-14 ppt to 14-16 ppt) was predicted to occur over a relatively small area south of West Sand Island, which is located just east of Jetty A.

For the bed layer, a small-scale extrusion of higher salinity water was predicted for the main channel and along the South Jetty. For the existing condition, salinity in the range of 28-30 ppt occurs just upstream of Jetty A, whereas for the post-construction condition, this zone of salinity ends directly south of Jetty A. Only small changes were predicted in the bed layer near the North Jetty.

For the surface layer, a small-scale extrusion of higher salinity water was predicted for waters near the South Jetty. For the existing condition, salinity in the range of 24-26 ppt was predicted along the seaward one-third of the South Jetty, whereas for the post-construction condition, this area was predicted to support salinity in the range of 22-24 ppt. A minor reduction of lower salinity waters in the range of 18-20 ppt was predicted for along the landward half of the North Jetty.

Plume Conditions. Modeling the post-construction condition predicted that there would be only small changes to residual velocity and current directions for both bed layer and near surface layer in the plume. A decrease in bed layer salinity of 0 to 4 ppt (from 28-30 ppt to 26-28 ppt) was predicted in the plume west of the terminus of the North Jetty. Also, it was predicted that there would be only small changes to residual bed load transport and residual total load transport within the plume.

Bed Morphology. Modeling the post-construction condition predicted that a decrease in bed level would result in deeper water habitat than currently exists along the channel side of the seaward half of the North Jetty, with differences in bed elevation from 1.25 to 1.50 meters (4.1 to 4.9 feet). This change is relatively small, considering that water depth here is 12 to 24 meters (39.4 to 78.7 feet). Also, a decrease to bed level are predicted for a broad area in deep waters of the navigation channel off of Jetty A, deep waters around the seaward portion of Jetty A, and for locations north of the North Jetty, which includes shallow nearshore waters. Areas predicted to have an increase in bed level occur upstream and downstream of Jetty A, downstream of the above-mentioned broad area in the navigation channel, on the ocean side of the North Jetty, and downstream of Clatsop Spit.

From the modeling results for the spur groin structures, it was predicted that an increase in bed level due to sedimentation would occur upstream of the spurs, but that a decrease in bed level due to erosion would occur immediately downstream of the spurs.

The potential for jetty rehab to affect the circulation at existing MCR nearshore disposal sites (SWS and NJS) was considered using results from the Delft 3D model. The potential changes on these disposal sites would not inhibit the existing use of the sites. The likely effect of North Jetty rehab will be to slightly increase currents within the eastern 1/3 of the SWS, during part of the tidal cycle. This effect could enhance the already high dispersion rate within the SWS. Effects on the NJS associated with North Jetty rehab would be minimal. Use of the NJS was intended to reduce current scour effects on the North Jetty. If use of the NJS is no longer advantageous to stability of the MCR inlet and continued NJS use adds increased burdens to the MCR project, its use for dredged material placement could be reduced accordingly. In this case, the material destined for the NJS would be placed within the deepwater site or other available nearshore site. Several ongoing initiatives, brokered by the Lower Columbia Solutions group and sponsored by MCR regional stakeholders, are focusing on obtaining additional nearshore sites for MCR dredged material disposal.

13. Potential Consequences of Jetty Failure

a. Systematic Jetty Performance and Impacts

In an aerial sense, a jetty consists of three parts (see Figure A1- 163). The <u>head</u> is the seaward terminus and is exposed to the most severe wave action. The <u>trunk</u> forms the connection from jetty head to subareal beach, retains sub-tidal shoals, and confines circulation within the inlet. The <u>root</u> forms the connection from the jetty trunk to shore and prevents accreted landforms from migrating into the inlet. Deterioration of a jetty's head, trunk, or root will have different impacts on the functionality of the structure and inlet. Effective maintenance of the jetty and, reliability of navigation through an estuary entrance, depends on determining which of these weaknesses is most detrimental to a structure's stability and function.

Stabilization of the head of the jetty is critical to long-term project function and maintenance. A jetty head performs as a type of anchor for all of the components of the navigation entrance, serving to protect the landward portion of the jetty structure, the configuration of the underwater shoals and the adjacent shoreline position, the location and configuration of the seaward-most part of the navigation channel, and finally the overall ebb tidal shoal. Omission of stabilization of the jetty head in any long-term jetty maintenance or rehabilitation plan would introduce a higher level of uncertainty regarding maintenance funds required (jetty repair and dredging) as well as projected performance of the navigation entrance.

The most critical parts of a jetty in the short-term are the root and trunk. The jetty root (trunk) retains the subareal (sub tidal) part of a shoal that would otherwise encroach upon the navigation channel. A breach at the root or trunk would release the tidal shoal and result in rapid in-filling of the navigation channel. Additional complications resulting from a breached jetty root (or trunk) include reduced hydraulic efficiency of the inlet, destabilization of the remaining jetty foundation, and severe shoreline erosion within or outside of the inlet.

In some instances, a jetty segment may be damaged at such a high rate as to fail before timely repair can be implemented. A given jetty segment is assumed to lose function when the upper cross-section area has been reduced to less than 15 ±5% of the original standard upper cross-section. If a jetty segment fails within the body of the jetty, the segment is considered breached. If the breached segment was acting to retain the inlet's morphology, the failed segment may release a large volume of sand into the inlet which has the potential to impact MCR navigation. Figure A1- 249 and Figure A1- 250 show a breached jetty example at a smaller navigation entrance and the resulting adjacent shoreline sediment loss that resulted.

Figure A1- 249. Breached Jetty at Smaller Navigation Entrance

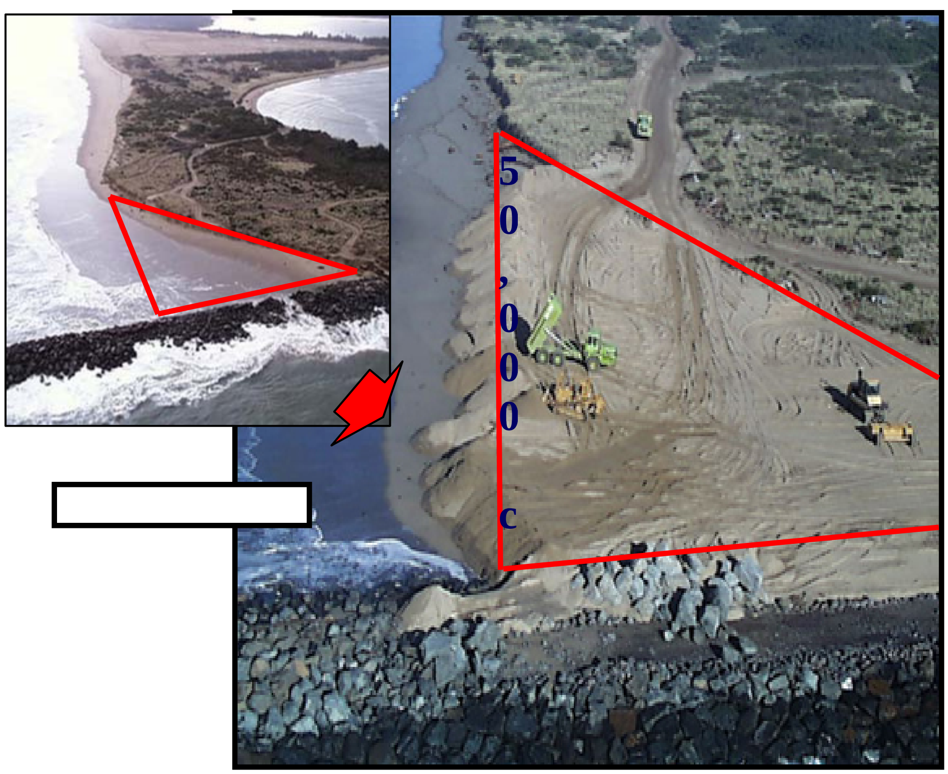


Figure A1- 250. Adjacent Shoreline Sediment Loss after Jetty Breach

Jetty head recession leads to progressive loss of jetty function which can impact inlet dredging requirements and stability of other jetty areas. Cumulative jetty trunk damage can result in a trunk breach which can have functional consequences on the inlet. Cumulative jetty root damage can result in a root breach which can have serious functional consequences on the inlet. Figure A1- 251 through Figure A1- 253, shown below, illustrates modifications to inlet with various jetty failures.

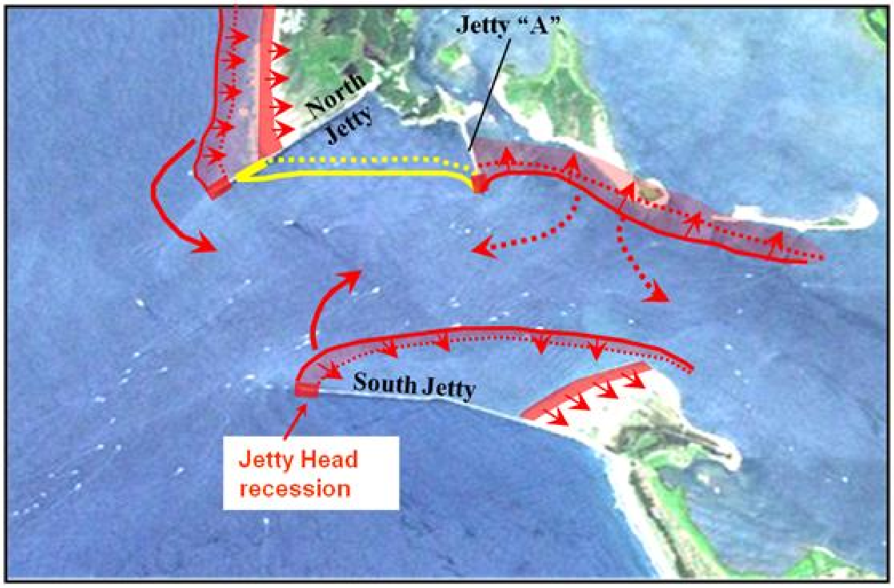


Figure A1- 251. Inlet Response to Jetty Length Loss

As a jetty head recedes landward, sand from the retained morphology is released and transported past the receding jetty and deposits within the MCR channel. The bathymetry deepens adjacent to the jetty and the morphology recedes, exposing the jetty to increased wave action. Head recession at Jetty A, exposes the North Jetty to increased scour.

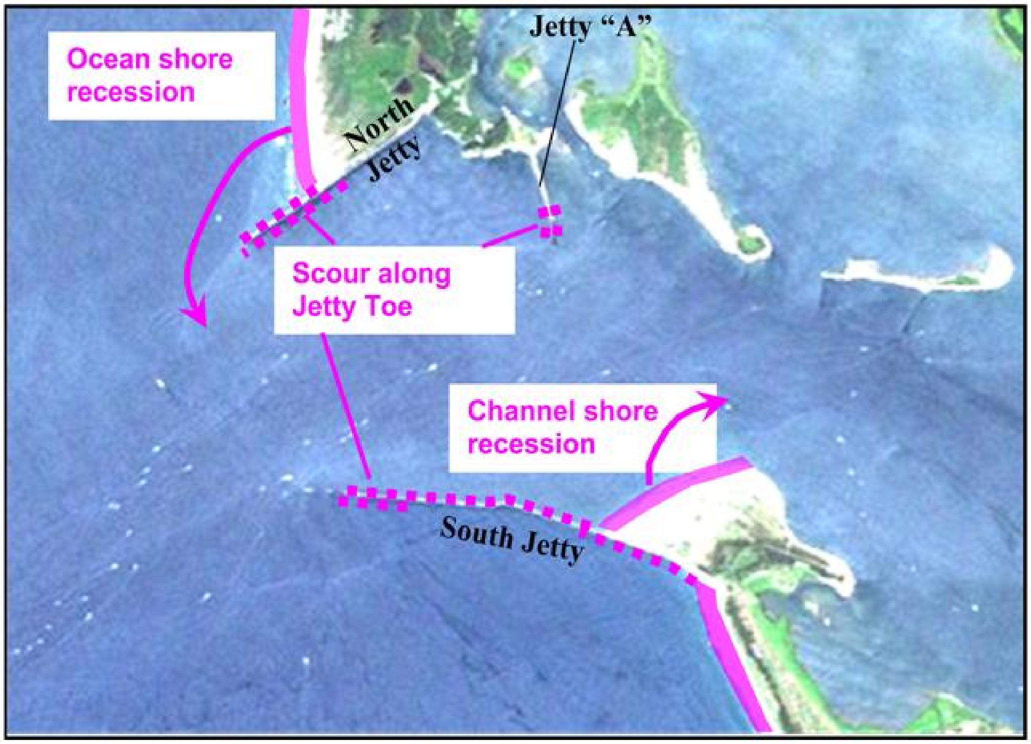


Figure A1- 252. Rip Currents along Jetty Length

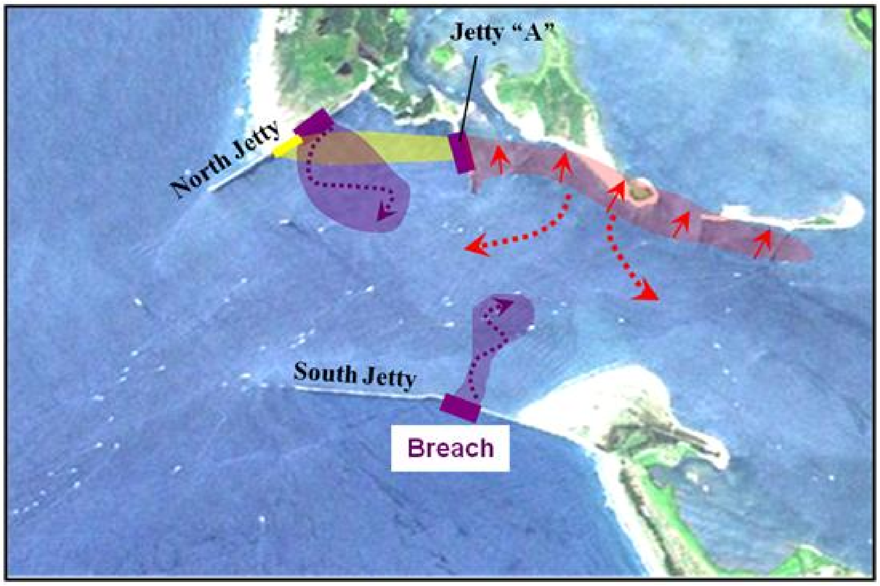


Figure A1- 253. Inlet Response to Jetty Breach

A jetty breach at MCR would establish flow through the jetty and destabilize adjacent morphology. Elevated shoaling within the MCR would occur. Aggressive dredging may be required to maintain the MCR channel, and the jetty may require emergency repair.

Enhanced rip currents form along the jetties acting to erode the jetty foundation (dotted line) and motivate continual loss of morphology adjacent to roots of the jetties, exposing the jetty foundation of each jetty to increased wave action and scour. Much of the eroded sediment is tranported into the MCR inlet

The longer a damaged jetty segment goes without repair, the higher the rate of cross-section degradation due to wave action, and the more likely that the jetty segment could breach before repairs are made. In rare instances, a jetty segment may be damaged at such a high rate as to fail (lose function) before timely repair can be implemented. A given jetty segment has the potential to lose function when the upper cross-section area has been reduced to less than 20% of the standard upper cross-section.

The distinction should be made between jetty damage and jetty failure and MCR project function failure. The primary function of the MCR project is to maintain the navigation channel for deep draft shipping. The secondary function evaluated in the structure rehabilitation effort is to significantly extend the life and reliability of the jetties in order to reliably maintain the primary function. Sub-categories addressed in order to accomplish the primary purpose included prevention of a significant breach to the jetties, minimizing dredging of the channel, minimizing the frequency and magnitude of the required jetty repairs, and reducing the degradation rate of the jetties over time.

If a jetty breach occurs, because of the higher wave heights it is likely to occur during the timeframe of November through March. Due to the typically severe weather conditions at the Mouth of the Columbia River during winter months, emergency jetty repairs (to fill the breach) and/or emergency dredging activities (to maintain the navigation channel) may not be possible or may only be possible at a reduced rate with the end result potentially being impacts to navigation until the actions can be completed. Jetty repairs are expensive and due to the sheer size of the structures usually include high costs of mobilization. Because these jetties are typically repaired from the top of the structure (especially during winter months), construction of a haul road is required for each jetty repair effort. In addition, there are some areas along the seaward half of the North Jetty and the seaward half of the South Jetty for which emergency jetty repairs during the winter months could not be conducted due to the exposure of the construction site to overtopping wave conditions.

The degree of navigation impact motivated by a breached segment is dictated by how many neighboring segments breach, the volume of shoaling that could be mobilized into the inlet, and the proximity of the breached segment(s) to the navigation channel. In the analysis of the MCR project, a breach of the North Jetty is expected to be a more serious threat to the primary function of the project. This is due to its proximity to the navigation channel as well as its current function of holding back Peacock Spit from encroachment into the channel.

b. Responding to a Breached Jetty at MCR

Attempting to perform emergency dredging at MCR in winter can be problematic, yet the activity may be required if deep draft navigation becomes threatened by a breached jetty. The cost of performing such dredging will be significant. The cost of repairing a breached jetty segment can be significantly higher under emergency conditions as compared to normal repair conditions. Although the likelihood of jetty breach is low, the consequences of jetty breaching can be high. The successive steps and consequences of jetty failure are explored and explained in more detail in the life cycle analysis in Appendix A2.

In a historical context, the South Jetty had breached extensively during the late 1920s affecting navigation and motivating a significant rehabilitation campaign of the south and north jetties during the 1930s. During the mid-2000s, reaches of the north and South Jetty become partially breached, motivating recent interim repairs to both the North and South jetties.

If a jetty segment fails at the seaward terminus, the subareal jetty head will recede landward as shown in Figure A1- 198. In most cases, some relic jetty head remains as a submerged structure extending vertically to somewhere between -20 ft and 0 ft MLLW. In most Pacific Northwest prototype cases, in the short term, jetty heads are allowed to recede landward without repair due to the difficulty and high cost associated with jetty head repair. Resilient jetty head repair alternatives are generally not considered to be within the "normal" maintenance budget. However, recession of the jetty head can result in larger process changes to the inlet and the navigation structures. In many cases, head recession will cause added shoreline recession along the jetty root, which can expose the jetty to increased wave action and increase the requirement for maintenance dredging. Long-term effects from jetty head recession can take the form of less reliable structures, higher degree of wave exposure in the navigation entrance for vessels, and increased shoreline and underwater shoal erosion.

If a breach along the North or South Jetty occurred, it would likely happen during winter (Oct-Mar) in response to a storm wave event. Wave action at MCR throughout winter can be intense. Initiating jetty repairs and performing channel dredging during winter would be difficult, especially if land access to the jetty breach is not available. If 100 to 500 ft of jetty were affected by the breach, approximately 10,000 to 50,000 tons of armor stone would be needed to affect an emergency repair. The cost of such an activity would be \$5 to \$15 million, which is 2-5 times more than a preventative (pre-breach) repair scenario. Procuring this amount of armor stone (5-25 ton size) in a 2-month period would be problematic.

If the breach promoted sand in-fill within the MCR channel, then dredging would be required to remove the shoal material. If the channel shoaling were severe enough to impede/restrict deep draft navigation through MCR, then emergency dredging of the material would have to be performed concurrent with emergency jetty repairs. Assuming that dredging of the MCR channel during winter is possible, the efficiency of dredging operations during winter would be reduced due to wave action. Dredging production during winter is estimated to be 1/2 to 1/3 of normal operations (or 15,000-25,000 cy/day). If the channel experienced 2 mcy of in-fill due to a jetty breach, removal by dredging would take 3 months (or about \$7 million).

After dealing with the short-term effects of a breached jetty at MCR, many of the breach-related effects (modified tidal shoal morphology) would be profound and long lasting. The reliability of the affected jetty and deep-draft navigation through the MCR would be challenged in a post-breached condition. This would be reflected in a higher O&M

expenditure over the long-term (10 years), and is estimated to be $1-2 million per year (associated with increased dredging at MCR).

14. Graduated Levels of Jetty Cross-Section Repair Design

In the jetty cross section template figures (Figure A1- 254 through Figure A1- 256), the light brown represents sand foundation or land, the dark brown represents existing relic stone (existing rock structure from earlier construction efforts), and the light blue represents proposed new cross section and new rock. The border around each cross section is also color coded (pink, yellow, blue, black) to help describe the composite cross section.

Jetty Head Cross Section. The jetty head cross section stays constant regardless of the cross section applied along the trunk of a jetty. All jetty caps are very substantial features designed to withstand wave attack from three sides and significant overtopping forces. Note that primarily to control costs, all of the jetty head templates are designed to be constructed on top of the existing relic stone base.

Minimum Template and Scheduled Repair Cross Section. This cross section rehabilitates both jetties along their current length using a minimum cross section that extends above the waterline and lies essentially within the existing jetty footprint.

Small Template Cross Section. This cross section was only considered for the South Jetty and Jetty A because the minimum and small cross-sections were essentially the same for the North Jetty. This cross section rehabilitates the South Jetty along its current length using a small cross section that only extends above the waterline; however, it is not constrained to fit within the existing footprint of the jetty.

Moderate Template Cross Section. This cross section was considered for the North and South jetties and rehabilitates both jetties along their current lengths using a moderate cross section that encases the existing jetty both above and below the waterline and extends beyond the existing footprint.

Large Template Cross Section. This cross section was considered for the North and South jetties and rehabilitates both jetties along their current length using a large cross section that encases the existing jetties both above and below the waterline, and also places a stabilizing toe berm along key reaches of each structure. The cross section would extend outside of the existing jetty footprint.

Composite Cross Section. This could entail any combination of the above cross-section types tailored to address structure concerns along specific jetty reach sections. Up to four cross sections could be used together over the length of a jetty to make a composite plan.

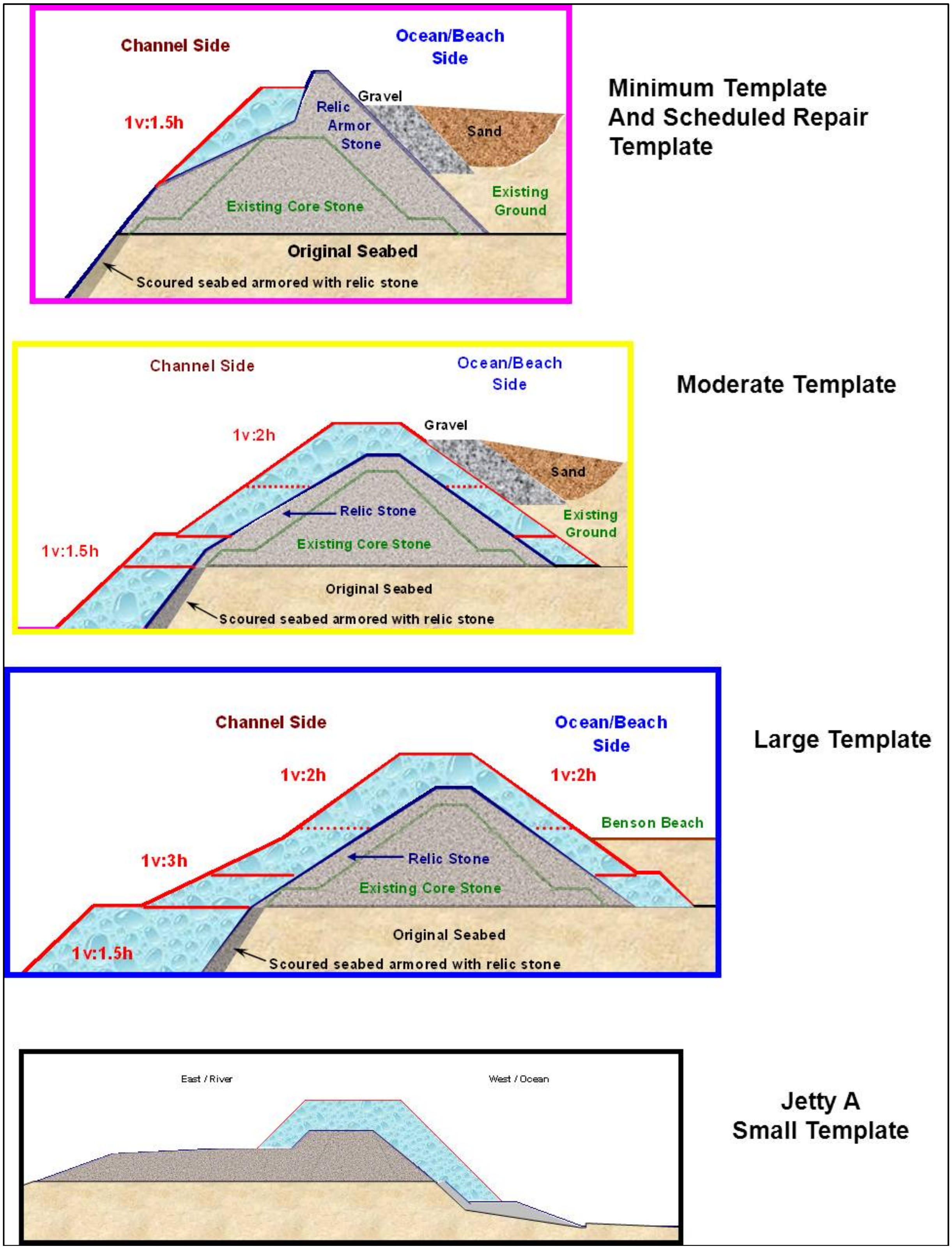


Figure A1- 254. North Jetty and Jetty A Conceptual Cross Section Templates

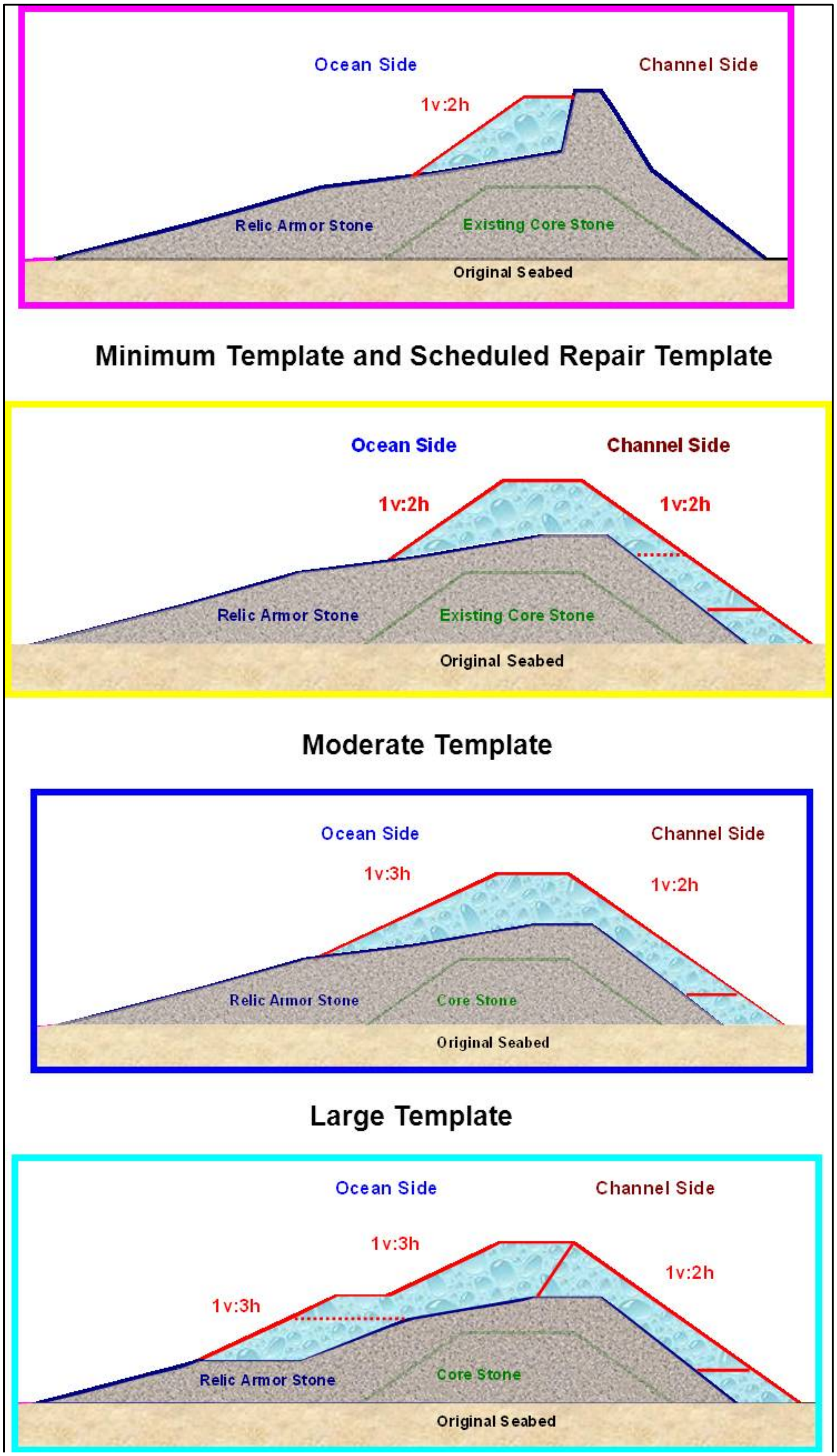
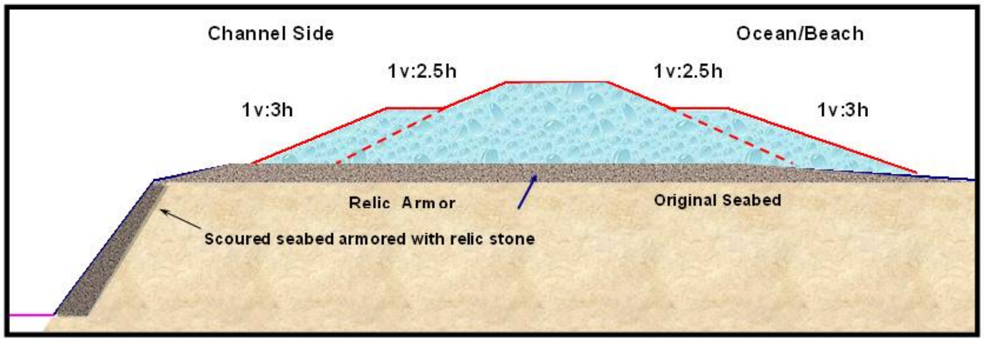
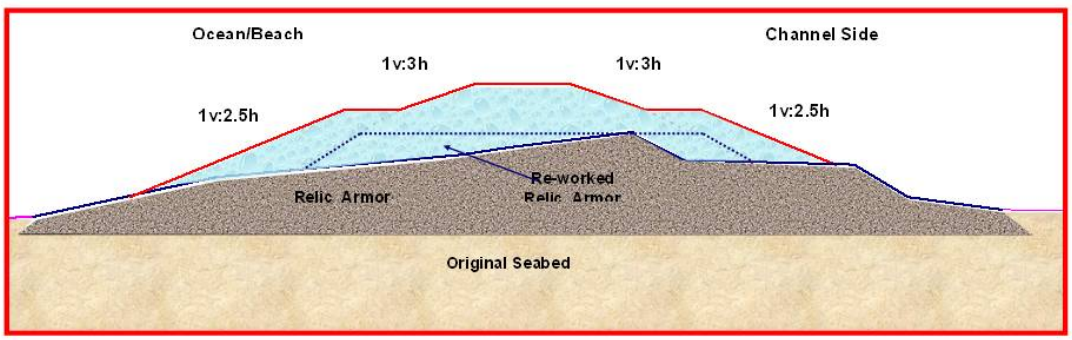


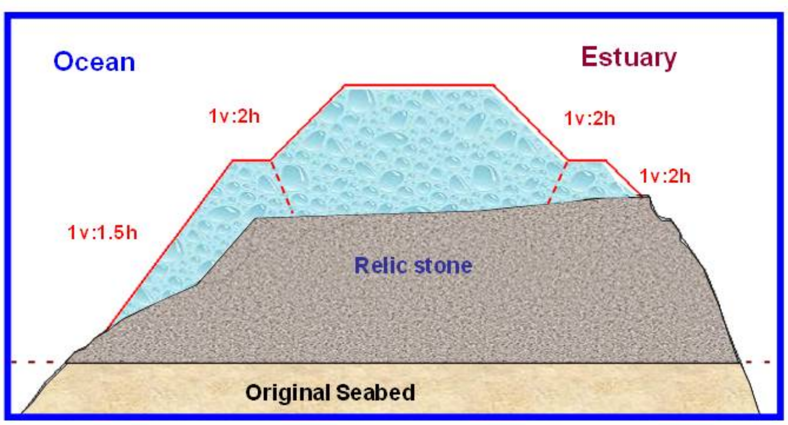
Figure A1- 255. South Jetty Conceptual Cross Section Templates



North Jetty Head Template



South Jetty Head Template



Jetty A Head Template

Figure A1- 256. Jetty Head Cross Section Templates

Figure A1- 254 through Figure A1- 256 are intended to be generic examples of the template types. It is important to realize that the particular template/cross section shown (as well as the relic stone base it is constructed on) will vary along the full length of each structure.

The top sketch in figures Figure A1- 254 and Figure A1- 255 show the minimum template or scheduled repair approach to the rehabilitation which does not require as much rework of the relic stone as the larger more substantial designs. The figure showing the minimum template is trying to convey that the repairs conducted will just build off of the existing relic configuration as much as possible. No attempt will be made to modify the backslope for additional stability in that area. The moderate and large templates are more substantial and comprehensive design templates requiring more re-work, more stone, and a larger area of placement.

The large template for the North Jetty does not show the gravel and sand area on the backside because, in general, for most of the alternative where this template is used, it is seaward of the lagoon fill area that requires the sand and gravel backfill. The horizontal red lines in the cross sections indicate transitions to different stone sizes within the cross section.

15. Categories and Features of Alternatives

a. Considerations

The following considerations were taken into account during the plan development and selection process. At a minimum, structure rehabilitation should restore project resilience to a prescribed baseline condition, such that future structure risk can be managed at a sustainable level. Structure risk is a function of repair timing, frequency, and maintenance costs. Metrics for jetty maintenance focused on repair timing (when do repairs occur) and repair frequency (how often). Minimum rehabilitation is appropriate in cases where the forcing-loading environment is stationary and not severe, and the structure can be adequately maintained in the future. In cases where the present loading environment is moderate to severe (or is non-stationary, increasing over time), more robust rehabilitation alternatives were required to increase project resilience and address increased structure loading. This approach may also be needed to address certain areas of a structure that cannot be easily maintained. Applying engineering features along a given jetty can reduce foundation scour and other jetty-specific degradation issues.

Repair and rehabilitation options comprise the general categories of alternatives considered and evaluated for the MCR jetty system, as described below.

b. Repair Alternatives

Repair alternatives involved adding limited amounts of stone to trunk and root features. Under repair options, stone placement is generally limited to above-water sections and remains within the existing jetty and relic stone structures. Repair alternatives also considered differing degrees of repair. Repair alternatives include dune augmentation at Trestle Bay, if needed. Repair alternatives were considered to occur either on the basis of a scheduled, predetermined time and place, or on a interim basis for which a stochastic model predicted both jetty repair and/or breach scenarios. The damage threshold for which the jetty repairs are implemented was also varied to some degree. With a lower damage threshold, the likelihood of a jetty breach is increased along with risk to navigational channel impacts. The implementation of the damage threshold in the stochastic model is discussed further in Appendix A2. Although a single damage threshold was used in the current analysis, there is the possibility of testing various thresholds to optimize the risk of failure against the possibility of deferring repair costs. For the North and South jetties, the repair alternative included repair combined with and without engineering features.

c. Engineering Features

Additional engineering features are potential options to address the larger system-based degradation processes that impact the project as a whole and over the long term. Engineering features included jetty head stabilization through a robust head construction, construction of spur groins at key locations along each jetty to promote foundation stabilization, and lagoon fill behind the North Jetty root. These features were evaluated individually and incrementally in the life-cycle model.

d. Rehabilitation Alternatives

Rehabilitation alternatives generally incorporate engineering components which may extend beyond the current footprint of jetty and relic stone structures and could entail both above and below-water fill. Certain engineering features were incorporated as common components present in all of the rehabilitation alternatives considered. These engineering features included capping the jetty heads, constructing additional spur groins, filling of the North Jetty lagoon area, and augmenting the Trestle Bay dune, if needed. Rehabilitation strategies were evaluated both immediate and scheduled. The scheduled rehabilitation alternative constructs at specific locations along the jetty at specific time periods in order to maximize the effectiveness of the federal investment.

16. Proposed Rehabilitation Plans

a. General

The rubblemound jetties have experienced significant deterioration since construction, mainly due to extreme wave attack and foundation instability associated with the erosion of tidal shoals on which the jetties were built. The purpose of the proposed action is to perform modifications to the North and South Jetties and Jetty A at the MCR to improve the reliability of the jetty structures (i.e., reduce the risk of failure), extend the jetties' functional life, and maintain deep-draft navigation.

A secondary purpose which is supportive of the above purpose is directed at slowing down the larger degradation processes that are impacting the long-term project reliability. These processes include ebb tidal and adjacent shoal erosion, jetty length loss, and shoreline erosion.

A reliability and life cycle analysis was used to examine the performance of the jetties (past and future) and develop structural alternatives to increase the reliability of the jetty system. Appendix A2 defines the coastal processes affecting jetty reliability and summarizes the event tree and life cycle analysis. Finally, a holistic approach is used to propose a phased strategy for jetty rehabilitation.

Despite intermittent repair and rehabilitation efforts over their lifetimes, all of the jetties are currently in a significantly deteriorated condition. The last partial rehabilitation on the North Jetty was conducted in 1964 and addressed 17% of its length. The last partial rehabilitation on the South Jetty was conducted in 1982 and addressed 25% of its length. The last partial rehabilitation on Jetty A was conducted in 1961 and addressed 56% of its length. The lengths of the north and south jetties which have never been repaired since original construction are 55% and 36%, respectively. The jetties continue to recede back from their original length. The South, North, and Jetty A head positions are currently shorter than authorized lengths by 6200 ft, 2200 ft, and 900 ft, respectively. Due to the interaction of wave patterns and currents with the jetty configuration, the shorter jetty lengths can increase underwater shoal erosion, influence shoreline position adjacent to the jetties, and alter the forcing climate at the project.

Progressive damages to one of the primary jetties could result in a significant breach which can trigger an emergency repair to the jetty, rapid infill into the navigation channel, and emergency dredging activities. The major rehabilitation approach for the MCR jetty system focused on adequately defining the larger processes affecting the jetty system, and then describing the jetty system reliability over time. Consequences evaluated included frequency and consequences of future jetty repairs as well as potential impacts to dredging and navigation. Each alternative adds additional elements of either process stabilization or above or below water cross section stabilization as well as varying degrees of cross section reliability improvement.

b. Alternative Approach

Rehabilitation will be considered as an alternative when it can significantly extend the physical life of the feature and can be economically justified by least cost analysis. Reliability is a measure of a facility to perform its intended function under specified operating conditions for a given period of time, in this case 50 years. The alternatives change the life-cycle cost time path of the project. In the case of the MCR jetty system, an adverse event is described as a jetty breach which has the potential to impact navigation at the entrance. Consequences are evaluated in three general categories: jetty repairs, dredging, and potential navigation impacts. In the execution of this major rehabilitation study, the assumption was made that all attempts to avoid navigation impacts would be employed by the District. Navigation impacts, therefore, were not evaluated quantitatively.

This alternatives investigation was conducted in phases. The first phase involved a detailed analysis and summary of the base condition for the jetty system. This phase is essential and provided the standard to which all of the other plans would be compared. An extensive hindcast analysis was conducted to simulate past performance of each jetty so that future performance could be projected with a level of confidence.

The second phase investigated and proposed actions for the larger system-based degradation processes which impact the project as a whole and over the long term. Those actions have been discussed under "Engineering Features" above. These features were evaluated individually and incrementally in the life cycle analysis model using the minimum cross section repair plan. Engineering features included head stabilization through a robust jetty head construction, construction of spur groins at key locations along each jetty to promote foundation stabilization, and lagoon fill behind the North Jetty root.

The third phase evaluated graduated levels of cross section repair or improvements. The conceptual cross sections for the three jetties can be seen in Figure A1- 254 through Figure A1- 256. Each of these cross sections was applied along the full length of each jetty to identify resiliency and performance of general design concepts along the jetty's length. Variability of segment-by-segment cross section resiliency is typically driven by existing condition of the structure, degree of exposure to wave attack, directions of wave attack, and foundation condition. Each of these plans was also evaluated using the life cycle analysis model which is described in detail in Appendix A2.

The fourth and final phase evaluated the feasibility of phasing the jetty repair to minimize project failure and maximize construction efficiency. Through this phase a plan to conduct a scheduled rehabilitation effort was developed.

c. Key Selection Criteria

The focus of this rehabilitation study was to identify and recommend a course of action which optimizes the future life-cycle costs for the system of jetties at MCR. While this was a least cost analysis, various other elements of project reliability, constructability and access, and potential navigation risk were also considered in the plan comparisons and ranking. Since potential navigation impacts were not evaluated quantitatively, greater importance is placed on quantifying the risk associated with not maintaining the system and considering other relevant criteria. The complexities of major jetty repair in challenging conditions as well as the feasibility of emergency winter time dredging at the Mouth of the Columbia River were considered in the final evaluation. Only four U.S. contract dredges are capable of dredging at MCR during winter conditions and those four dredges are normally scheduled for work in milder climates during winter months. Key selection criteria considered included:

- Initial construction cost;
- Total repair costs over life;
- Average annual costs (AACs);
- Number of repairs and year of first repair;
- Number of expected jetty breach events;
- Reliability over project life and residual risk;
- Constructability and access;
- Potential to impact navigation entrance function; and
- Potential impacts to larger inlet system.

At a minimum, structure rehabilitation should restore project resilience to a prescribed baseline condition, such that future structure risk (maintenance costs) can be managed at a sustainable level. This approach is appropriate in cases where the forcing-loading environment is stationary and the structure can be adequately maintained in the future. In some cases (i.e., where a non-stationary loading environment is increasing over time or if questions remain regarding the ability to maintain), more robust rehabilitation alternatives are required to increase project resilience, to match increased structure loading. This approach may be needed to address certain areas of a structure that cannot be easily maintained, such as the outer half of the South Jetty. The recommended plan will identify the optimum investment both in terms of proposed actions and timing of proposed actions, given the risk and uncertainty identified during the study. That plan will offer the greatest benefit to the project with respect to the cost and reliability.

There are some basic and broad distinctions between the analyzed plans that should be considered as further reduction of plans is conducted:

- With the exception of the base condition which utilizes an interim repair strategy, all of the other plans utilize a programmed repair strategy which is initiated approximately 4 years prior to construction.
- The base condition and the scheduled repair plans were evaluated both with and without maintaining current jetty head positions. Without head stabilization, the jetties continue to lose length at a rate of 5 to 50 feet per year with any accompanying impacts to project resilience and performance. Significant changes to the navigation inlet and surrounding environment are expected under these scenarios.
- The base condition and the scheduled repair plans do not include the construction of spur groins or lagoon area infill to help stabilize jetty foundation.
- All of the scheduled repair plans and the minimum template plans address only the above water portion of the jetty cross section.
- Life cycle maintenance of the MCR navigation entrance can be handled in two different ways: (1) large initial cost, lower maintenance costs resulting in higher reliability and lower risk, or (2) low initial cost, higher maintenance costs resulting in lower reliability and higher risk. The full rehabilitation plans represent the former and the scheduled repair and minimum template plans represent the latter.
- Environmentally, the full rehabilitation plans are similar in that they all include engineering features (jetty head capping, spur groins, lagoon fill) and all address the full length of each structure in some manner. The plans that may have a different environmental impact would be those allowing significant physical alteration of the system (base condition, scheduled repair) and those requiring frequent and continual construction activities (base condition, scheduled repair, minimum template plans).

d. Alternative Comparison and Selection Process

Due to the complexity of the MCR system and the potential range of alternatives, alternative selection was an iterative process which involved several levels of technical and project analysis. Numerous plans were run using modified cross section layout and/or timing of repair. Each of the jetties was evaluated separately and had slightly different emphasis in the criteria for plan selection.

The North Jetty is distinctive in that it is closest to the navigation channel as well as serves to hold back a very large subaerial and subaqueous sediment feature in the form of Benson Beach and Peacock Spit. The existence of this large shoal has served as protection for the oceanside of the North Jetty for a good portion of its life. A major breach along this jetty has the potential to impact navigation if either (a) emergency repairs cannot be instituted quickly and/or (b) emergency dredging cannot be conducted of the resulting sediment infill in the channel. For this reason, a major breach along this jetty would result in emergency repairs being instituted immediately, regardless of the time of year or the cost of those repairs. Another significant difference for the North Jetty is the 60 to 80 ft depths on the channelside of the seaward half of the structure and the rapid loss of jetty length, two to three times the jetty length loss as for the South Jetty and Jetty A.

The South Jetty is very important to the MCR inlet serving as a type of anchor that aids in controlling the overall shape of the ebb tidal shoal which ultimately impacts sediment pathways as well as wave approach patterns. The South Jetty is also distinctive in that it extends for over 4 miles out into the ocean and is exposed to the greatest wave forces of any of the structures. The exposed nature of the South Jetty makes it difficult to repair quickly since fall through spring construction on the jetty is too hazardous. Access to the outer half of the South Jetty is particularly problematic and results in extreme exposure of any equipment being used. The South Jetty is located further from the navigation channel than the North Jetty and a major breach would not immediately impact the channel. Due to a slower potential impact to navigation response as well as the hazardous access, the South Jetty would not be repaired following a major breach until the following summer.

Jetty A is less exposed than either the North Jetty or the South Jetty and it is also oriented perpendicular to the navigation channel, making a breach in this structure less likely to have an immediate impact on the channel. This jetties evolution over time, however, has been impacted by the large, +100-foot deep scour hole which has developed off of the south end of the head. The rehabilitation/repair of this jetty is primarily to maintain a robust cross section and stable jetty length so that the forces along the length of the North Jetty are controlled and the alignment of the navigation channel remains centered in the inlet.

e. Environmental Considerations

Comparisons were made between the alternatives and results were evaluated regarding three categories predicted to have some degree of environmental impact. The categories included: (1) frequency of required repair and construction activities; (2) potential morphological changes at the inlet from continued jetty recession; and (3) shallow-water habitat loss due to placement of engineering features, specifically spur groins and lagoon fill. Category one was evaluated based on minimizing repeated impact to the same area after the area had re-established. Category two evaluated the changes to the jetty foundation, the inlet, and the adjacent beaches as a result of continued recession of jetty length. The current assumptions favored rigidity as a surrogate for resilience, and assumed fewer environmental impacts by maintaining current habitat locations. Category three reflected the loss of shallow-water habitat by the engineered structures and fill. These categories were rated high, medium, and low depending on the loss of habitat or frequency of repair or change in morphology of the inlet. Maximum effects were assumed to occur with the largest jetty cross section, maximum change in morphology from the largest reduction in jetty length or highest amount of breaching, and the highest amount of repairs. Other construction and staging elements also were evaluated to determine the best way to avoid and minimize environmental impacts. Additional common project elements across alternatives included location of stockpile storage, selection of staging areas, location of barge offloading sites, and construction access.

f. Definition of Base Condition

The base condition assumes that no action would be taken to slow down the large-scale physical processes that are negatively affecting the structural stability of the MCR jetty system. Those larger physical processes include landward recession of the jetty head, shrinking of the ebb tidal shoal, foundation erosion, and adjacent shoreline erosion. The heads of each jetty would continue to recede landward with the expected response of the surrounding morphology including continued shrinking of adjacent underwater shoals and the overall shrinking of the ebb tidal shoal. Much of the material eroded from the inlets shrinking shoals would be transported into the MCR inlet, thereby adding the requirement for maintenance dredging. The underwater sand shoals upon which the jetties are built would continue to erode, leaving deeper water depths along the jetties. The deeper water (over the eroded shoals) would allow larger waves to attack the jetties resulting in a greater rate of jetty deterioration and foundation erosion. Wave and current action within the MCR inlet would increase. The lagoon near the root of the North Jetty, where tidal flow and wave surge through the jetty is de-stabilizing the structure foundation, is assumed to be filled. This improvement was addressed in the 2011 Major Maintenance Report.

Due to the level of construction and the high mobilization costs, the base condition does not include any jetty head re-construction. Only the trunk and the root of the jetty are maintained, and the jetty head is allowed to recede landward. Maintenance of the trunk and root of the jetty is minimized by deferring repair activities into the future for as long as possible. Jetty repairs are initiated only when a failure of the upper portion of the jetty cross section seems to be progressing. A rubblemound structure can incur a certain level of damage before the whole cross section fails resulting in a functional impact; however, a complete breach through the above water portion of the structure can result in rapid deterioration. The base condition is identified as an interim repair approach because the upper portion of the cross section is allowed to be damaged to approximately 40% remaining prior to repair actions being taken. In this way, the jetty is maintained close to the margin of functional loss.

Depending on the percentage of lost cross section which results from the deferred action, maintenance actions may need to be conducted on an expedited basis. In all cases, the repair occurs before the complete failure of the upper part of the cross section

The interim repair approach carries an elevated risk for incurring added costs either through expediting repairs (to prevent functional loss of a jetty). Consequently, there is an elevated likelihood that jetty repairs may be more expensive (cost/ton of repair stone placed) when they do occur

g. North Jetty Base Condition

The North Jetty has receded approximately 2,100 feet in length since original construction in 1916. The jetty head will continue to deteriorate at a rate of about 20 to 50 feet per year. In 50 years, it is estimated to reach Stations 76-90 (or about 1,800 feet lost), in very close proximity to where the existing shoreline is today. Under the base condition, the jetty head is not repaired or rebuilt during the 50-year period. Peacock Spit and Benson Beach are expected to continue to erode shoreward at a similar rate to the jetty length deterioration. Much of the sediment loss associated with shoreline retreat will migrate into the federal navigation channel and routine maintenance dredging of the entrance will increase over time. The maintenance dredging volume could be greater than present by an amount of 0.5 to 1 mcy per year (or by a rate up to 25% greater). The resulting head loss would have moderate effect on wave climate and navigability. Erosion of the surrounding shoal would expose more vulnerable areas of the jetty to increased damages. Continued loss of jetty length (and Peacock Spit) could potentially expose the seaward half of the South Jetty to higher wave conditions.

The trunk of the jetty is expected to degrade by three distinct processes: direct wave impact, wave overtopping (affecting the above water level of the jetty) and scour at the base of the jetty (affecting the below water portion until it fails and destabilizes the above water portion of the jetty). During the 50-year project life, it is predicted that the North Jetty may breach, destabilizing more of the jetty and allowing significant amounts of sand to move through the jetty. Breaching typically occurs during severe winter storm attack. The model suggests that during the 50-year project life, breaching will occur approximately 10 times at multiple locations along the North Jetty resulting in emergency repairs. If a segment breaches, adjacent segments have a high probability of also breaching.

For significant breach events, approximately 2-3 mcy of material could move from Peacock Spit and Benson Beach into the navigation channel. A shoal within the navigation channel would begin to form. In the absence of emergency dredging, it is expected that the depth of the navigation channel could be reduced from -55 feet to -40 feet in about 2 to 4 months. In order to maintain navigability of the navigation channel, the USACE would perform emergency repairs on the breach and attempt to mobilize sufficient dredges to maintain the authorized channel depth. During the 50-year project life, approximately 2 to 5 planned repairs would be expected to occur along the North Jetty.

To perform emergency repairs to the breached area, a contractor would truck in readily available stone to the North Jetty, build a haul road on top of the jetty, and place jetty stone in the breached area with a tracked mounted excavator or similar piece of equipment to stop the volume of material migrating into the navigation channel. Not only will the breach allow for sand to move through the jetty opening, but also sea water may flood low-lying Benson Beach park areas complicating access to the repair. The contractor may need to pioneer a road into a jetty access point for breach repairs.

The Columbia River Bar can only be maintained with the use of a hopper dredge. These types of dredges have two drag arms that extend to the river bottom and hydraulically remove material. The material is temporarily stored within the ship in a hopper, and then transported to a disposal location. Once at the proper location, doors on the bottom of the ship open or the hull of the ship opens and the material falls from the hopper through the water column to the disposal site. To perform emergency dredging, one or two dredges would be mobilized. Production rates for the dredges would be approximately 20% to 25% of normal due to weather conditions and storm events. The dredges would rely on weather windows and favorable sea conditions to remove as much of the shoal as possible with a goal of maintaining navigation. Due to the physical limitation of the dredges, it is unlikely they could achieve the -55 feet of depth of the outbound lane with swells of 10 to 16 feet.

It should be noted that this course of action would present high risks to the dredges and their crew. Given the winter wave conditions that the dredges would be performing in, it is highly likely that damage would occur to the drag arm of the dredge while working. Environmental concerns regarding loss of hydraulic fluid or oil spills may result if the dredges are damaged. Dredged material will be disposed of at an approved in-water disposal site. Because it is predicted that 2 to 3 mcy of material will enter the navigation channel, the dredges are not expected to be able to remove all of the material that has migrated into the channel; therefore, the following dredging year could require up to three dredges to work the entrance to remove twice the amount of material of a normal maintenance year. During the last 23 years, there were about 7 years when the wave climate would have been too severe to do emergency dredging. Under those circumstances, there would be more risk of not being able to do emergency dredging with the potential impacts to navigation.

h. South Jetty Base Condition

The South Jetty has receded approximately 6,200 feet in length since original construction in 1885-1913. Under the base condition, the jetty head is not capped and no spur groins are constructed to control foundation scour. The jetty head continues to recede back at a rate of 5 to 20 feet per year until the concrete monolith collapses at which point the head recession is projected to be more rapid. In 50 years, it is expected to reach approximately Station 292 (or about 2,100 feet lost). The jetty head would not be repaired or rebuilt during the entire 50-year period. Continued loss of the jetty length (and Clatsop Spit) under the base condition would expose the seaward half of the South Jetty to higher wave conditions. Loss of jetty length would contribute to continued loss of the underwater shoal, exposing the jetty to increasing wave action and the shoreline at the root of the jetty to higher wave forces. The shoreline would continue to erode and recede, resulting in a shoreline breach into Trestle Bay in about 8-16 years. Based on the present condition of the concrete monolith, it is expected to slump into the ocean and basically be non-existent within 12-20 years adding additional deteriorating forces to the seaward half of the jetty. The remaining rubblemound portion of the South Jetty would then begin to deteriorate in an accelerated way.

The trunk of the jetty is expected to degrade by three distinct processes discussed above. During the 50-year project life, about 3 to 6 repairs would be expected to occur along the South Jetty. Unlike the North Jetty, emergency dredging would not occur because the material is not anticipated to affect the federal navigation channel in the short term. Increased dredging would occur during the summer maintenance months. The breach would not be repaired by emergency actions; rather repairs would be performed during the following summer.

i. Shore Area along South Jetty

The shore area along the South Jetty root has experienced profound changes since the time of jetty construction. Before construction, the nearshore area immediately south of the jetty was dominated by a broad shallow ebb tidal shoal, exhibiting relatively shallow water depth. Construction of the South Jetty dissipated this shoal, resulting in a rapid trend of increasing water depth through time. As the water depth along the south side of the jetty increased, wave action along the jetty root and adjacent shore area increased. The increased wave environment motivated rapid deterioration of the entire South Jetty and culminated with the significant breaching event along the jetty root in the late 1920s. During the 1930s, extensive efforts were undertaken to rebuild the South Jetty and re-establish the shore-land interface along the south side root of the jetty. The effort was successful; however, the result has been subjected to an increasingly harsh environment of wave action and related circulation since the 1930s.

Currently, the coastal shore interface along the South Jetty is in a condition of advanced degradation. The foredune separating the ocean from the backshore is almost breached. The backshore is a narrow strip of low elevation, accretionary area, separating Trestle Bay from the ocean by hundreds of yards. The offshore area along the South Jetty (and to the south) continues to erode, promoting larger wave action to affect the shoreline along the jetty root. The shoreline at the jetty root will continue to erode and recede, resulting in a possible shoreline breach into Trestle Bay in approximately 8-16 years. If this sand spit breach occurs, the resulting scenario would be catastrophic. The MCR inlet would establish a secondary flow way from the estuary to the ocean along this area (south of the South Jetty). This condition would profoundly disrupt navigation at the MCR and bring lasting changes to the physical nature of the inlet. Augmentation of the foredune along the South Jetty root is required to prevent the above realization.

Augmentation of the foredune would consist of placing 60,000 to 70,000 cy of cobble material to fortify the toe of the foredune and improve the foreshore fronting to resist wave induced erosion/recession. The augmentation material would be composed of a well graded mixture spanning the size range of large gravel (3-inch diameter) to large cobble (12-inch diameter.). The material would likely be delivered by truck and placed by earth moving equipment. There is the possibility that MCR sand or coarse-grained sand from the lower Columbia River could be hydraulically placed to enhance the foredune augmentation effort. However, use of sand-sized material would require a significantly large volume (200,000 to 400,000 cy) to produce the equivalent resilience as the proposed cobble material augmentation. The timing of this action is expected to be within first 8 years of proposed jetty rehabilitation. Note that the nearshore placement of MCR dredged material within the proposed South Jetty Site would mitigate the erosion of the South Jetty root area. The South Jetty Site is a potential nearshore dredged material placement site located in a water depth of 40-50 feet approximately 1 mile south of the South Jetty. This would complement the proposed foredune augmentation and help ensure balance of the sediment budget south of the South Jetty. However, this action should not be viewed as a replacement for foredune augmentation.

j. Concrete Monolith

During rehabilitation of the South Jetty in the 1930s, a significant effort was expended to stabilize the rapidly receding jetty head. The effort culminated with the construction of a 500-foot long concrete cap on the South Jetty to secure the jetty head at Station 330, approximately 4,500 feet inshore of the original seaward terminus of the jetty and approximately 3.3 miles offshore. The seaward most 200 feet of the concrete cap was composed of a solid core monolith. This cap has served well since 1940; however, the entire cap has been severely damaged due to the severe wave climate that exists 3 miles offshore and is progressively failing. The cap serves as an anchor to secure and protect the un-reinforced area of the South Jetty immediately inshore of the cap. When the cap fails completely (i.e., falls off the jetty crest), the land area adjacent to the cap will rapidly deteriorate because of severe wave action. Based on its current condition, the concrete monolith is expected to slump into the ocean and basically be non-existent within 12-20 years, adding additional deteriorating forces to the seaward half of the jetty. The remaining rubblemound portion of the jetty would then begin to deteriorate in an accelerated way.

k. Jetty A Base Condition

Jetty A has receded approximately 900 feet in length since original construction in 1939. The head of the jetty will continue to deteriorate at a rate of about 5 to 20 feet per year. In 50 years, it is estimated to reach Stations 78-86 (or about 1,500 feet lost). Under the base condition, the jetty head is not repaired or rebuilt during the 50 year period. There will be increases in dredging as Jetty A recedes. Clatsop Spit will prograde northward toward the navigation channel. The bathymetry in front of Sand Island will be cut back, mobilizing that additional material. The shallower area between Jetty A and the North Jetty will also be impacted allowing movement of that material toward the channel. The deepening which will be expected to happen in the vicinity of the North Jetty will further destabilize the foundation of that structure impacting its long-term reliability. The primary purpose of Jetty A is to direct river currents away from the North Jetty. It is expected that a one-time increase in dredging will occur on the order of 800,000 to 1.6 mcy followed by incremental increases in dredging that will depend on changes in channel shoaling patterns and spit movement.

The trunk of Jetty A is expected to degrade by three distinct processes: direct wave impact, wave overtopping (affecting the above water level of the jetty) and scour at the base of the jetty (affecting the below water portion until it fails and destabilizes the above water portion of the jetty). During the 50-year project life, it is predicted that Jetty A will breach, destabilizing more of the jetty and allowing significant amounts of sand to move through the jetty. Breaching typically occurs during severe winter storms. Modeling suggests that during the 50-year project life, breaching will occur between 5 and 8 times along Jetty A. If a segment breaches, adjacent segments have a high probability of also breaching. It is estimated that 2 to 4 repairs would occur along Jetty A. Unlike the North Jetty, emergency dredging would not be needed because the material is not expected to affect the navigation channel in the short term. Increased dredging would occur during the summer maintenance months. Also, repairs to the breach would occur the following summer.

I. Range of Alternatives Considered

The alternatives under consideration ranged from the interim repair approach of the base condition to increasingly higher levels of repair or rehabilitation action to prevent cumulative jetty damage and possibility of jetty failure and impacts to project function. Not all of the plans address the full range of structure and project degradation and each of the plans has varying levels of risk as well as need for repair and emergency action readiness associated with it. The alternatives considered included scheduled repairs, immediate rehabilitation, and scheduled rehabilitation.

Scheduled Repair
Scheduled repair without engineering features (North Jetty, South Jetty, Jetty A)
Scheduled repair with engineering features (North and South jetties)

Immediate Rehabilitation
Using minimum cross section
Using small cross section (South Jetty and Jetty A)
Using moderate cross section
Using large cross section
Using composite cross section

Scheduled Rehabilitation
Using minimum cross section (North and South Jetties)
Using composite cross section (North and South Jetties)

All of these alternatives were evaluated with and without an option to hold the jetty heads at their current location. When the jetty head was held at the specified location, the repair alternative being simulated was used to repair the jetty head when damage occurred.

The importance of engineering features (spur groins, jetty capping, lagoon fill) that target damaging long-term degradation processes at the inlet was discussed earlier in this appendix. These features have been incorporated in all of the above plans except for scheduled repair for the North Jetty and Jetty A. In the case of the South Jetty, scheduled repair with engineering features was evaluated. In addition, scheduled repair utilize a minimum cross-section repair template that addresses only above-water jetty structure degradation processes.

Two types of repair strategy were used to realistically assess the life cycle performance of each plan. A great deal of work went into defining the necessary damage threshold which would trigger a repair and/or a failure. More detail on this work is provided in Appendix A2. Two general categories were utilized: (1) interim repair scenario, and (2) programmed repair scenario. The interim repair strategy which is only used in the base condition, allows the jetty to degrade at each 100 ft segment until only 40% of the above water cross section remains for a given segment. Once that threshold is reached, a repair action is triggered. The repair action does not always repair the structure before a breach happens. The programmed repair strategy monitors each 100 ft segment for current cross section and degradation rate. When a threshold occurs (calculated separately for each 100 ft segment and for each repair plan) which represents approximately 4 years prior to a failure, a jetty repair action is triggered. This repair strategy is used for all of the alternative plans.

The intent of a full rehabilitation of the jetties is three-fold: (1) to improve the stability of the foundation (toe) of each jetty affected by scour; (2) to improve the side-slope stability (above and below water) of each jetty; and (3) to improve the stability of each jetty to withstand wave impact. Two different methods were used to apply the full rehabilitation alternatives: immediate and scheduled. Under the immediate rehabilitation, actions would begin at a given year and continue annually until the entire jetty is completed. Under a scheduled approach, the timing of the rehabilitation would be staged throughout time applying the rehabilitation to only the portion of the jetty when it was needed, postponing the federal outlay of funds throughout the 50-year project life. The sheer size of the MCR jetties along with the limited construction window available at the project would require that any rehabilitation effort would result in scheduling the construction over a number of years. Construction of the North and South jetties is projected to take between 5 and 20 years, depending on the alternative.

Full rehabilitation plans would all include the engineering features and would also address, in some manner, the full length of each structure. The intent of a full rehabilitation of the jetties is three-fold: (1) to improve the stability of the foundation (toe) of each jetty affected by scour; (2) to improve the side-slope stability (above and below water) of each jetty; and (3) to improve the stability of each jetty to withstand wave impact.

Two different methods were used to apply the full rehabilitation alternatives; immediate and scheduled. Under the immediate rehabilitation, actions would begin at a given year and continue annually until the entire jetty is completed. Under a scheduled approach, the timing of the rehabilitation would be staged throughout time applying the rehabilitation to only the portion of the jetty when it was needed, postponing the federal outlay of funds throughout the 50-year project life. The sheer size of the MCR jetties along with the limited construction window available at the project would require that any rehabilitation effort would result in scheduling the construction over a number of years. Construction of a full rehabilitation plan on the North and South jetties is projected to take a minimum of 5 and 8 years, respectively. Due to the length of time required to implement a full rehabilitation on the South Jetty and the extent of that jetty's exposure to extreme conditions, scheduling construction over a broader time window was not found to be effective. On the North Jetty, the scheduling of rehabilitation efforts was assessed due to vulnerability and was spaced out over about a 12-year time frame.

The modeling performed to assess the project alternatives assumes that Jetty A is in place and fully functioning. This is because Jetty A, as originally constructed, protects the North Jetty and helps to train the Columbia River mainstem. In addition, Jetty A is believed to play an important function for the Columbia River plume. The plume is an important food source for the 13 Columbia River salmonid evolutionarily significant units (ESUs) listed under the Endangered Species Act. Jetty A will be treated as the first added increment for the North Jetty, and because of this only one plan was developed and analyzed for each of the alternative categories. The three alternatives (scheduled repairs, immediate rehabilitation, and scheduled rehabilitation) for Jetty A will be evaluated against each other in the same manner as the North and South jetties.

m. Alternative Descriptions

The characteristics of the alternatives analyzed are summarized in the following paragraphs.

Scheduled Repair. This alternative consists of conducting scheduled repairs that only address above-waterline instability, performing emergency repairs as needed, and performing emergency/increased routine dredging. This alternative is slightly more proactive than the base condition, but like the base condition would not include any engineering features (there would be no lagoon fill, spur groins or capping performed on any jetty) but would include action to improve the South Jetty shore area near the root. This type of repair strategy would continue for the entire project life, with only slight increases to the reliability of the structures. Aggressive and ongoing monitoring of the structures is necessary to prevent loss of function to the project. This alternative was evaluated for the North and South jetties and Jetty A.

Scheduled Repair with Engineering Features (South and North Jetty only). This alternative consists of conducting scheduled repairs that only address above-waterline instability, performing emergency repairs as needed, and performing emergency/increased routine dredging. This alternative is slightly more proactive than the base condition and would include action to improve the South Jetty shore area near the root. This type of repair strategy would continue for the entire project life, with only slight increases to the reliability of the structures. Aggressive and ongoing monitoring of the structures would be necessary in order to prevent loss of function to the project. Construction efforts to implement these plans are estimated to extend from 2 to 5 years.

Immediate Rehabilitation using Minimum Cross Section. This plan would rehabilitate the jetties along their full length using the minimum cross section which basically repairs the cross section above the waterline and within the existing footprint, and includes spur groins, jetty capping, lagoon fill, and South Jetty shore area near the root. If the minimum cross section template does not fit within the existing jetty footprint, the crest elevation is lowered until the cross section does fit. It is envisioned that it would take approximately a minimum of 5 years to complete all three jetties, assuming that work could be conducted on all three jetties concurrently. In the event that concurrent construction does not occur, completion of the three jetties could take up to one-and-a-half to two times as long. This alternative was evaluated for the North Jetty and for the South Jetty.

Immediate Rehabilitation using Small Cross Section. This plan would rehabilitate the jetties along their full length using the small cross section which basically repairs the cross section above the waterline, and includes spur groins, jetty capping, lagoon fill, and South Jetty shore area near the root. Although this cross section template is relatively small, it is not constrained to fit within the footprint of the existing structure. It is envisioned that it would take approximately a minimum of 5 years to complete all three jetties, assuming that work could be conducted on all three jetties concurrently. In the event that concurrent construction does not occur, completion of the three jetties could take up to one-and-a-half to two times as long. This alternative was evaluated for the South Jetty and for Jetty A.

Immediate Rehabilitation using Moderate Cross Section. This plan would rehabilitate the jetties along their full length using a large cross section which encases the existing jetty cross section. It would repair the cross sections both above and below the waterline, and include spur groins, jetty capping, lagoon fill, and South Jetty shore area near the root. It is envisioned that it would take approximately a minimum of 9 years to complete all three jetties, assuming that work could be conducted on all three jetties concurrently. In the event that concurrent construction does not occur, completion of the three jetties could take up to one-and-a-half to two times as long. This alternative was evaluated for the North Jetty and the South Jetty.

Immediate Rehabilitation using Large Cross Section. This plan would rehabilitate the jetties along their full length using a large cross section which encases the existing jetty cross section and which also places a stabilizing toe berm along key reaches of each structure. It would repair the cross sections both above and below the waterline, and include spur groins, jetty capping, lagoon fill, and South Jetty shore area near the root. It is envisioned that it would take approximately a minimum of 9 years to complete all three jetties, assuming that work could be conducted on all three jetties concurrently. In the event that concurrent construction does not occur, completion of the three jetties could take up to one-and-a-half to two times as long. This alternative was evaluated for the North and South jetties.

Immediate Rehabilitation using Composite Cross Section. This plan would rehabilitate the jetties along their full length using a plan suited to deterioration processes by jetty station, repair the cross section above and below the waterline where needed, foundation instability issues addressed where needed, and include jetty capping, spur groins, lagoon fill, and South Jetty shore area near the root. It is envisioned that it would take about a minimum of 8 years to complete all three jetties, assuming that work could be conducted on all the jetties concurrently. In the event that concurrent construction does not occur, completion of the three jetties could take up to one-and-a-half to two times as long. Five separate immediate composite plans were evaluated for the South Jetty and one immediate composite plan for the North Jetty.

Scheduled Rehabilitation using Minimum or Composite Cross Section. In reality, due to the sheer size of the MCR jetties and the limited construction window, any rehabilitation work on the MCR structures will need to occur over a number of years. A scheduled rehabilitation plan takes the scheduling a step further to implement the rehabilitation of specific reaches of each jetty at designated times to address the most vulnerable reaches first; includes adding spur groins on the jetties to promote structure stability, capping the head of both the North and South jetties to stop deterioration, lagoon fill at the North Jetty to stop erosion at the jetty root, and South Jetty shore area near the root. Rehabilitation is not conducted until conditions indicate that there is a need for rehabilitation of specific portions of the jetty. The reliability and the cost of the scheduled alternatives were evaluated for the minimum and composite templates. Conducting the rehabilitation when needed instead of continuously, as in the immediate rehabilitation alternative increases the length of time construction occurs to 15 years but construction actually occurs only 11 years out of that total. This is expected because construction is not expected to occur on all jetties at the same time. These alternatives were evaluated for the North and South jetties.

The alternatives analyzed are:

1. Scheduled Repair without Engineering Features
2. Scheduled Repair with Engineering Features
3. Immediate Rehabilitation using Minimum Cross Section
4. Immediate Rehabilitation using Small Cross Section
5. Immediate Rehabilitation using Moderate Cross Section
6. Immediate Rehabilitation using Large Cross Section
7. Immediate Rehabilitation using Composite Cross Section
8. Scheduled Rehabilitation using Minimum or Composite Cross Section

A summary of the alternatives evaluated is provided in Table A1- 10 through Table A1- 12for the North Jetty, South Jetty, and Jetty A, respectively.

Table A1- 10. Future Condition Alternatives for MCR North Jetty

Alternative	Alternative Description
	Alternatives: Allow Head Recession
1	Base Condition
2	Scheduled Repair
3	Scheduled Repair w/ Engineering Features
4	Scheduled Repair w/ Spur
5	Minimum Template Rehab - Immediate
6	Composite 4 Small Rehab - Immediate
7	Moderate Template Rehab - Immediate
8	Large Template Rehab - Immediate
9	Minimum Template Rehab - Scheduled
10	Composite 3 Small Rehab - Scheduled
11	Composite 4 Small Modified Rehab - Scheduled
12	Composite 2 Medium Rehab - Scheduled
13	Composite 1 Large Rehab - Scheduled
14	Moderate Template Rehab - Scheduled
15	Large Template Rehab - Scheduled
	Alternatives: Hold Existing Jetty Head Location
16	Base Condition (Hold Head)
17	Scheduled Repair (Hold Head)
18	Scheduled Repair w/ Engineering Features (Hold Head)
19	Scheduled Repair w/ Spur (Hold Head)
20	Minimum Template Rehab - Immediate (Hold Head)
21	Composite 4 Small Rehab - Immediate (Hold Head)
22	Moderate Template Rehab - Immediate (Hold Head)
23	Large Template Rehab - Immediate (Hold Head)
24	Minimum Template Rehab - Scheduled (Hold Head)
25	Composite 3 Small Rehab - Scheduled (Hold Head)
26	Composite 4 Small Modified Rehab - Scheduled (Hold Head)
27	Composite 2 Medium Rehab - Scheduled (Hold Head)
28	Composite 1 Large Rehab - Scheduled (Hold Head)
29	Moderate Template Rehab - Scheduled (Hold Head)
30	Large Template Rehab - Scheduled (Hold Head)

Table A1- 11. Future Condition Alternatives for MCR South Jetty

Alternative	Alternative Description
	Alternatives: Allow Head Recession
1	Base Condition
2	Scheduled Repair w/ Engineering Features
3	Scheduled Repair w/ Head Capping
4	Scheduled Repair
5	Minimum Template Rehab - Immediate
6	Composite 3 Small Rehab - Immediate
7	Small Template Rehab - Immediate
8	Moderate Template Rehab - Immediate
9	Large Template Rehab - Immediate
10	Composite 4 Medium Rehab - Immediate
11	Composite 1 Large Rehab - Immediate
12	Composite 5 Modified 2 Rehab - Immediate
13	Composite 2 Modified 1 Rehab - Immediate
14	Minimum Template Rehab - Scheduled
15	Composite 5 Modified 2 Rehab - Scheduled
	Alternatives: Hold Existing Jetty Head Location
16	Base Condition (Hold Head)
17	Scheduled Repair w/ Engineering Features (Hold Head)
18	Scheduled Repair w/ Head Capping (Hold Head)
19	Scheduled Repair (Hold Head)
20	Minimum Template Rehab - Immediate (Hold Head)
21	Composite 3 Small Rehab - Immediate (Hold Head)
22	Small Template Rehab - Immediate (Hold Head)
23	Moderate Template Rehab - Immediate (Hold Head)
24	Large Template Rehab - Immediate (Hold Head)
25	Composite 4 Medium Rehab - Immediate (Hold Head)
26	Composite 1 Large Rehab - Immediate (Hold Head)
27	Composite 5 Modified 2 Rehab - Immediate (Hold Head)
28	Composite 2 Modified 1 Rehab - Immediate (Hold Head)
29	Minimum Template Rehab - Scheduled (Hold Head)
30	Composite 5 Modified 2 Rehab - Scheduled (Hold Head)

Table A1- 12. Future Condition Alternatives for MCR Jetty "A"

Figure No	Alternative Description
	Alternatives: Allow Head Recession
1	Base Condition
2	Scheduled Repair
3	Small Template Rehab (Plan A) - Immediate
4	Small Template Rehab (Plan B) - Immediate
	Alternatives: Hold Existing Jetty Head Location
5	Base Condition (Hold Head)
6	Scheduled Repair (Hold Head)
7	Small Template Rehab (Plan A) - Immediate (Hold Head)
8	Small Template Rehab (Plan B) - Immediate (Hold Head)

17. Engineering Evaluation and Life-Cycle Model Results for the Range of Alternatives

a. General

The SRB model uses a Monte Carlo method to increase the confidence of life cycle estimates and allow for the evaluation of variance. In general terms, the model can assist with managing the future life-cycle of each jetty at MCR. Due to their porosity and flexibility, rubblemound jetties are relatively resilient structures which can sustain a certain amount of damage before a structural failure can be considered to occur. The event tree cycles through each year of the project life and accumulates damages along each jetty segment until a specified threshold or percent damage above the water line occurs. Once that threshold occurs, one of two branches will be initiated. The first branch triggers an interim repair action intended to address an imminent failure before a breach occurs. If the interim repair action is not conducted, the jetty segment will continue to damage until an actual breach occurs.

Once a breach occurs, adjacent jetty segments are evaluated for level of damage and may be included in the overall breach length if damage is at a high enough level. A breach in one of the jetties results in a repair action, sediment movement through the gap in the jetty toward the navigation channel, and additional dredging activities. All of these additional costs are accumulated over the life cycle for each individual plan.

Model considerations include: (1) existing condition of structure, (2) previous repairs of structure, (3) foundation conditions, (4) structural failure modes, (5) function, and (6) exposure to waves. The life cycle model application was initiated by simulating the structures' previous life cycle history thus producing a calibrated model of structure performance in the project environment. After the calibration to historical performance, the life cycle analysis model was used to evaluate the effectiveness of the proposed engineering features; jetty head capping, spur groins, and North Jetty lagoon fill. The smallest proposed rehabilitation plan was run with and without the engineering features, each feature separately, to determine if significant benefits were accrued to the project performance. All of the engineering features were found to be justified through the life cycle model application.

The engineering features described above have been applied to all of the full rehabilitation plans. Those features address the larger system deterioration processes and include: (1) jetty head capping to reduce structure loss and morphological impacts, (2) spur groins to stabilize foundation shoals and adjacent shorelines, and (3) backfill of lagoon behind North Jetty root.

The SRB model allows one to review the simulated future life-cycle cost stream in current year value or net present value. Forecasted costs associated with increased dredging are incremental, above normal outlays. Metrics provided by the SRB model which can be used to evaluate life-cycle performance include: time-varying structural and functional reliability, jetty repair occurrence, jetty breach occurrence, components of life-cycle cost, cross-section evolution, and jetty end-state condition. The SRB model is used to formulate an optimal plan for rehabilitating each jetty, predicated on the need to minimize life-cycle costs or maximize reliability. A more detailed description of the SRB model and its application to the MCR jetties can be found in Appendix A2.

The paragraphs and tables below summarize the SRB model results for each alternative type and for each jetty, focusing on the following output parameters:

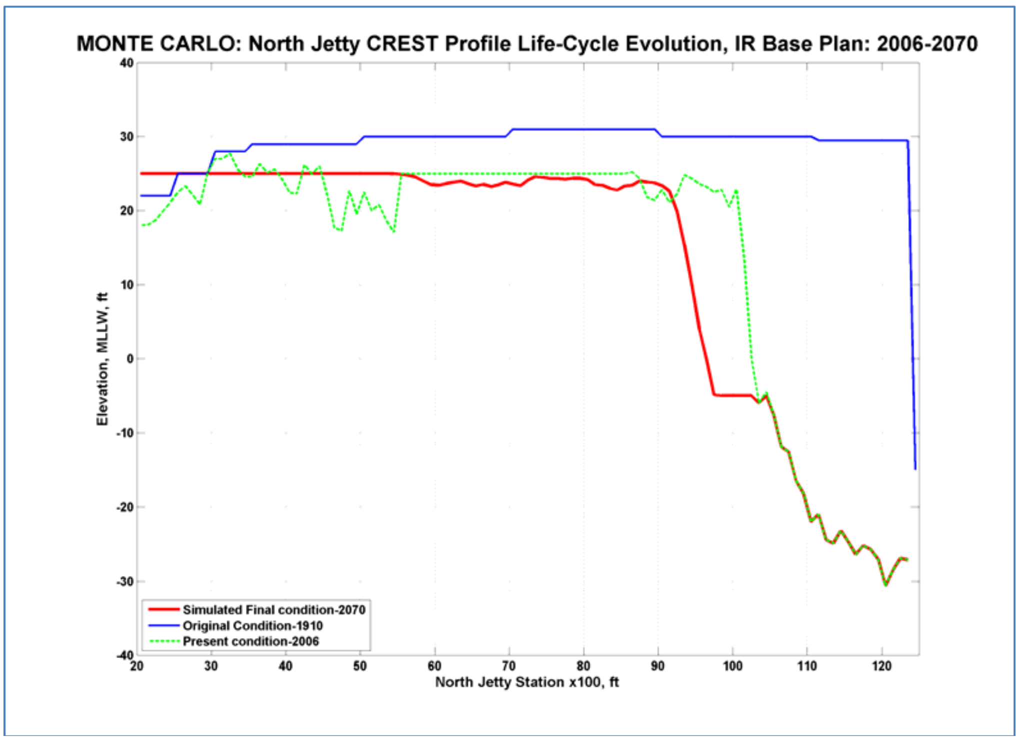
- Degree to which larger system degradation processes are addressed.
- Final projected position of the jetty head.
- Number of large scale repair efforts expected over the project life.
- Expected jetty repair costs over the project life.
- Initiation and frequency of jetty repairs expected.
- Expected increases in dredging costs over project life.
- Extent to which emergency dredging may be expected.
- Estimate the number of significant breach events with potential to impact navigation.
- Average projected structural and functional reliabilities.
- Additional comments on expected jetty maintenance program and potential environmental and inlet effects.

b. Base Condition

1. North Jetty Base Condition

The base condition takes no action to address the larger system degradation processes. The head of the North Jetty continues to recede back at a rate of 20-50 feet per year. The modified head position at the end of the life cycle analysis is estimated at Station 82+00 (about 1,900 feet shorter than the current head position). Potential repairs are expected to begin immediately and extend for the life of the project, as needed. The base condition is expected to result in significant changes to the navigation entrance.

Figure A1- 257, shown below, illustrates the simulated North Jetty crest profile evolution over the project life. In this figure, the blue line depicts the originally constructed North Jetty showing both the authorized length and crest elevation. The green line shows the 2006 condition of the jetty and the red line depicts the changes predicted to occur in the jetty over the next 50 years if the jetty is maintained as described in the base condition. The second graph illustrates the estimated repair and breach frequency per 100 ft segment along the jetty under the base condition. The abbreviation "IR" refers to the Interim repair scenario. The pink line refers to breach frequency and the blue line refers to repair frequency. The dotted black vertical line identifies the head position at the beginning of the simulation. The solid black line shows the head position at the end of the simulation. The third graph shows the functional and structural reliability over the project life.



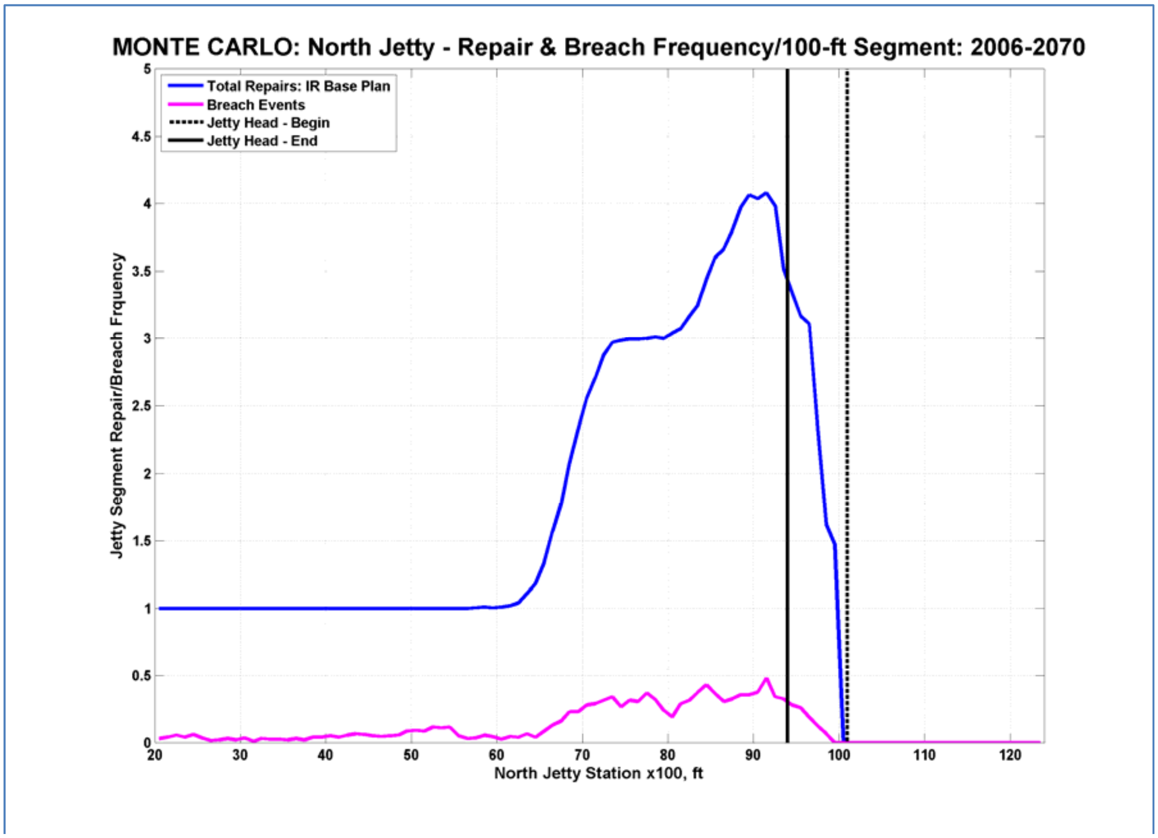


Figure A1- 257. North Jetty Base Condition

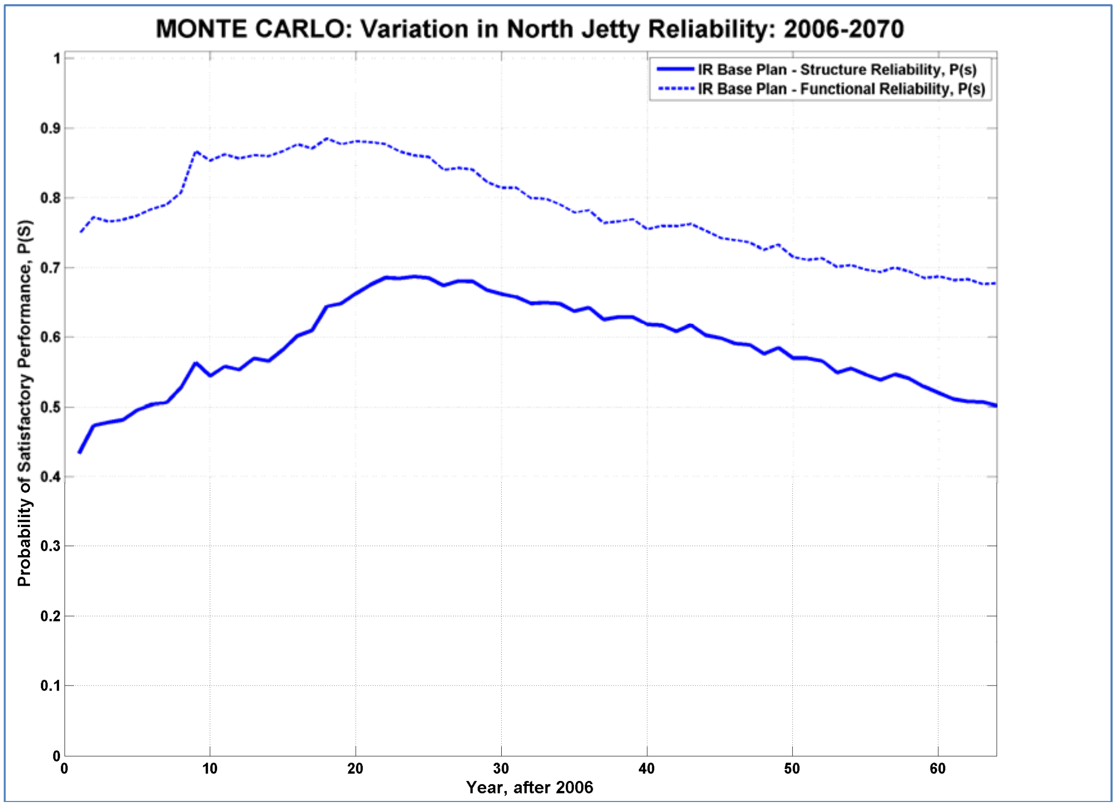


Figure A1- 257 (continued). North Jetty Base Condition

2. South Jetty Base Condition

The base condition takes no action to address the larger system degradation processes except for some shoreline stabilization work at the root of the jetty. The South Jetty head continues to recede back at a rate of 5 to 20 feet per year. The modified jetty head position at the end of the life cycle analysis is estimated to occur at approximately Station 292+00 (about 2,100 feet shorter than the current jetty head position). The base condition is expected to result in significant changes to the navigation entrance.

Figure A1- 258, shown below, illustrates the simulated South Jetty crest profile evolution over the project life. In this figure, the blue line depicts the originally constructed South Jetty showing both the authorized length and crest elevation. The green line shows the 2006 condition of the jetty and the red line depicts the changes that are predicted to occur in the jetty over the next 50 years if the jetty is maintained as described in the base condition. The second graph shows the expected breach and repair frequency and the third graph shows the functional and structural reliability over the project life.

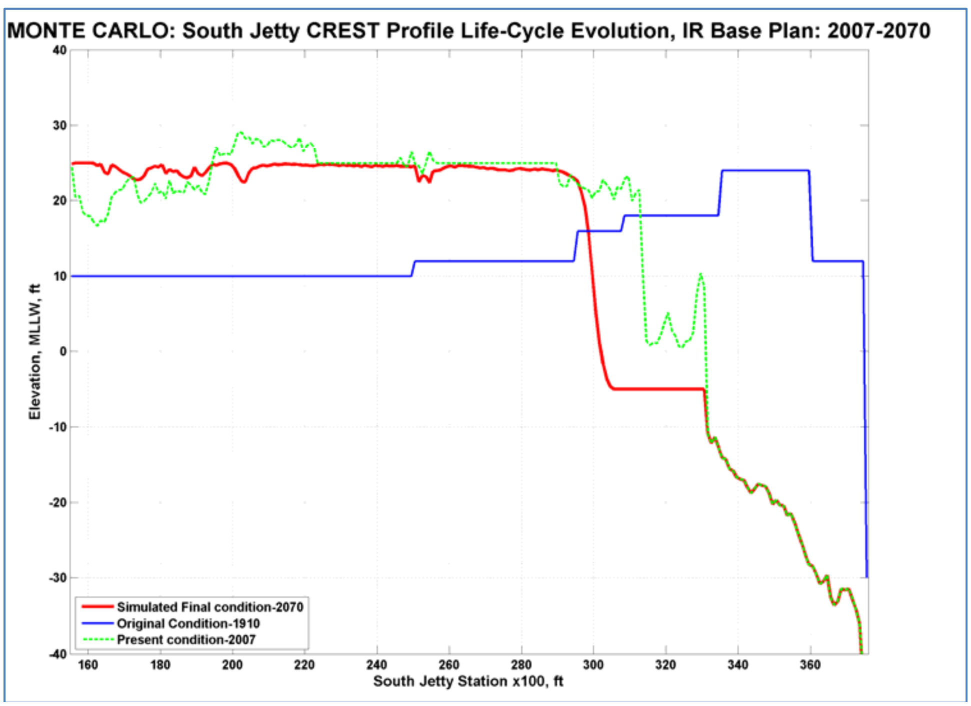


Figure A1- 258. South Jetty Base Condition

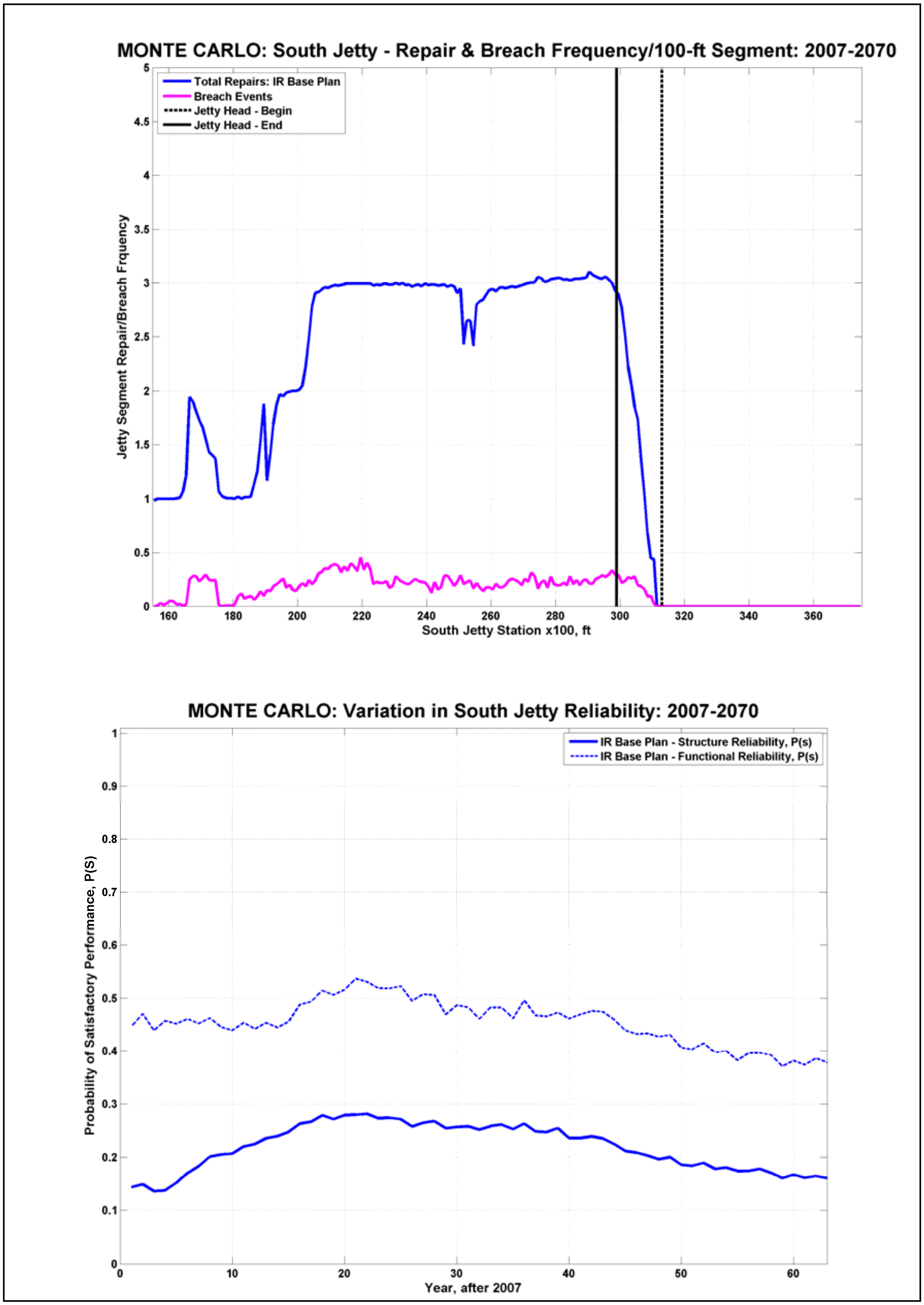


Figure A1- 258 (continued). South Jetty Base Condition

3. Jetty A Base Condition

The base condition takes no action to address the larger system degradation processes. The head of Jetty A continues to recede back at a rate of 5 to 20 feet per year. The modified jetty head position at the end of the life cycle analysis is approximately at Station 82+00 (about 600 feet shorter than the current jetty head position). The base condition is expected to result in significant changes to the navigation entrance.

In Figure A1- 259, shown below, the blue line depicts the originally constructed Jetty A showing both the authorized length and crest elevation. The green line shows the 2006 condition of the jetty and the red line depicts the changes that are predicted to occur in the jetty over the next 50 years if the jetty is maintained as described in the base condition.

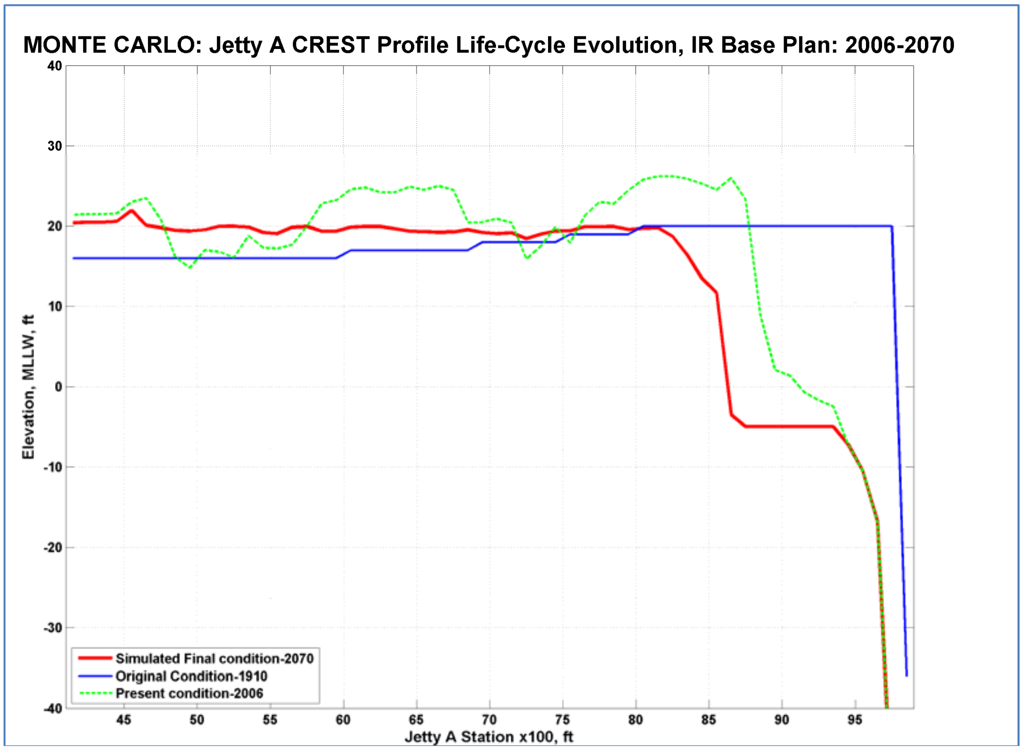


Figure A1- 259. Jetty A Base Condition

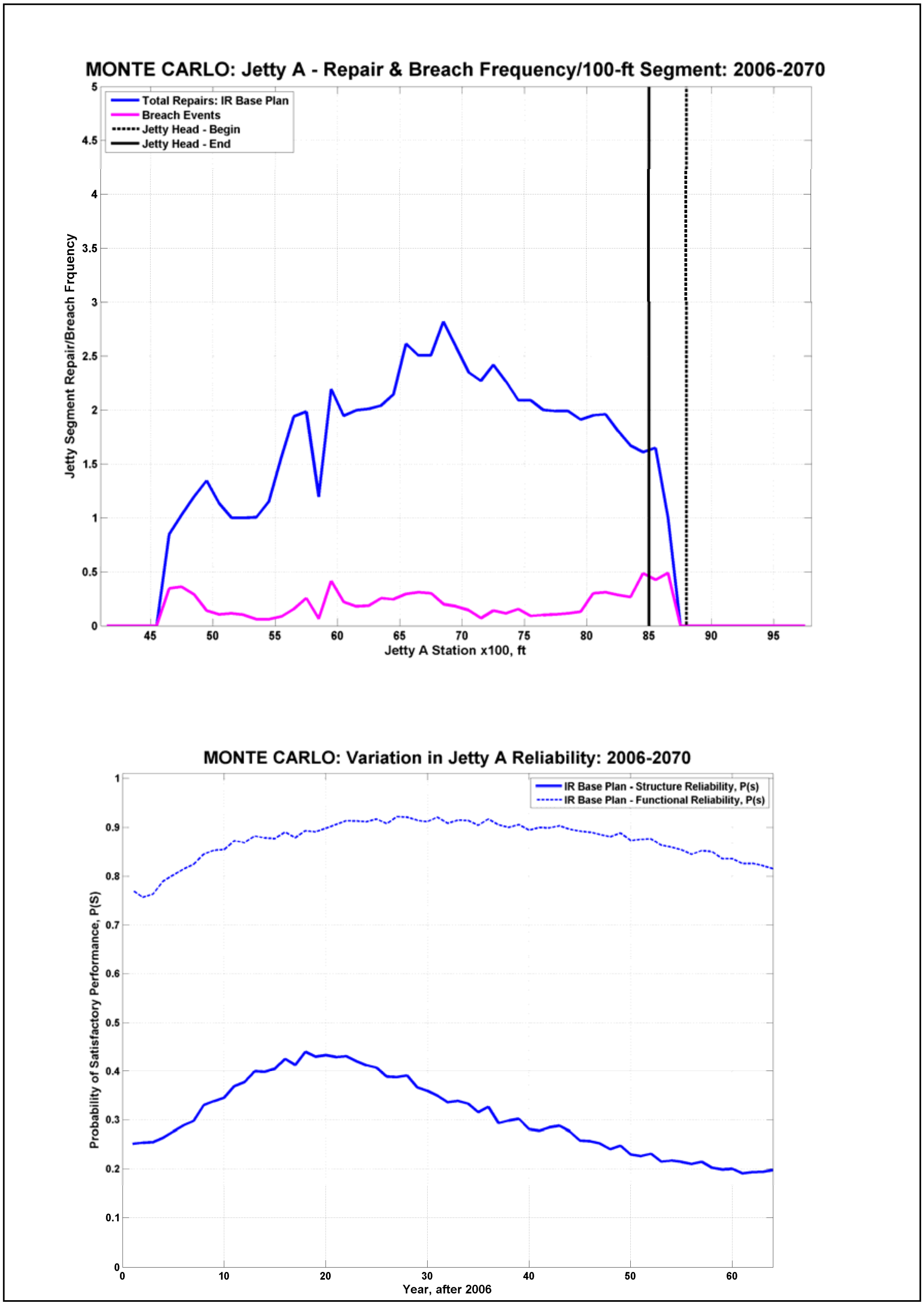


Figure A1- 259 (continued). Jetty A Base Condition

The focus of this major rehabilitation study was to identify alternatives and recommend a course of action that optimizes future reliability and life-cycle cost for the MCR jetty system. Optimized alternatives were developed through a step-wise procedure. First, the structural and functional risks affecting the present life cycle of each jetty were identified and evaluated. Second, a range of incremental alternatives were developed to mitigate present and future risks affecting the life cycle of each jetty. Alternatives included various repair maintenance scenarios, cross-section rehabilitation schemes, and several engineering features. Third, an implementation schedule was developed for each alternative to match construction timing project risk over the life-cycle period. Alternatives included non-rehabilitation based on implementing different levels of future maintenance strategies. Evaluation of alternative maintenance strategies focused on varying the threshold level for initiating jetty repairs. Non-rehabilitation alternatives avoid the initial cost of structure rehabilitation, but can incur elevated future maintenance commitment and cost by having to mitigate continual low reliability. In cases where repairs were deferred during the previous life cycle, a proactive future maintenance strategy may require online repairs very early into the future life cycle, emulating the magnitude of initial costs associated with structure rehabilitation.

c. Scheduled Repair Alternatives

This alternative consists of conducting scheduled repairs only addressing above-water structural instability of the three MCR jetties, performing repairs as needed, and performing expedited or emergency/increased routine maintenance dredging. This alternative is slightly more proactive than the without project alternative. This type of repair strategy would continue for the entire project life with only slight increases to the reliability of the jetty structures. Scheduled repairs would be somewhat more robust than repairs conducted under the without project alternative. In general, a scheduled repair could be initiated when the Portland District jetty monitoring team conducts the annual inspection and observes changes in crest width, cross section, or length, or when the Coast Guard or Columbia River Bar Pilots notify the Portland District that a significant change has occurred due to a winter storm event. Subsequent to the identification of damage areas, surveys would be conducted to determine if a scheduled repair action was justified in the near term. At that point, a decision would be made to begin the budget process to initiate the repair. Scheduled repair plans were developed with and without engineering features (spur groin and head capping for the South Jetty, and spur groin, head capping and lagoon fill for the North Jetty).

1. North Jetty Scheduled Repair Alternatives

The North Jetty was evaluated for two scheduled repair alternatives: scheduled repair without engineering features and scheduled repair with head capping, spur groins and lagoon fill (all engineering features). Both of these alternatives were evaluate with and without an option to hold the jetty head at its current location. Note that the scheduled repair cross-section template, shown in Figure A1- 260, places repair stone only in the upper portion of the cross section. Improved below water stabilization for the jetty cross section is achieved only through the placement of spur groins for one of these alternatives.

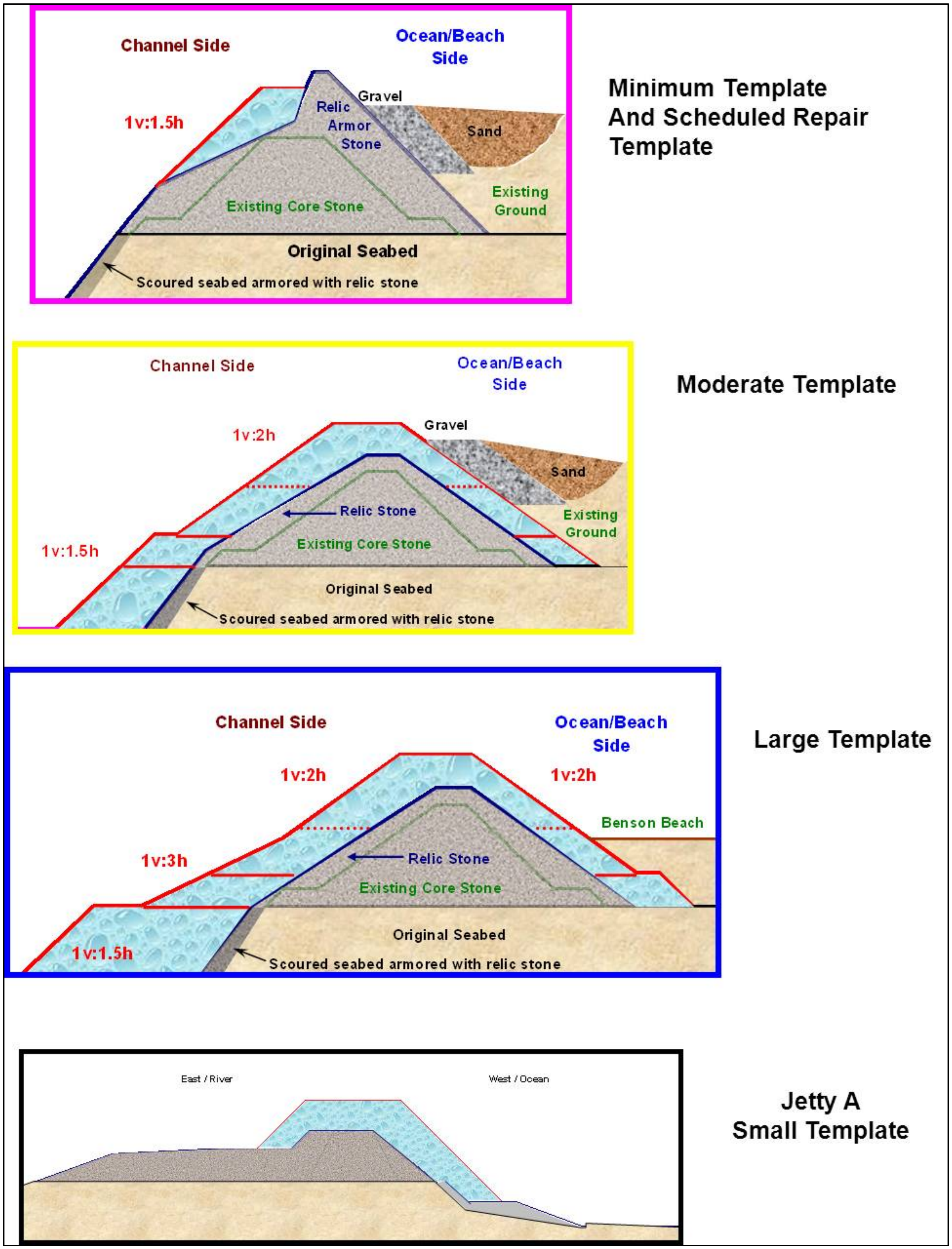


Figure A1- 260. North Jetty and Jetty A Conceptual Cross Section Templates

Model results for the two scheduled repair alternatives as compared to the base condition are shown in Figure A1- 261 and Figure A1- 262 with and without holding the head at the existing location. Due to the present deteriorated condition of the North Jetty, the scheduled repair alternatives will require an aggressive monitoring and maintenance program for the life of the project. Improved below-water stabilization for the jetty cross section is achieved only through placement of spur groins for one of these alternatives. Repairs are expected to begin immediately and extend through the period of analysis.

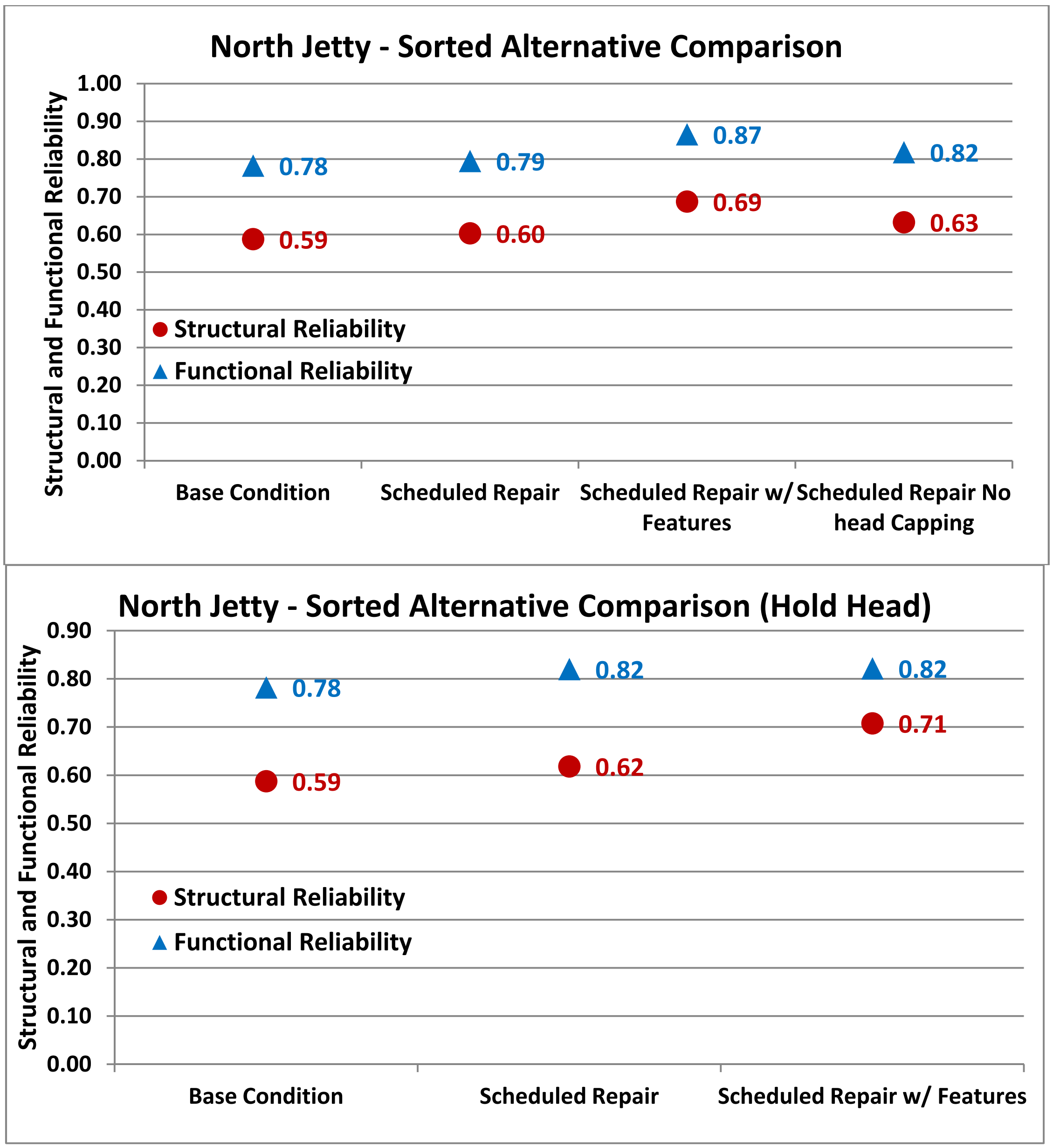
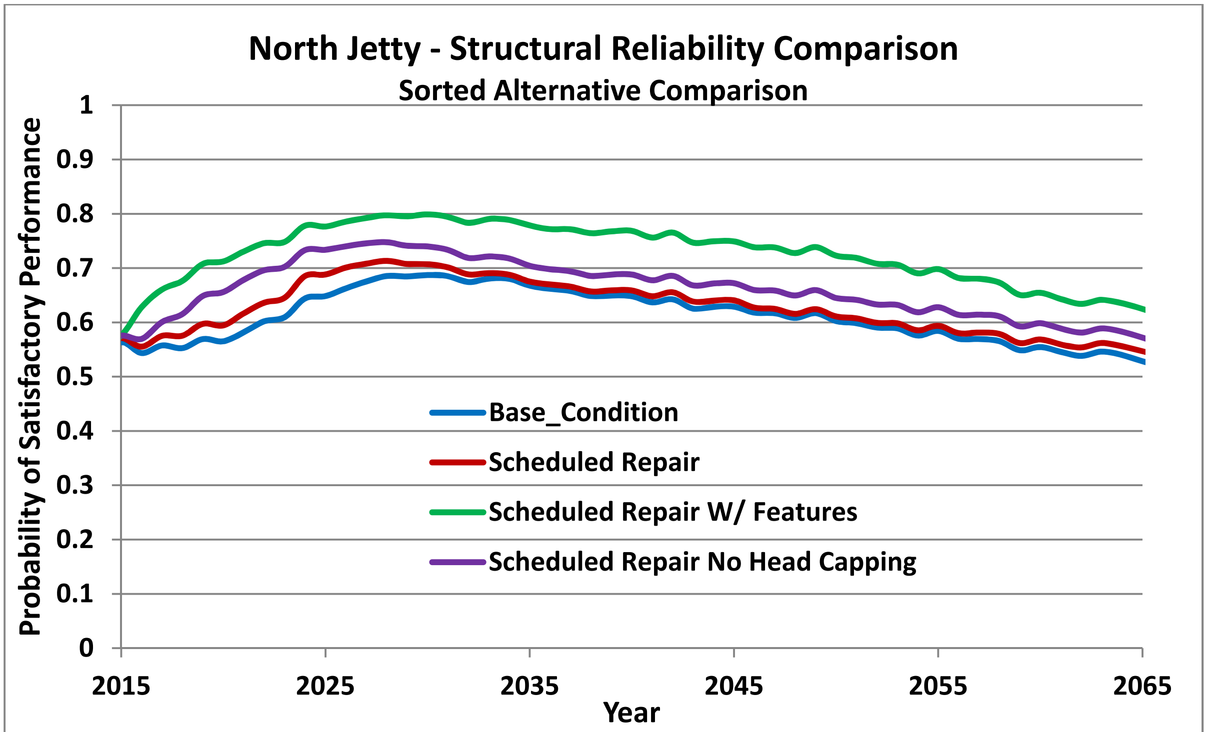


Figure A1- 261. North Jetty Base Condition and Scheduled Repair Alternatives Comparison



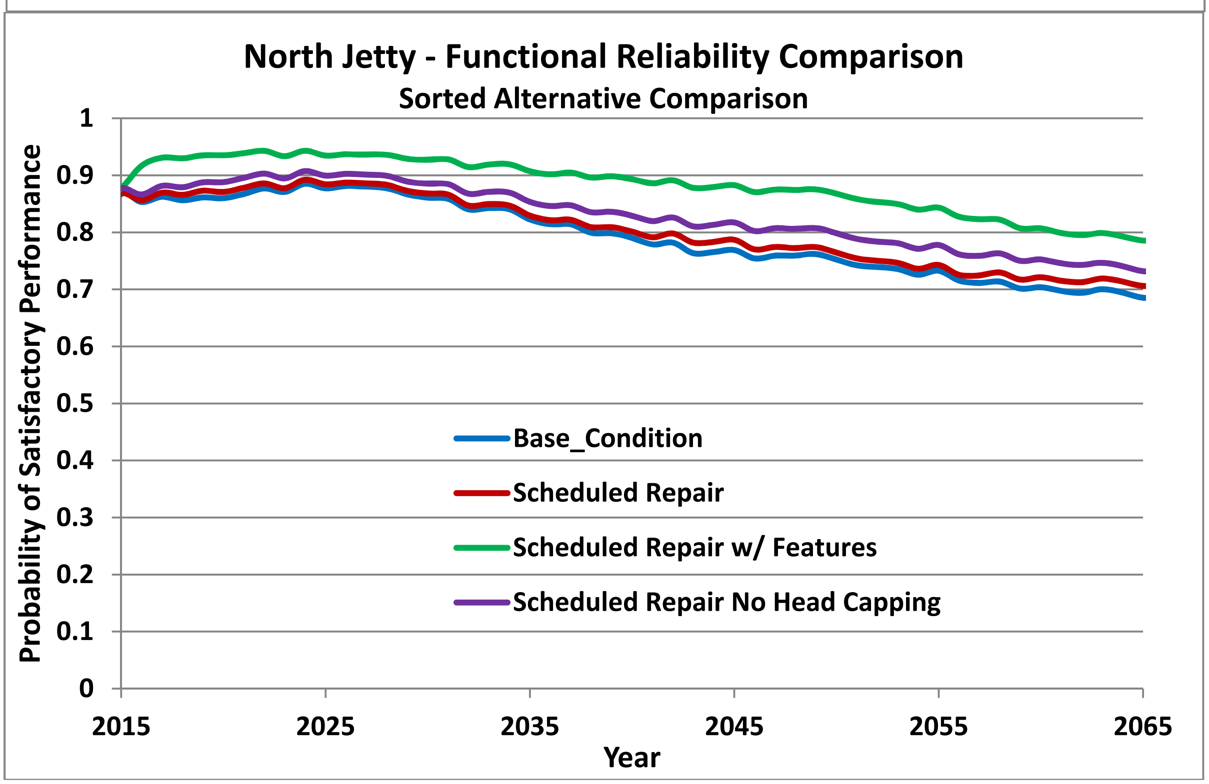
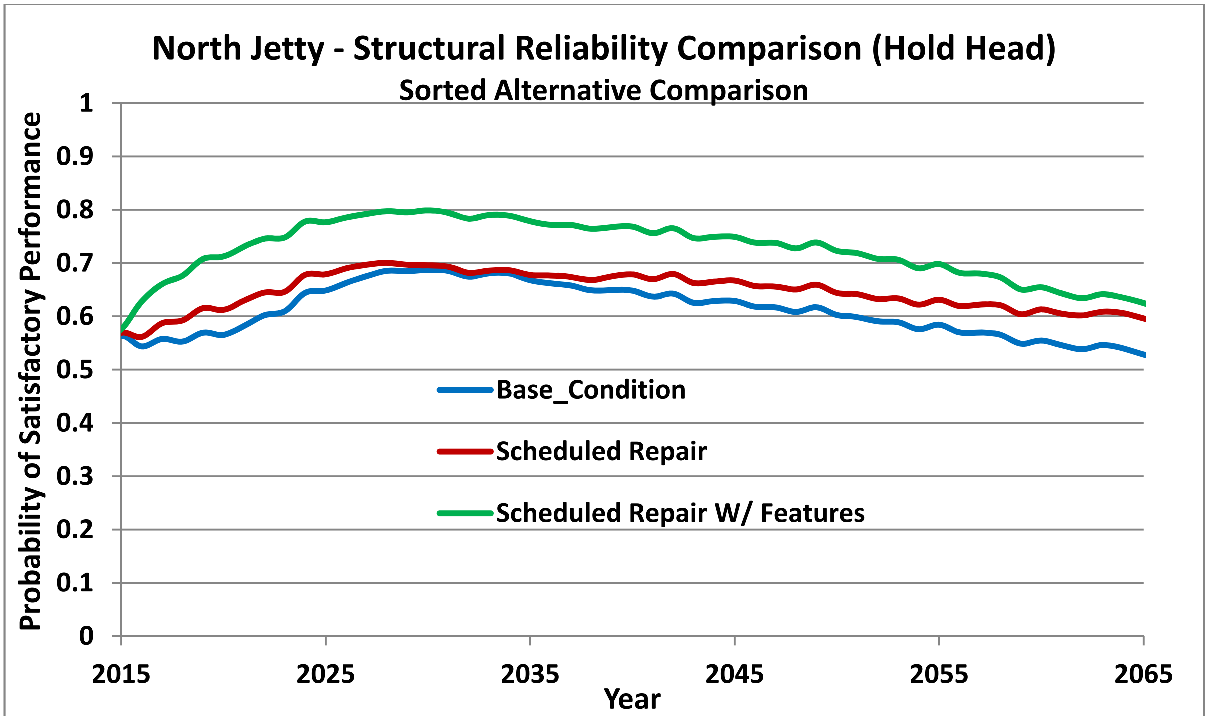


Figure A1- 262. North Jetty Reliabilities for Scheduled Repair Alternatives

The scheduled repair alternative without engineering features takes no action to address the larger system degradation processes. Despite the aggressive maintenance program required, significant changes to the navigation entrance would be expected to occur primarily due to unchecked jetty length recession and continued foundation erosion. At the current projected rate of recession, North Jetty length loss is expected to be approximately 1,400 ft. The scheduled repair alternative with engineering features (head stabilization, spur groins, lagoon fill) addresses the larger areas of destabilization (head recession, foundation erosion, jetty root backside erosion); however, the alternative will still require an aggressive monitoring and maintenance program to maintain reliability of the structure.

Both structural and functional reliabilities are improved over the base condition and are also incrementally improved with the addition of the engineering features. This result is achieved through the execution of an aggressive and frequent maintenance program over the entire period of analysis. Figure A1- 263 illustrates the structural and functional reliability over the period of analysis for this group of plans.



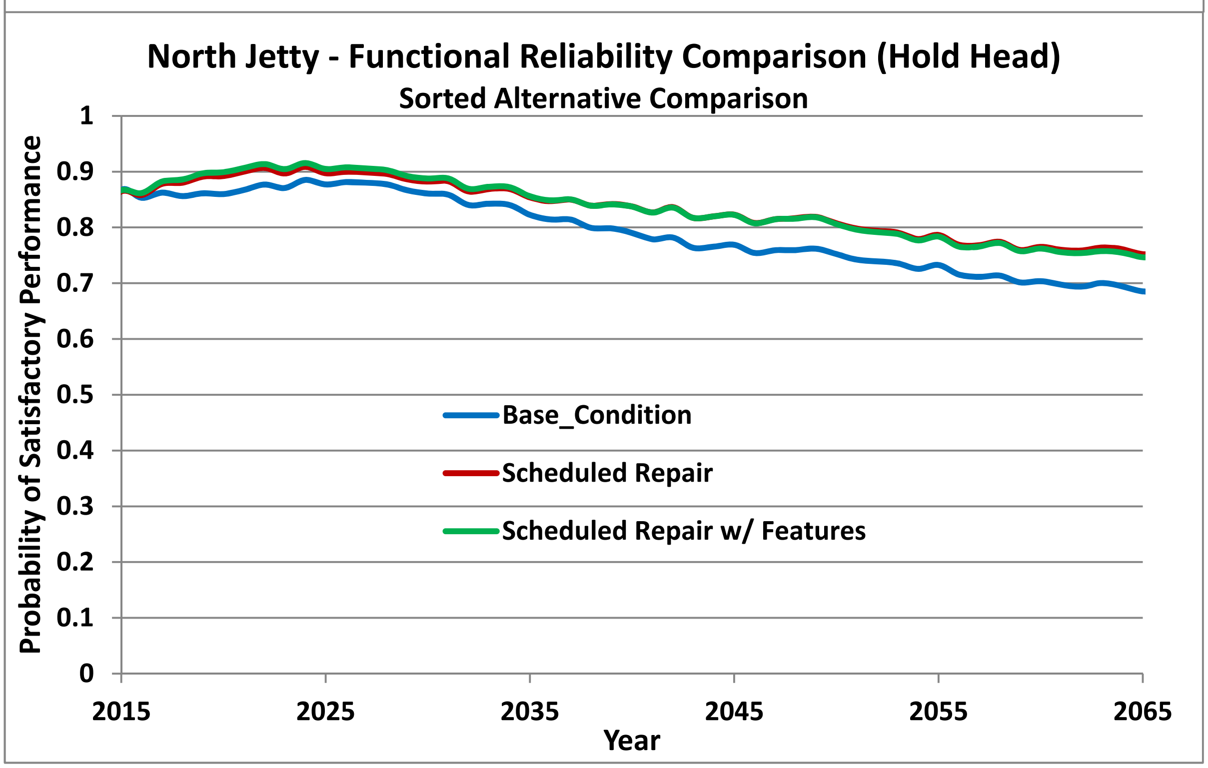


Figure A1- 263. North Jetty Reliabilities for Scheduled Repair Alternatives

The scheduled repair alternative without engineering features results in a higher additional dredging requirement related to jetty length recession, although this amount is less than the required dredging under the base condition. The jetty length recession under this plan also increases the projected jetty repair costs due to increased loading on the remaining structure. The environmental impacts are expected to be high for both the base condition and the scheduled repair alternative without engineering features primarily due to hydrodynamic and morphologic changes to the navigation entrance resulting from jetty length recession. Of these alternatives, the scheduled repair alternative with engineering features has the lowest number of projected breaches at (1.9) and the lowest number of expected future repairs (4).

2. South Jetty Scheduled Repair Alternatives

The South Jetty was evaluated for three scheduled repair alternatives: (1) scheduled repair without engineering features, (2) scheduled repair with head capping, and (3) scheduled repair with head capping and spur groins (all engineering features). All of these alternatives were evaluated with and without the option to maintain the jetty head at the existing location. Note that the scheduled repair cross-section template, shown in Figure A1- 264, places repair stone only in the upper portion of the cross section. Improved below water stabilization for the jetty cross section is achieved only through the placement of spur groins for one of these alternatives. All of these plans include work conducted to ensure shoreline stabilization at the South Jetty root. Those plans that include jetty head stabilization of the head position at approximately Station 313. Model results for these three alternatives are shown in Figure A1-265 and Figure A1- 266. Due to the present deteriorated condition of the South Jetty, all scheduled repair alternatives will require an aggressive monitoring and maintenance program for the life of the project. Repairs are expected to begin immediately and extend through the period of analysis.

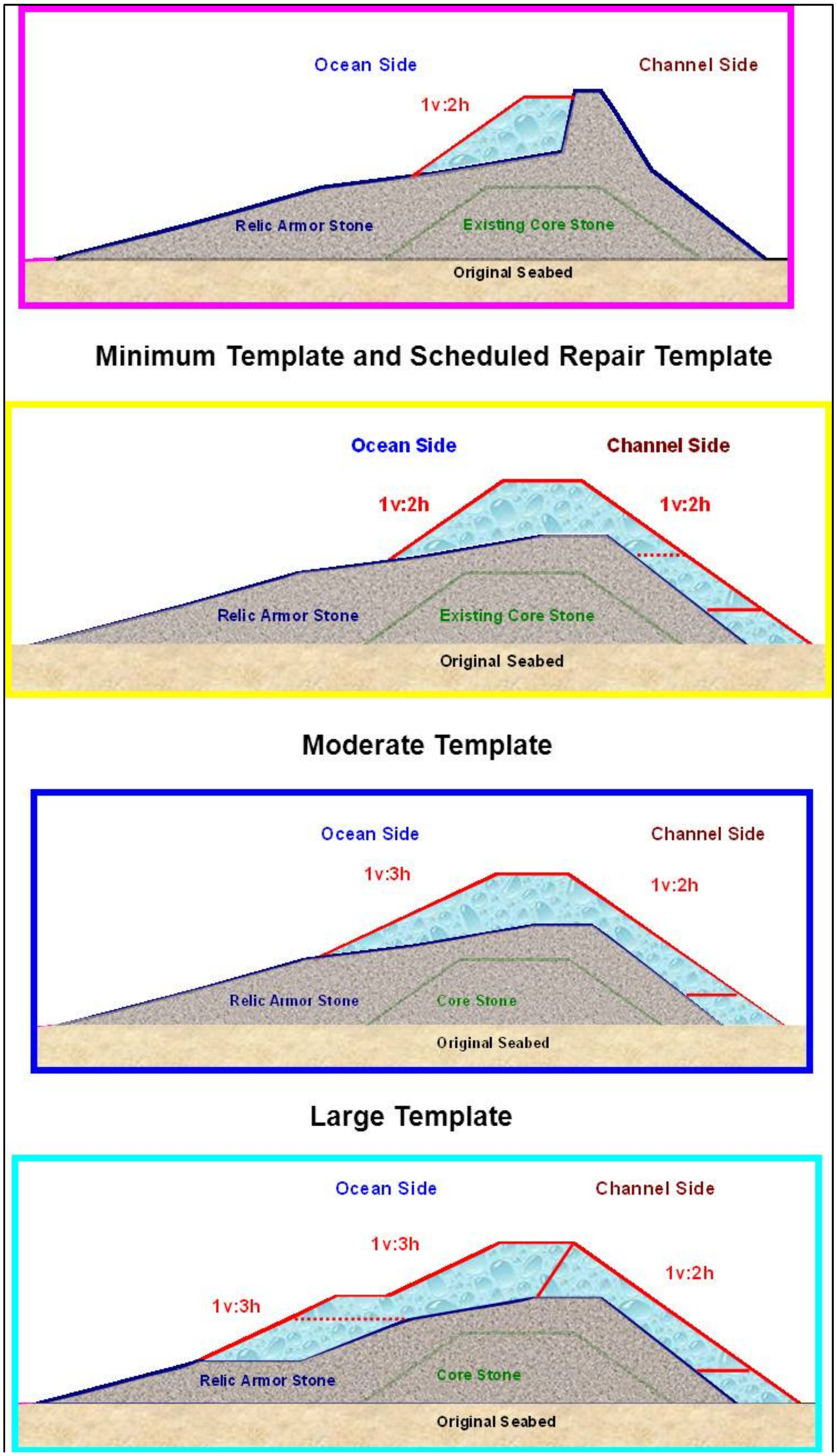


Figure A1- 264. South Jetty Conceptual Cross Section Templates

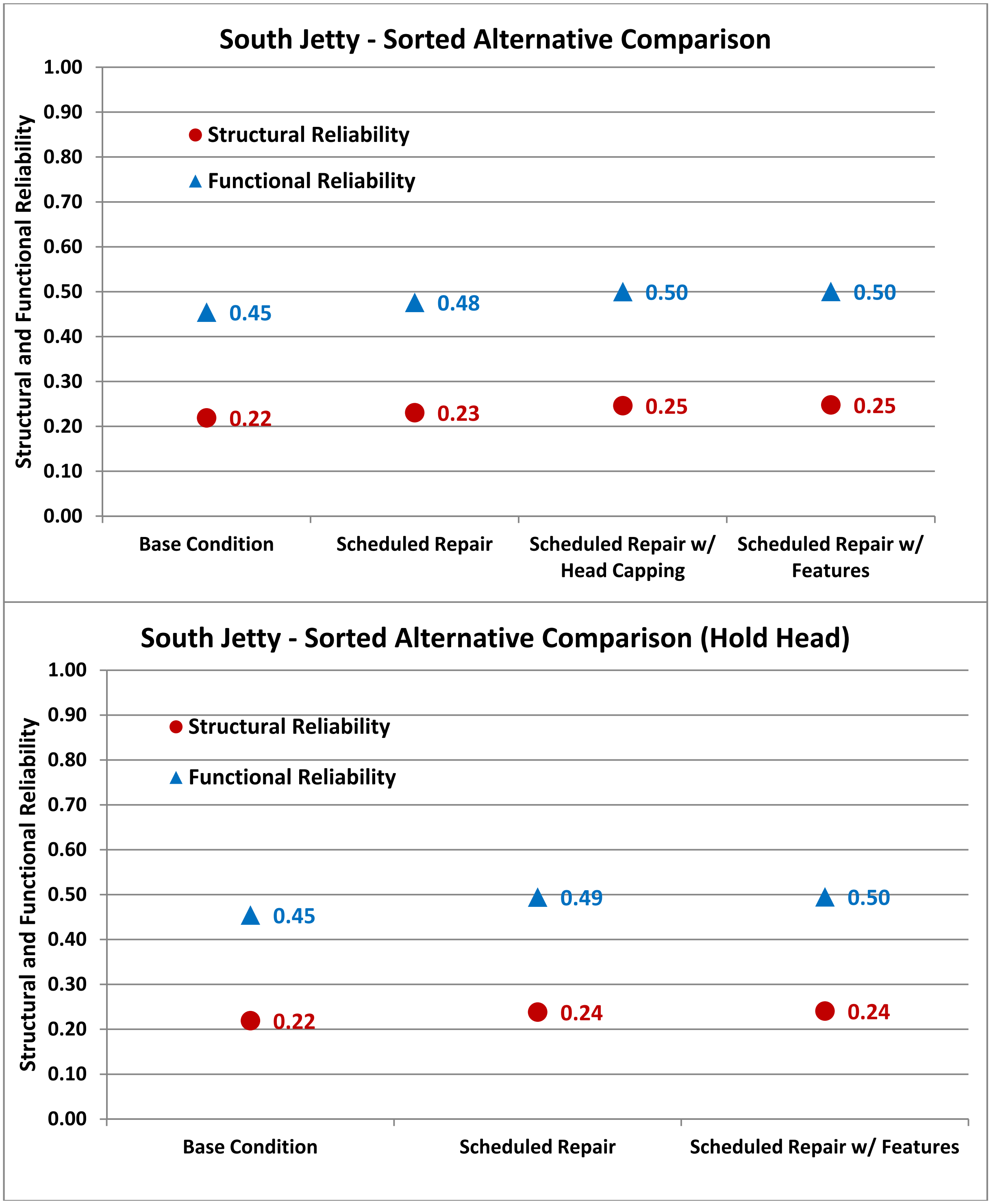
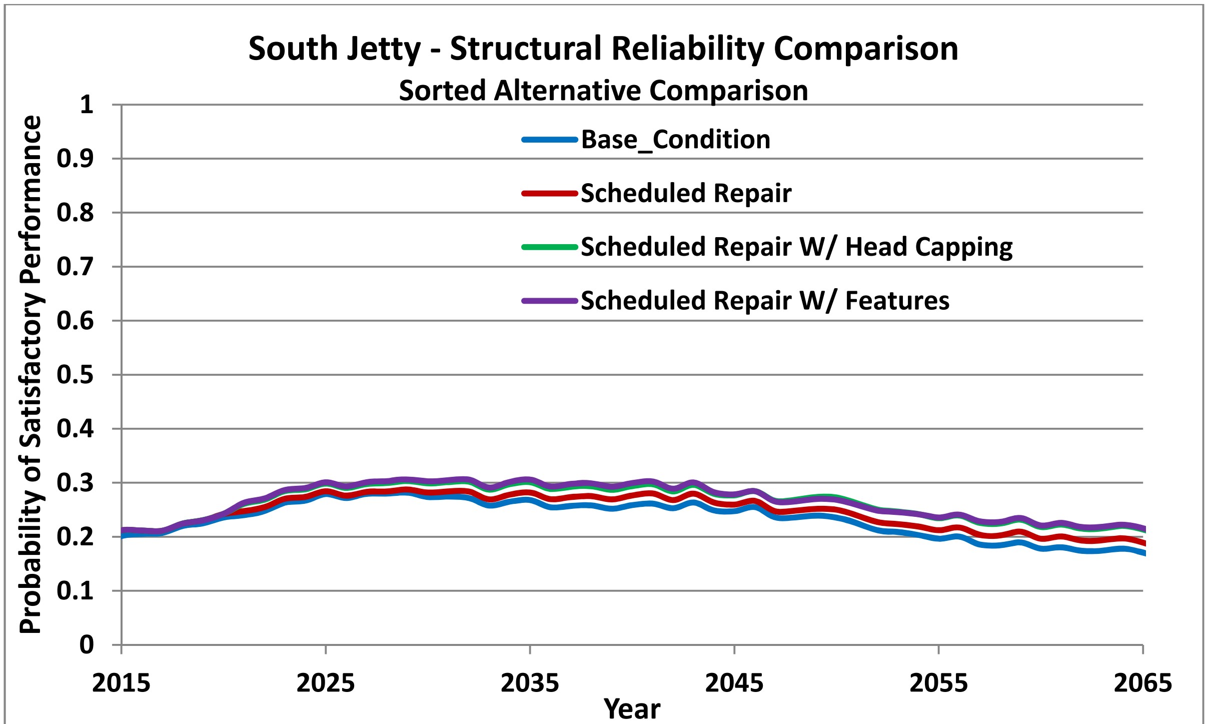


Figure A1- 265. South Jetty Base Condition and Scheduled Repair Comparison



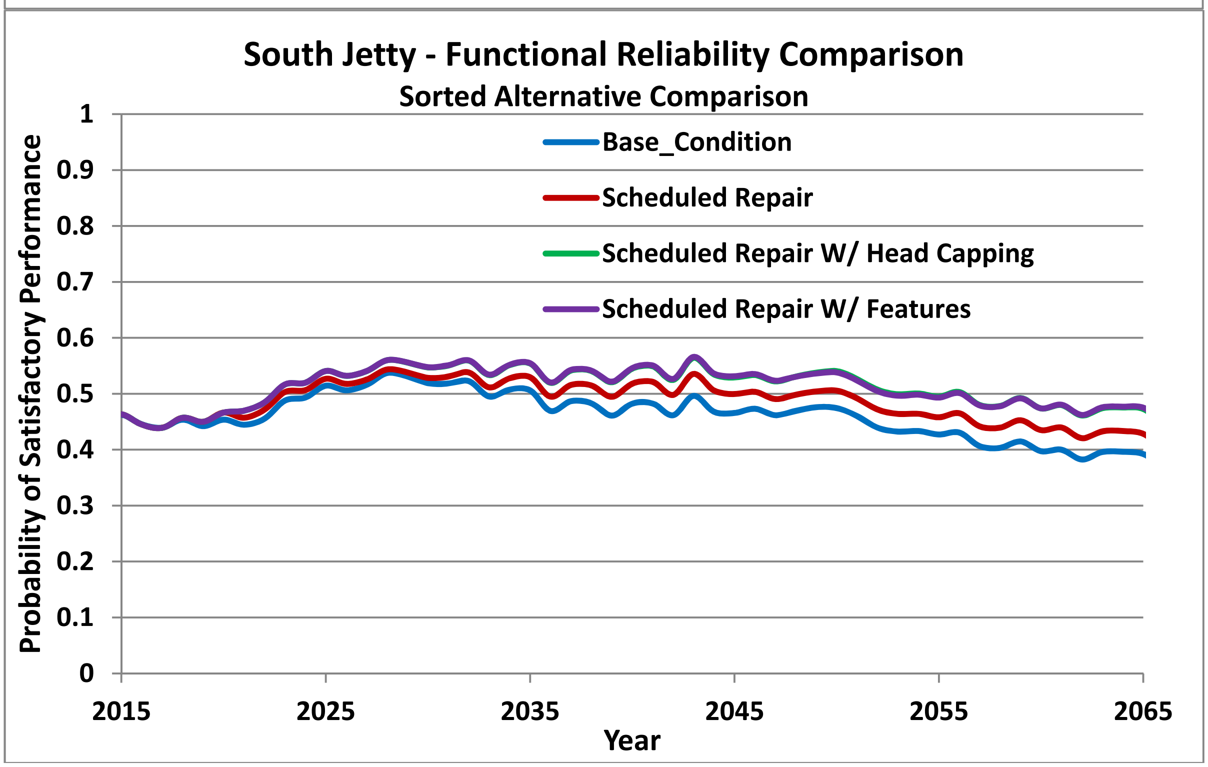
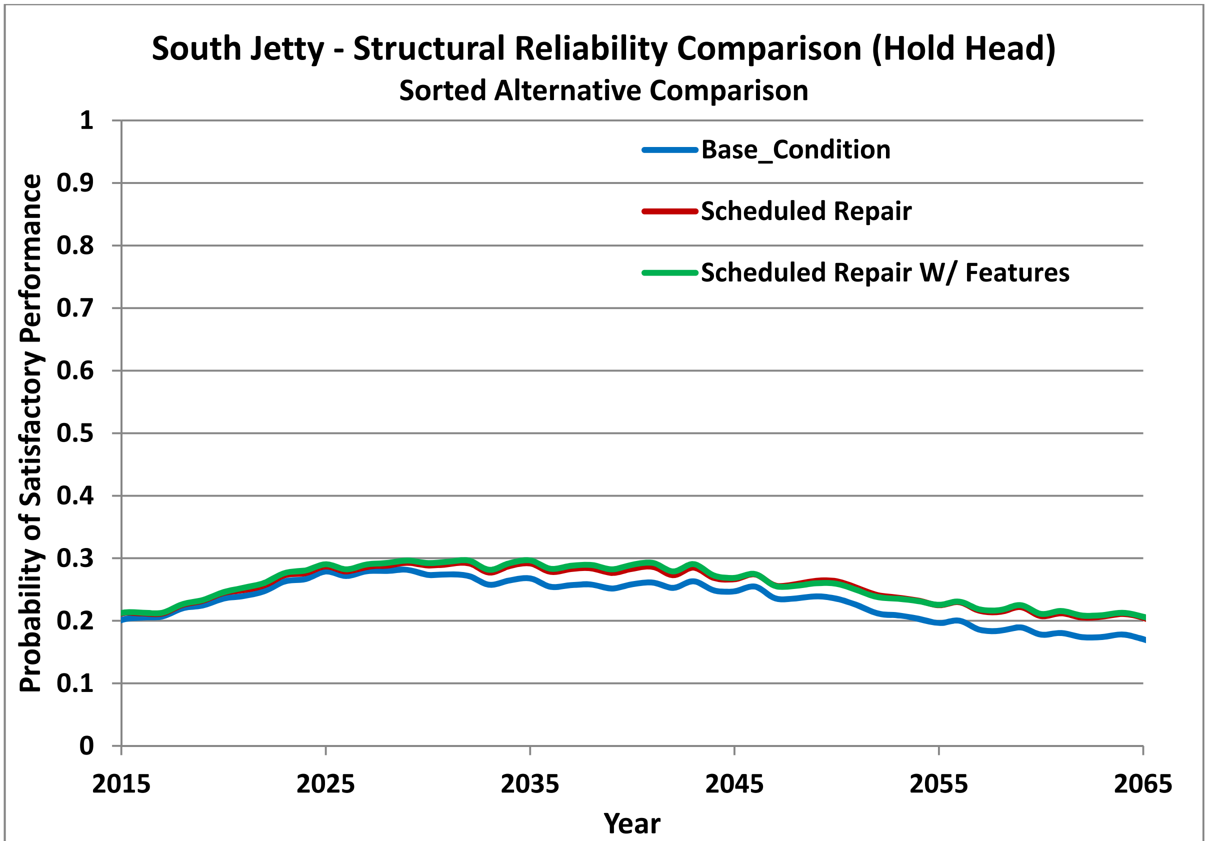


Figure A1- 266. South Jetty Reliabilities for Scheduled Repair Alternatives



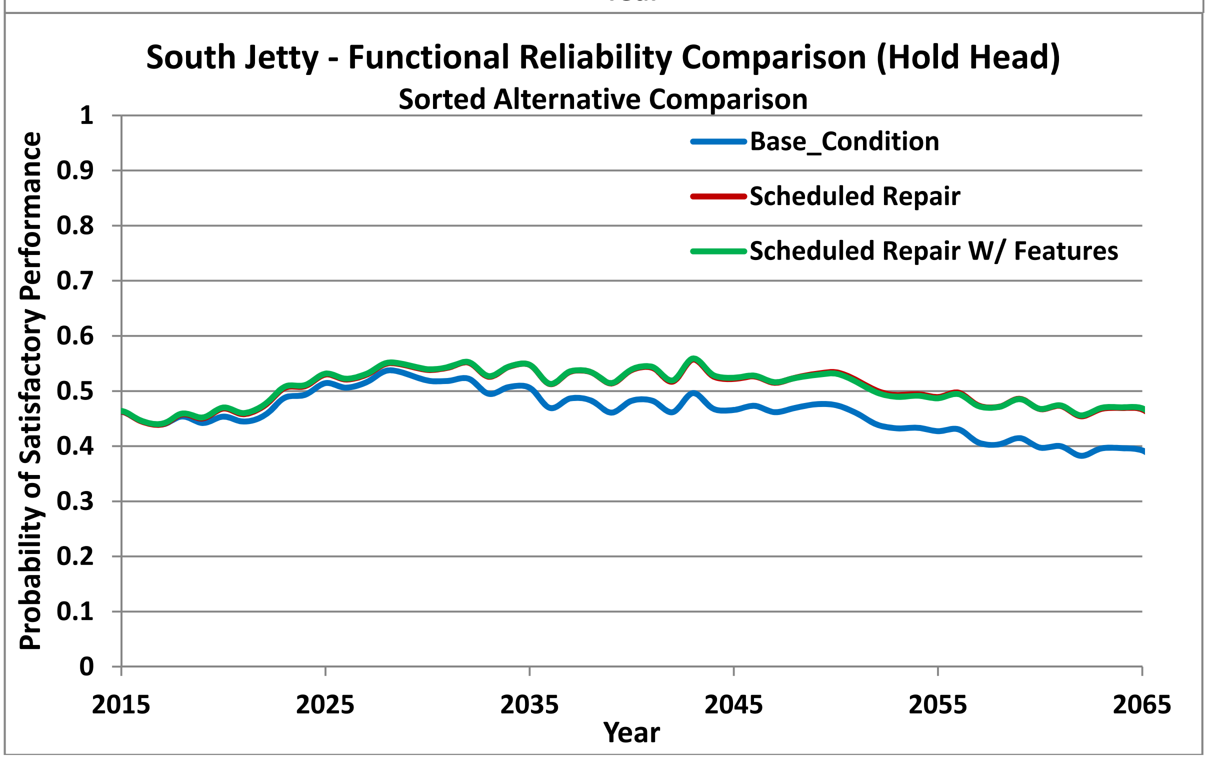


Figure A1- 266 (Continued). South Jetty Reliabilities for Scheduled Repair Alternatives

The scheduled repair alternative without engineering features takes no action to address the larger system degradation processes. Despite the aggressive maintenance program required, significant changes to the navigation entrance would be expected to occur primarily due to unchecked jetty length recession and continued foundation erosion. At the current projected recession rate, jetty length loss is expected to be approximately 900 ft.

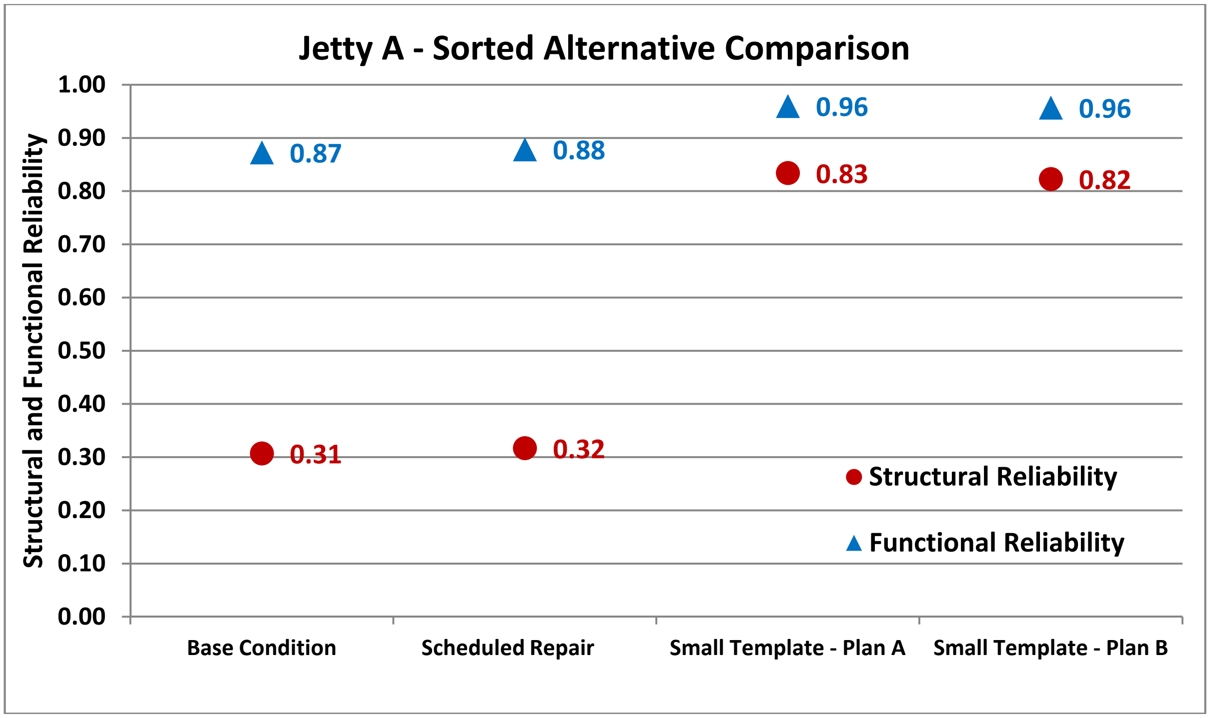
The scheduled repair alternative with head capping stabilizes the head position but due to the lack of spur groin construction, does not improve on foundation stability. The scheduled repair alternative with engineering features (head capping, spur groins) addresses the larger areas of destabilization (head recession, foundation erosion); however, it will require an aggressive monitoring and maintenance program to maintain reliability of the structure.

As compared to the base condition, the South Jetty scheduled repair alternatives are successful in reducing the total project costs over the period of analysis. Both structural and functional reliabilities are improved over the base condition and are also incrementally improved with the addition of the engineering features. This result is achieved through the execution of an aggressive and frequent maintenance program over the entire period of analysis, resulting in the expected placement of approximately 1,040,000 tons of stone through the first 20 years of project execution. Figure A1- 266 illustrates the structural and functional reliability over the period of analysis for this group of plans.

The impacts to the environment are expected to be high for both the base condition and scheduled repair without engineering features primarily due to hydrodynamic and morphologic changes to the navigation entrance resulting from jetty recession. The three scheduled repair plans have similar predicted number of breaches and number of projected repairs. The scheduled repair alternative without engineering features, however, has projected large impacts on the navigation inlet due to continued jetty recession, foundation erosion, and hydrodynamic modifications.

3. Jetty A Scheduled Repair Alternative

One scheduled repair option was considered for Jetty A, scheduled repair without engineering features, which takes no action to address the larger system degradation processes. This alternative was evaluated both with and without holding the jetty head at the existing location. Without the head stabilization option, the jetty head continues to recede back at a rate of 5-20 feet per year. The modified head at the end of the life-cycle analysis is at approximately Station 84 (about 400 feet shorter than current position). This alternative requires an aggressive monitoring/maintenance program for the life of the project. Significant changes to the navigation entrance would be expected to occur due to jetty length recession. Continued loss of length is expected to have negative impacts to the North Jetty channelside foundation. Figure A1- 267 compares the scheduled repair alternative (and two immediate rehabilitation alternatives) to the base condition. Figure A1- 268 illustrates the structural and functional reliability over the period of analysis.



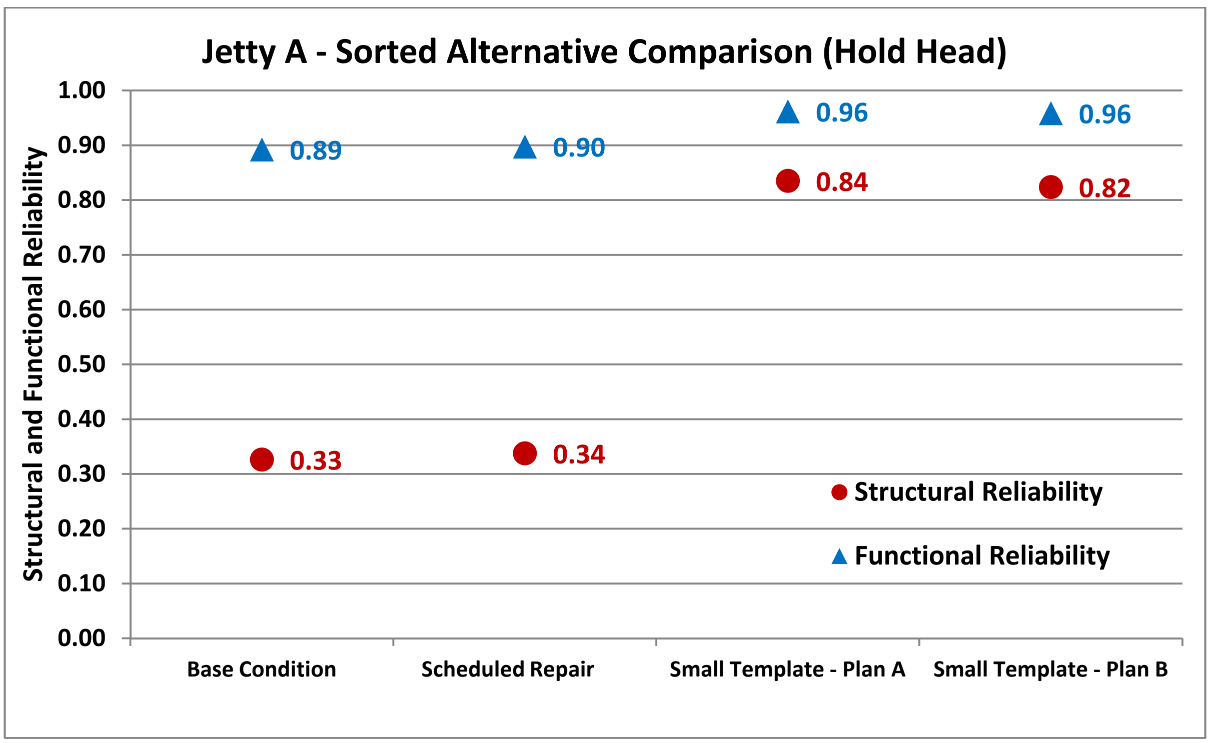


Figure A1- 267. Jetty A Base Condition and Scheduled Repair Comparison

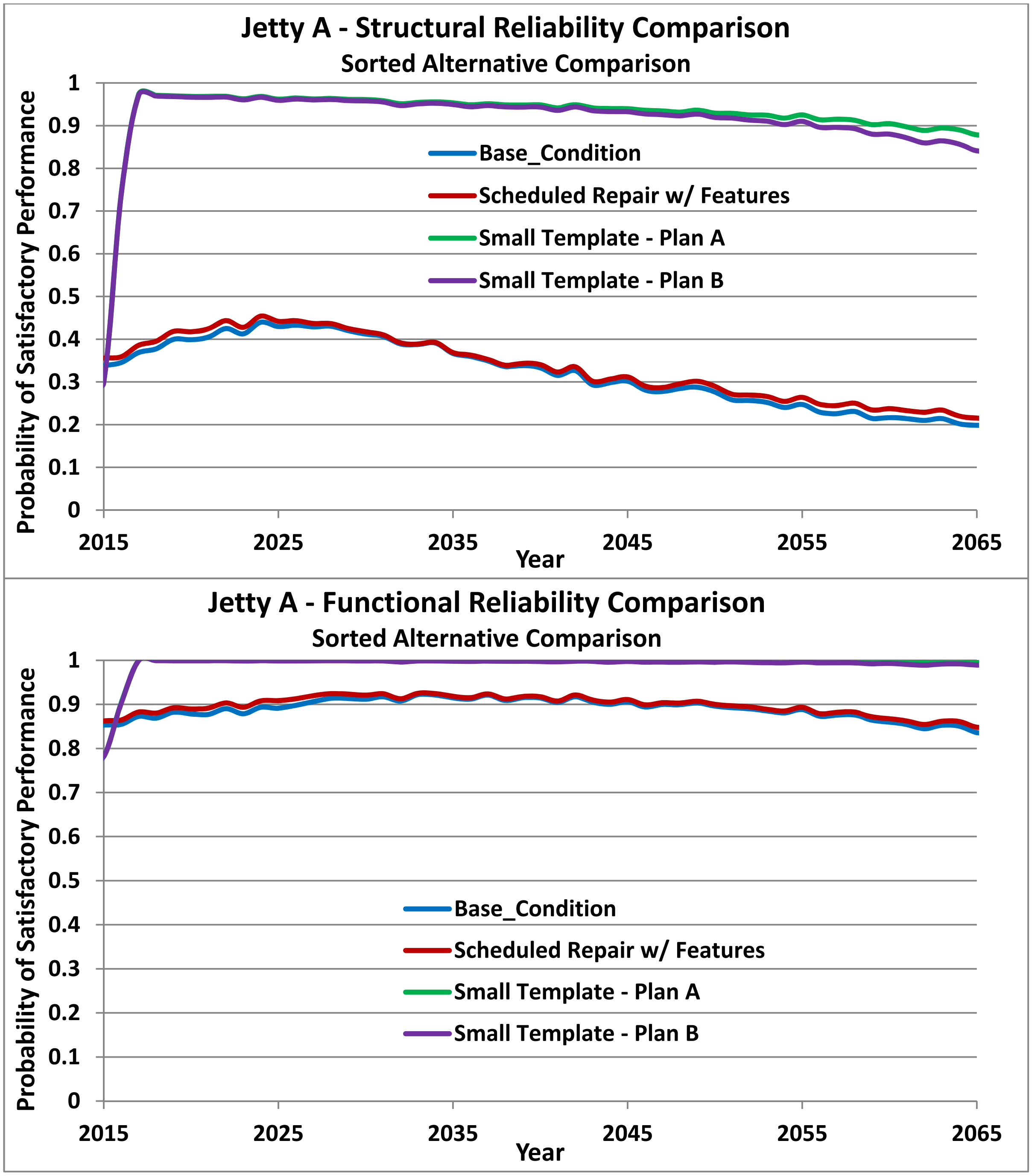


Figure A1- 268. Jetty A Reliabilities for Scheduled Repair Alternatives

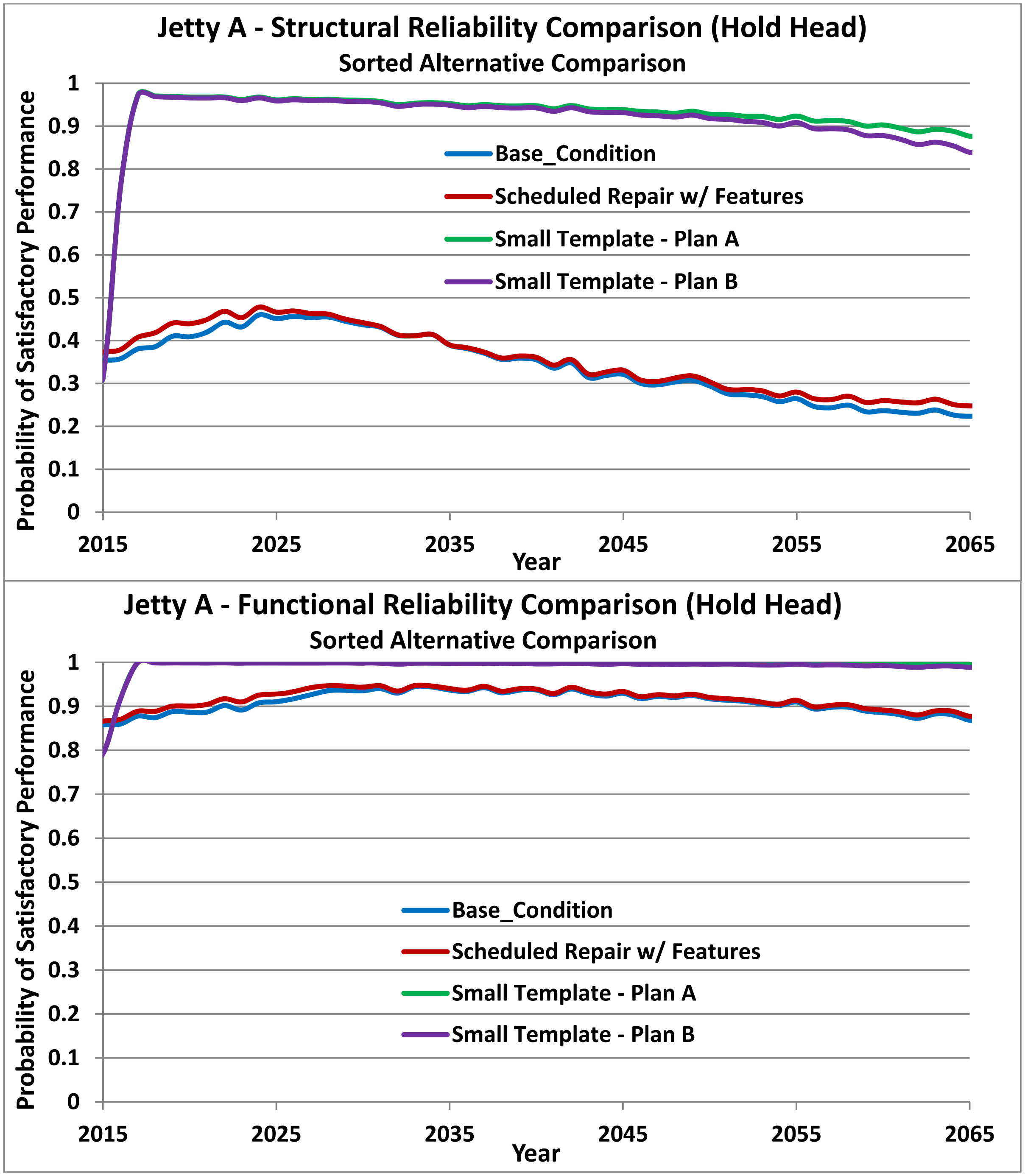


Figure A1- 268 **(continued). Jetty A Reliabilities for Scheduled Repair Alternatives**

d. Major Rehabilitation Alternatives

Rehabilitation alternatives focused on reconstructing (or enhancing) the jetty cross-section based on a range of cross-section templates that eventually informed on the development of the composite plans. Jetty rehabilitation alternatives induce a high initial cost, but restore project reliability early into the future life-cycle and can reduce the future maintenance commitment. Incremental structural enhancements (engineering features) were developed as a way to mitigate chronic effects of jetty foundation scour and jetty root degradation.

The rehabilitation alternatives include all engineering features for structure stability. The intent of rehabilitation of the MCR jetties is three-fold: (1) to improve the stability of the foundation (toe) of each jetty affected by scour; (2) to improve the side-slope stability (above and below water) of each jetty; and (3) to improve the stability of each jetty to withstand wave impact. Not all of the full rehabilitation plans address these 3 areas along each structure to the same degree. Two different methods were used to apply the rehabilitation alternatives: immediate and scheduled.

Development of the composite plans utilized the life cycle model results from the minimum, small, moderate, and large templates to establish initial transition points. Refer to Figure A1-269 for the distribution of the various templates along the jetty. The color border around each cross section corresponds to the same color bars on the jetty length. The first composite plan developed for both the North and South jetties, composite 1-large, identified the transition point along the jetty length that each jetty cross section template began to have increasing repair and breach occurrences. Therefore, the composite 1 plan for the North and South jetties is the most robust composite plan and the plan identified as best suited to resist the particular design loading along the jetty length. Subsequent composite plans were developed to optimize costs while trying to achieve an acceptable structural and functional reliability

1. Immediate Rehabilitation

Under immediate rehabilitation, actions would begin at a given year and continue annually until the entire jetty is completed. Several composite plans were developed for each of the three jetties whereby the cross-section of the jetty varies along the length of the jetty. The approximate location where the cross section is increased was based on individual model runs of one cross section applied along the entire jetty. The model results were analyzed and transition points determined based on how reliable the cross section performed over the project life and minimizing federal cost over time. All of these plans include engineering features; head stabilization at approximately Station 101, spur groins, and lagoon fill. Therefore there was no loss of jetty length for any of these plans.

The option for maintaining the jetty heads at their existing location was also evaluated for each of the rehabilitation plans. This was evaluated by utilizing the rehabilitation repair alternative rather than a head cap feature.

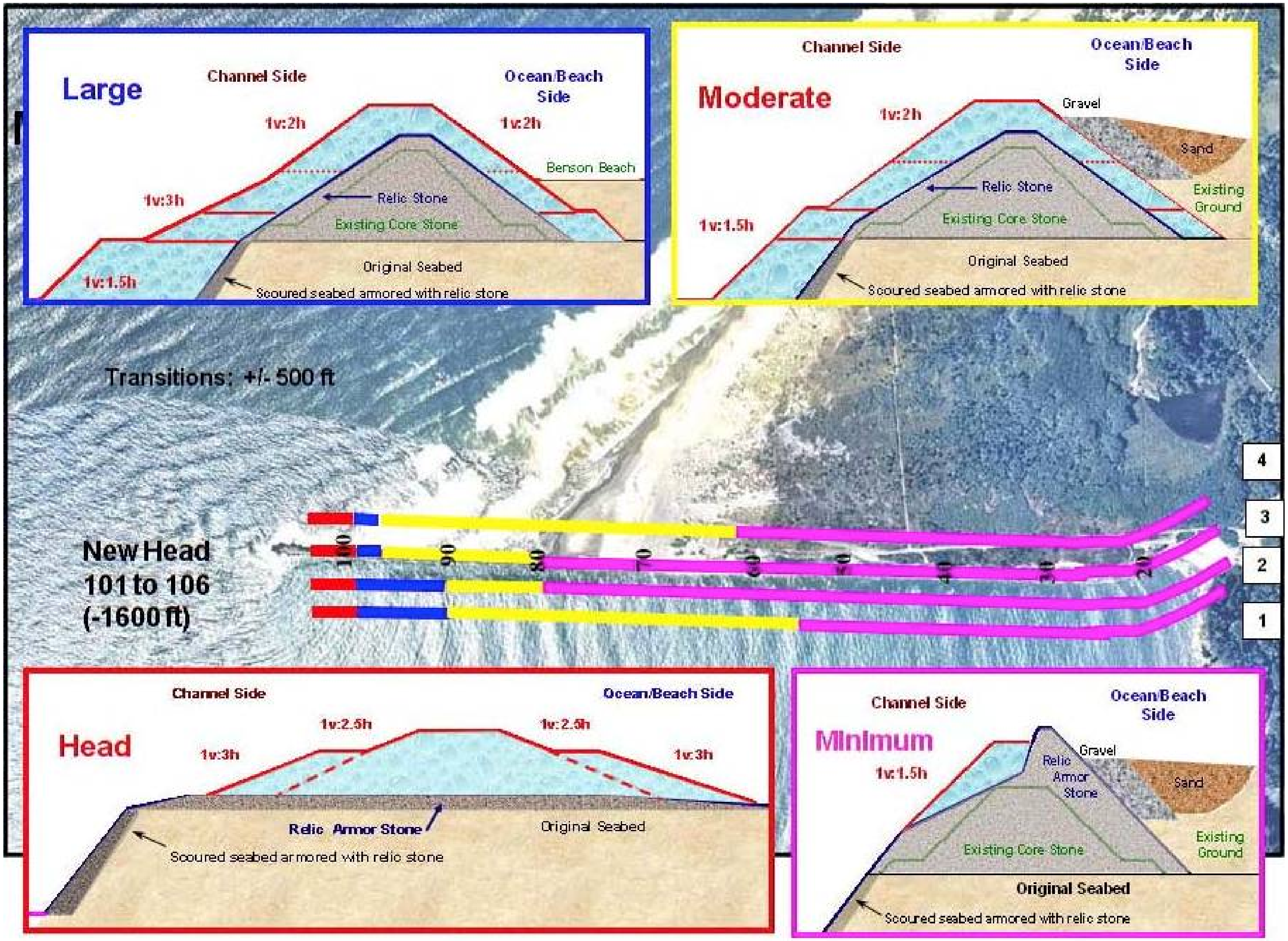


Figure A1- 269. North Jetty Immediate Rehabilitation Composite Plan Layouts

Final cost review of the results for the rehabilitation alternatives suggested these scenarios were not cost effective. Therefore, the results are not described in detail in this appendix. However, the SRB model results for all of the rehabilitation scenarios are provided in Appendix A2.

North Jetty. For the North Jetty, the following graduated cross section templates were evaluated under the Immediate Rehabilitation alternative approach: minimum, moderate and large. These cross sections were then further utilized to produce four composite plans. The small cross section was not evaluated for the North Jetty because of the contemporary depths of the channel side toe of this structure. The amount and placement of stone necessary to attain a stable slope and base would automatically exceed descriptive thresholds of a small cross section. The results are summarized
Four composite plans were developed for the North Jetty; each plan uses the cross sections discussed above but transitions the cross sections at different locations along the North Jetty. The first composite plan, composite 1 – large, utilized the model output for each of the minimum, moderate, and large alternative plans to identify the most robust transition points. The first composite plan, composite 1, applies the minimum template to Station 55 at which point the moderate template is applied to the reach of jetty which experiences greater channel depths and greater loading from waves. Further seaward the large cross section and head capping are applied. Subsequent composite plans were developed to optimize costs while trying to achieve an acceptable structural and functional reliability.

The first two composite plans were eliminated from further consideration under the immediate rehabilitation alternative because the composite 3 – small and composite 4 - small modified plans optimized the cross section for the longest length (least cost) while providing acceptable functional reliability. The layout of those plans is shown in Table A1- 13. Using composite 4, the critical area between Stations 60 and 80 is protected by a robust design template which addresses both the above and below portion of the jetty, reducing the risk in this area for breach events resulting in sediment infill to the navigation channel.

Table A1- 13. North Jetty Immediate Rehabilitation Composite Plans.

North Jetty Immediate Rehabilitation	
Composite	**Cross Section Transition Station**
Composite 3-Small	Minimum cross section - Stations 10-80 Moderate cross section - Stations 80-98 Large cross section - Stations 98-100 Head capping - Station 101
Composite 4 - Small Modified	Minimum cross section - Stations 10-62 Moderate cross section - Stations 62-98 Large cross section - Stations 98-100 Head capping - Station 101

South Jetty. For the South Jetty, the following graduated cross section templates were evaluated under the immediate rehabilitation alternative approach: minimum, small, moderate, and large. These cross sections were then further utilized to produce five composite plans, starting with composite 1 - large alternative which utilizes the graduated cross section template model output to select the most robust jetty cross section template along the length of the South Jetty. Due to the significant length of the South Jetty and the degree of exposure during construction, construction of any of the alternative plans is already very similar to a scheduled rehabilitation. The minimum template alternative was run using a scheduled implementation and is shown with the immediate rehabilitation results. All of these alternatives include the engineering features, head capping and spur groins. The head is projected to be capped at approximately Station 313.

Final cost review of the results for the rehabilitation alternatives suggested these scenarios were not cost effective. Therefore, the results are not described in detail in this appendix. The SRB model results for all of the rehabilitation scenarios are provided in Appendix A2.

Five composite plans were evaluated for the South Jetty; composite plan layouts along the jetty are shown in Table A1- 14 and Figure A1- 270. All composite plans included engineering features - head capping and spur groins.

Table A1- 14. South Jetty Immediate Rehabilitation Composite Plan Layout

South Jetty Immediate Rehabilitation	
Composite	**Cross Section Transition Station**
Composite 1-Large	Minimum cross section - Stations 155-175 Small cross section - Stations 175-180 Moderate cross section - Stations 180-265 Large cross section - Stations 265-311 Head capping - Station 313
Composite 2-Modified 1	Minimum cross section - Stations 155-200 Small cross section - Stations 200-265 Moderate cross section - Stations 265-290 Large cross section - Station 290-311 Head capping - Station 313
Composite 3-Small	Minimum cross section - Stations 155-245 Small cross section - Stations 245-290 Moderate cross section - Stations 290-310 Large cross section - Stations 310-311 Head capping - Station 313
Composite 4-Medium	Minimum cross section - Stations 155-180 Small cross section - Stations 180-230 Moderate cross section - Stations 230-285 Large cross section - Stations 285-311 Head capping - Station 313
Composite 5-Modified 2	Minimum cross section - Stations 155-215 Small cross section - Stations 215-260 Moderate cross section - Stations 260-285 Large cross section - Stations 285-311 Head capping - Station 311

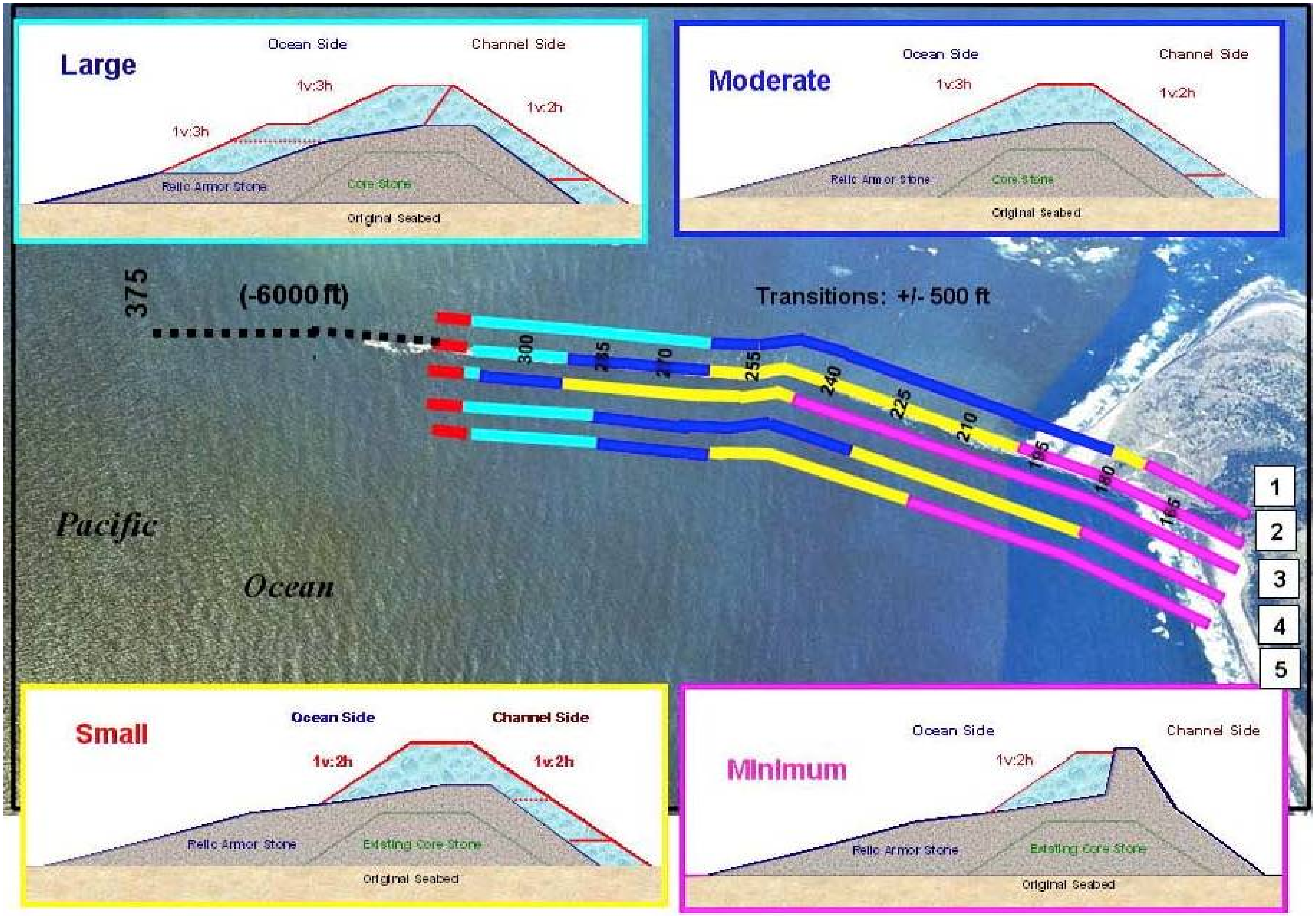


Figure A1- 270. South Jetty Composite Plans Immediate Rehabilitation

2. Scheduled Rehabilitation

Under a scheduled approach, the timing of the rehabilitation would be staged by applying the rehabilitation only to a portion of the jetty when it was needed, which would postpone the federal outlay of funds throughout the 50-year project life span. Depending on funding and equipment availability, completion of each alternative could take even longer than the estimates predicted below.

Due to the size of the jetties and the limited construction window, any rehabilitation work on the jetty structures would need to occur over a number of years. A scheduled rehabilitation alternative would implement the rehabilitation of specific reaches of each jetty at designated times to address the most vulnerable reaches first. It would repair the cross section above and below the waterline, repair foundation instability issues where needed, and includes construction of spur groins, North Jetty lagoon fill, jetty head capping, and improving the shoreline near the root of the South Jetty at Trestle Bay. Rehabilitation would not be conducted until conditions indicate that there is a need at specific portions of the jetty. Conducting the rehabilitation when needed, instead of continuously as in the immediate rehabilitation alternatives, would increase the length of time construction occurs to about 15 years, although construction would actually occur only 11 years out of that total (construction is not expected to occur on all jetties at the same time).

North Jetty. The Scheduled Rehabilitation approach for the North Jetty evaluated the minimum template as well as four composite plans. Each of these alternatives was evaluated both with and without maintaining the jetty head at the existing location. The layout of these four composite plans is shown in Table A1- 15. All of these plans incorporate all of the engineering features for the North Jetty, including capping the jetty head at approximately Station 101. The schedule developed for implementation was determined using model output which identified the projected sequence and timing of vulnerable reaches of the jetty combined with practical limitations such as weather windows for construction and limiting placement rates of stone.

The results of the model evaluation for these alternatives are presented in Appendix A2.

Table A1- 15. North Jetty Scheduled Rehabilitation Composite Plans

North Jetty Scheduled Rehabilitation	
Composite	**Cross Section Transition Station**
Composite 1-Large	Minimum cross section - Stations 10-55 Moderate cross section - Stations 55-90 Large cross section - Stations 90-100 Head capping - Station 101
Composite 2-Medium	Minimum cross section - Stations 10-80 Moderate cross section - Stations 80-90 Large cross section - Stations 90-100 Head capping - Station 101
Composite 3-Small	Minimum cross section - Stations 10-80 Moderate cross section - Stations 80-98 Large cross section - Stations 98-100 Head capping - Station 101
Composite 4-Small Modified	Minimum cross section - Stations 10-62 Moderate cross section - Stations 62-98 Large cross section - Stations 98-100 Head capping - Station 101

South Jetty. Two scheduled rehabilitation plans were initially evaluated for the South Jetty because the length of the jetty (over 6 miles) meant that there was no significant difference in construction timing and sequencing between immediate and scheduled rehabilitation. These plans were not developed to the same level as the other plans because results showed that constructability and timing of the scheduled rehabilitation alternative would not offer benefit to the South Jetty, as was the case for the North Jetty.

Jetty A. The scheduled rehabilitation with small template alternative for Jetty A addresses the larger system degradation processes. The Jetty A head is stabilized at approximately Station 92. Potential repairs are expected to occur approximately in year 2046 and extend throughout the life of the project.

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MCR Jetty System Major Rehabilitation Evaluation Report

Appendix A2

Reliability Analysis, Event Tree Formulation and Life-cycle Simulation

Appendix A2
Reliability Analysis, Event Tree Formulation and Life-Cycle Analysis

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Appendix A2
Reliability Analysis, Event Tree Formulation and Life-Cycle Analysis

1. INTRODUCTION

a. Scope

Appendix A2 describes how reliability methods and life-cycle concepts were used to evaluate alternative plans for improving future performance of the three jetties at the mouth of the Columbia River (MCR). The three MCR jetties have been in service for 70 to 100 years and are essential for maintaining deep draft navigation through the 6-mile long inlet. Many areas of each jetty are presently in an advanced stage of degradation. The MCR jetties continue to incur damage, motivating the need to systematically address the life-cycle of these structures. To address this need, the U.S. Army Corps of Engineers (USACE), Portland District, developed a stochastic risk-based (SRB) model to evaluate alternatives for optimally managing the life-cycle of jetty infrastructure. The SRB model was developed specifically for the MCR jetty system in support of this major rehabilitation study and was used to assess both the historical and future performance of MCR jetties. Accurate portrayal of historical jetty performance was necessary to perform model calibration and provide the basis for forecasting future life-cycle performance. Formulation of the project event tree, reliability analysis, and SRB life-cycle simulation are discussed in this appendix.

Topics in this appendix are described sequentially, from the general to the detailed view. The first part of the appendix describes the SRB model's structure and how the model relates environmental forcing to jetty performance. The present condition of each jetty is summarized in terms of realized life-cycle performance. The physical processes that are addressed within the SRB model, and related jetty response, are also provided as an overview. Later, individual components of the SRB model are described. Finally, details of the SRB model are integrated with details of MCR inlet physical processes which affect jetty life cycle performance. Some repetition of topics occurs though the appendix and was needed to provide an incremental description of the SRB model, inlet processes, and affected jetty performance. Appendix A1, *Coastal Engineering* and Chapter 3 of the *Major Rehabilitation Evaluation Report* describe how output from the SRB model was used to evaluate future life-cycle performance of the MCR jetties.

1. Deep-Draft Navigation at MCR and Life-Cycle Analysis of Jetties

During 1885-1939, phased construction of the three MCR jetties reformed a broad and treacherously variable 5.5 mile-wide inlet into a stable 2 mile-wide inlet having a consistent channel suitable for year-round navigation. Refer to Figure A2- 1 and Figure A2- 2 for a view of the present MCR inlet. The central project feature at the MCR inlet is the deep draft navigation channel (-48 to -55 ft MLLW), which is 2,640 ft wide and 5 miles long and extends through the inlet, connecting the lower Columbia River navigation channel with the

Pacific Ocean.

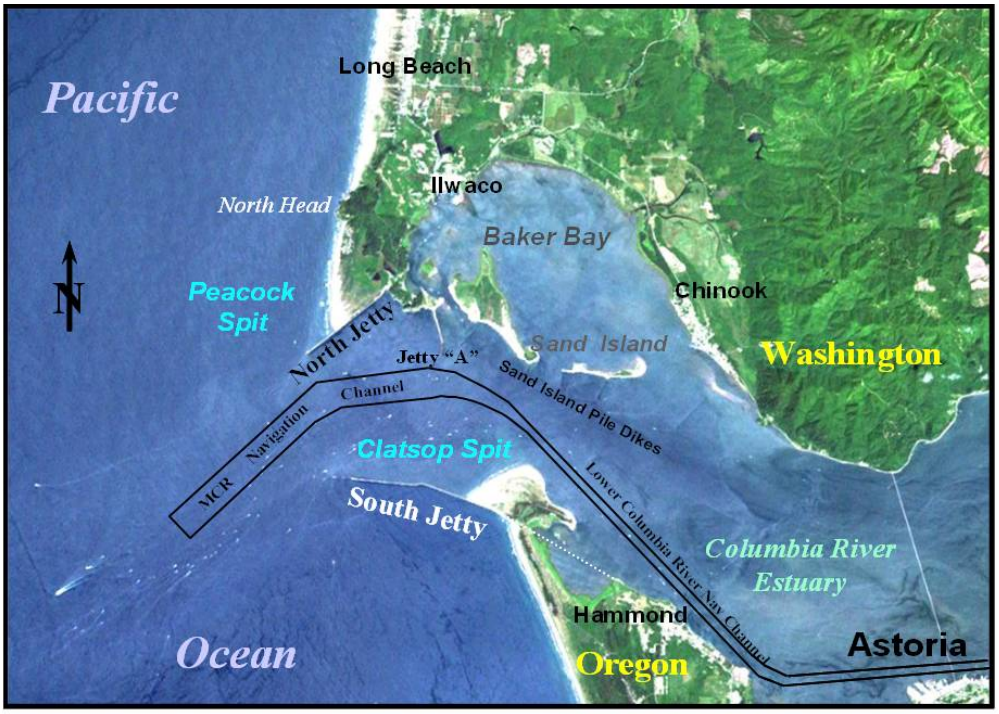


Figure A2- 1. MCR Inlet, Jetties and Navigation Channel

Mouth of the Columbia River (MCR) Inlet and the Three Jetties which Secure the Deep Draft Navigation Channel.

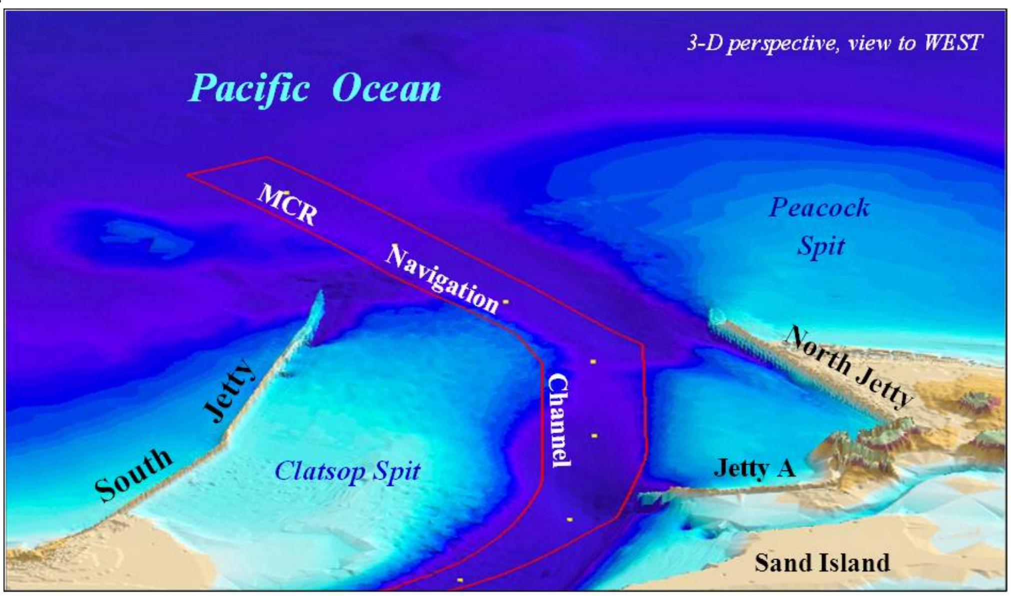


Figure A2- 2. Perspective View of the MCR

Perspective view of the Mouth of the Columbia River, showing the morphology on which the three jetties are founded. The distance between the seaward ends of the North and South Jetties is 2 miles. Water depth within the MCR thalweg varies from 43 to 110 ft.

Mean lower low water (MLLW) is approximately equal to -3.5 ft NGVD. Each jetty acts to stabilize large shoals that would otherwise enter the navigation channel. The jetties facilitate deep draft navigation by favorably redirecting currents through the inlet and protecting the inlet's interior from large waves. Continued function of the MCR jetties is essential for maintaining the inlet's present configuration and securing the deep draft navigation channel, which facilitates $16 billion in annual commerce. The MCR jetties have been in service for multiple decades and have, for the most part, functioned well. However, the recent onset of deferred maintenance, accelerating damage, and evolving site conditions has significantly degraded the resilience of the MCR jetties. Reduced resilience can lead to an unexpected loss of functional performance. Loss of jetty function could compromise deep-draft navigation at the MCR.

Active monitoring of vulnerable navigation structures at MCR has facilitated real-time risk assessment and immediate contingency planning. However, managing infrastructure at the threshold of functional loss may not be a cost-effective option, over the long-term, at an inlet such as the MCR [USACE 2005, Moritz 2008]. It has become necessary to assess future life-cycle conditions to enable optimal formulation of long term investment strategies; including the option of jetty rehabilitation. A firm understanding of a structure's present condition and loading and response characteristics is required before one can successfully optimize life-cycle management strategies. Refer to Appendix A1 for a full discussion of the MCR jetties.

2. Problem Statement and Objectives

The MCR jetties have experienced significant deterioration since initial construction, necessitating multiple repair campaigns. Jetty deterioration at MCR is motivated by foundation instability (toe scour) associated with the erosion of tidal shoals on which the jetties were built and extreme incident wave impact on the structures. Despite intermittent repair and rehabilitation campaigns over their respective service lives and a low rate of maintenance investment, the present condition of the jetties is one of moderate-severe deterioration which, if allowed to progress unabated, will result in progressive loss of jetty function. As the seaward end of each jetty (head) is damaged and recedes landward, the morphology on which the jetty is founded is incrementally dissipated by wave and current action. Progressive loss of the inlet's morphology due to jetty deterioration motivates shoaling within the navigation channel and increases wave and current action along each jetty and within the inlet. In certain failure scenarios, loss of jetty function could be abrupt, resulting in a breached jetty, whereby a large volume of sand shoal could be activated to deposit within the MCR navigation channel significantly impairing deep-draft navigation at the MCR.

Aspects of jetty performance are described by life-cycle metrics, provided as SRB model output, which provide an objective basis to compare alternative plans. Neither the SRB model nor this appendix conducts alternative plan selection. Chapters 3 and 4 describe how SRB model output (data and metrics) were used for alternative plan development, evaluation, and selection. Analyses described in this appendix were performed pursuant to applicable guidance for life-cycle analyses and rehabilitation of coastal navigation infrastructure [USACE-IWR 1992, USACE 1992, 1997, 2006, 2008]. The SRB model provided an evaluation frame-work to address the following rehabilitation study objectives:

- Improve the reliability of the MCR jetty structures.
- Extend the functional life of each jetty, as a system of structural elements.
- Reduce jetty life-cycle costs.
- Maintain deep-draft navigation at MCR.

3. SRB Model Framework

The SRB model is a computer simulation (MALTAB®) that stochastically evaluates the environmental loading affecting each jetty, and relates structural response (cross-section evolution) of each jetty to functional performance. The structure response is evaluated in terms of cross-section area change (loss) over time due to jetty degradation. Jetty repairs are activated within the SRB model, after the jetty cross-section is reduced below a specified threshold value. Jetty repairs are calculated in terms of the tonnage of armor stone required to re-establish the jetty cross section to its standard dimensions. Life-cycle costs estimated by the SRB model include jetty repair and incremental dredging attributed to jetty degradation and loss of function. Because life-cycle costs are estimated using stochastic methods, their realization can be considered probabilistic. Although reliability is also calculated within the SRB model, reliability is not used to simulate structure response and related consequences (life-cycle cost). Reliability is used as a supplemental metric to inform on overall jetty performance. The SRB model is considered to be an *engineering model* and was developed based on USACE guidance for major rehabilitation evaluation and life-cycle analysis. Details of the model are discussed in Section 5 of this appendix. Table A2- 1 summarizes the physical processes that affect jetty life-cycle performance vs. how those processes are addressed in the SRB model.

Table A2- 1. Physical Processes and Jetty Responses Emulated within the SRB Model

DEFINE INITIAL CONDITIONS Hindcast or Forecast →	SIMULATE ENVIRONMENTAL FORCING & STRUCTURE RESPONSE →	EVALUATE END STATE
Jetty Segment Attributes	**Environmetal Forcing and Jetty System Response**	**SRB Life-Cycle Performance Metrics**
(mean value, std dev)	(mean value, std dev for each side of jetty)	(mean value, std dev)
toe elevation	time-varying shoreline evolution	time-varying structural reliability
crest elevation	time- and spatially-varying scour rates	time-varying functional reliability
crest width	time- and spatially-varying wave conditions	timing and location of repairs
jetty side slope	time-varying water levels	repair tonnage & shoaling volume
armor stone size	variable jetty root degradation rates	jetty breach occurrence
armor stability number	repair history by jetty segment	components of life cycle cost
stone density	tonnage placed on the jetty	jetty crest elevation change
core stone presence	cost functions for jetty repair scenarios	cross-section evolution
jetty head position	channel shoaling associated with jetty performance*	jetty end state
	cost functions for dredging effect scenarios*	

*** = used for life-cycle cost forecasting**

The SRB model does not calculate the impact of jetty performance on navigation or commodity markets. Changes in navigability through the MCR inlet which may be attributed to jetty degradation (and related shoaling or morphology change within the inlet) are not addressed within the SRB model. The SRB model was used to estimate life-cycle engineering data for each MCR jetty, in terms of repair/rehab tonnage placed on a jetty and the incremental volume of sediment entering the MCR channel associated with jetty performance. A separate economic evaluation (external to the SRB model) utilized the SRB life-cycle cost data to determine the economic characteristics for a given jetty configuration. The overall time span for assessing the future life-cycle condition of the MCR jetties spans from 2006 to 2070. The period of analysis for this rehabilitation study included 2015 to 2064, which was based on a 50-year period beginning with an on-line year of alternative implementation (base year). The base year was assumed to be 2015 for all alternatives and for each jetty. Refer to Appendix C, *Economic Analysis*, for economic evaluation details.

4. Alternative Synthesis Using the SRB Model

Within the SRB model, each jetty is treated as an integrated system of components interacting with the inlet's forcing environment and morphology. The SRB models were calibrated by simulating (hindcasting) the historical life-cycle for each jetty. Relevant SRB parameters were adjusted to achieve hindcast model results that matched observed condition. Calibrated SRB models were used to forecast the future "baseline" condition for each jetty, against which a battery of alternative future conditions where compared. The "baseline" condition represents the no-action plan; structure repairs are deferred for as long as possible and no improvements are implemented to prolong the life-cycle.

Both with- and without-project alternatives were developed to address the objectives of this rehabilitation study. Without-project alternatives centered on a range of jetty maintenance strategies to address options for advance jetty maintenance of the standard design (existing) jetty template. Development of with-project alternatives was based on the incremental variation of jetty cross-section templates, additional engineering features, rehabilitation maintenance options, and implementation sequences (construction scheduling). The SRB model was used to estimate life-cycle metrics for all with- and without-project alternatives considered within the study. Appendix A1 gives a detailed description of the MCR project setting and discussion of rehabilitation alternative development.

Selection of a "preferred" plan, to manage the future life-cycle of each jetty, was based on the alternative that minimized future life-cycle costs, as represented by the monetary metric of average annual cost (AAC). To the extent possible, the preferred plan was based on supplemental consideration for the above non-monetary metrics. Comparative assessment of life-cycle metrics was performed by the Project Delivery Team (PDT) to arrive at an optimized plan. Through the course of alternative synthesis, the comparative assessment of life-cycle options evolved to a trade-off analysis of initial and large capital reinvestment versus incremental and deferred reinvestment. Refer to Chapters 3 and 4 in the *Major Rehabilitation Evaluation Report* for alternative plan development, evaluation, and selection.

5. Life-Cycle Metrics

The SRB model incorporates principles of performance-based design to evaluate the MCR jetties in hindcast or forecast mode. Performance-based design is a framework that relates performance requirements to respective metrics [Burcharth 1991 and Takahashi 2003]. A common set of life-cycle metrics were estimated by the SRB model to describe the performance for each jetty within a historical and future context. Metrics used to describe *historical* performance include: jetty repair aspects (timing, frequency, location), jetty geometry configuration (crest profile, cross-section, jetty head location), and jetty reliability. Metrics used to describe *future* jetty performance and compare alternatives for rehabilitation include:

- Annual and cumulative life-cycle stone replacement tonnage.
- Components of life-cycle jetty repair, incremental dredging, rehabilitation.
- Reliability (probability of a project feature to perform satisfactorily).
- Timing and frequency of repairs (time to first repair after project implementation).
- Timing and frequency of significant jetty breach events.

The monetary metric used to portray future life-cycle cost is expressed as a single amortized value, referred to as AAC. The AAC and derivative monetary metrics (benefit-to-cost ratio [BCR], etc) were calculated externally from the SRB model, using engineering cost data provided by the SRB model. Refer to Appendix C for AAC calculation methodology.

Specific events associated with timing and frequency of risk (realized negative project performance) are not directly conveyed within the AAC. Consideration of non-monetary life-cycle metrics (noted above) in conjunction with AAC can supplement the process of alternative development and assessment, and optimize the process of evaluating alternative plans to enable the selection of a preferred plan. Chapters 3 and 4 in the *Major Rehabilitation Evaluation Report* describe how ACC was used in conjunction with non-monetary metrics to evaluate alternative plans and select a preferred plan for each jetty.

b. SRB Life-Cycle Simulation

SRB life-cycle simulations are used to characterize the time-varying risk of structures subjected to complex loading and response scenarios. SRB models can simulate non-stationary processes that affect structure performance, which may be a requisite element to correctly simulating the life-cycle of infrastructure within the coastal margin. The three MCR jetties based on the project event tree (Figure A2- 3 through Figure A2- 11) simulate the life-cycle of each jetty for past and future conditions. The SRB models were used to formulate optimal long term investment strategies; including options for jetty rehabilitation.

The SRB model is stochastic because it integrates an annualized cycle of environmental loading in terms of random variables defined by specific probability density functions. Many of the parameters affecting structure response and life-cycle management outcomes are also expressed as random variables and treated stochastically. To emulate jetty damage resulting from wave attack, the SRB model uses wave-structure damage functions, developed through scaled physical model studies. Jetty damage resulting from foundation scour is also emulated within the SRB model.

It must be stressed that the consequences (jetty repair tonnage, incremental channel shoaling, and associated life-cycle costs) produced by the SRB model are driven by the stochastic processes and responses described above, and not by reliability. Although reliability is also calculated within the SRB model, reliability is not used to simulate structure response and related consequences (life-cycle cost). Reliability is used as a supplemental metric to inform on overall jetty performance.

The SRB model evaluates the structural and functional performance of jetties in terms of a reliability index (beta-value) which is expressed as reliability (Ps). As the cross-section of a jetty changes through time (due to cumulative damage or repairs), the reliability also changes. The SRB model uses the Monte Carlo method to increase the confidence of life cycle estimates and allows for an evaluation in the variance of life-cycle cost and other metrics.

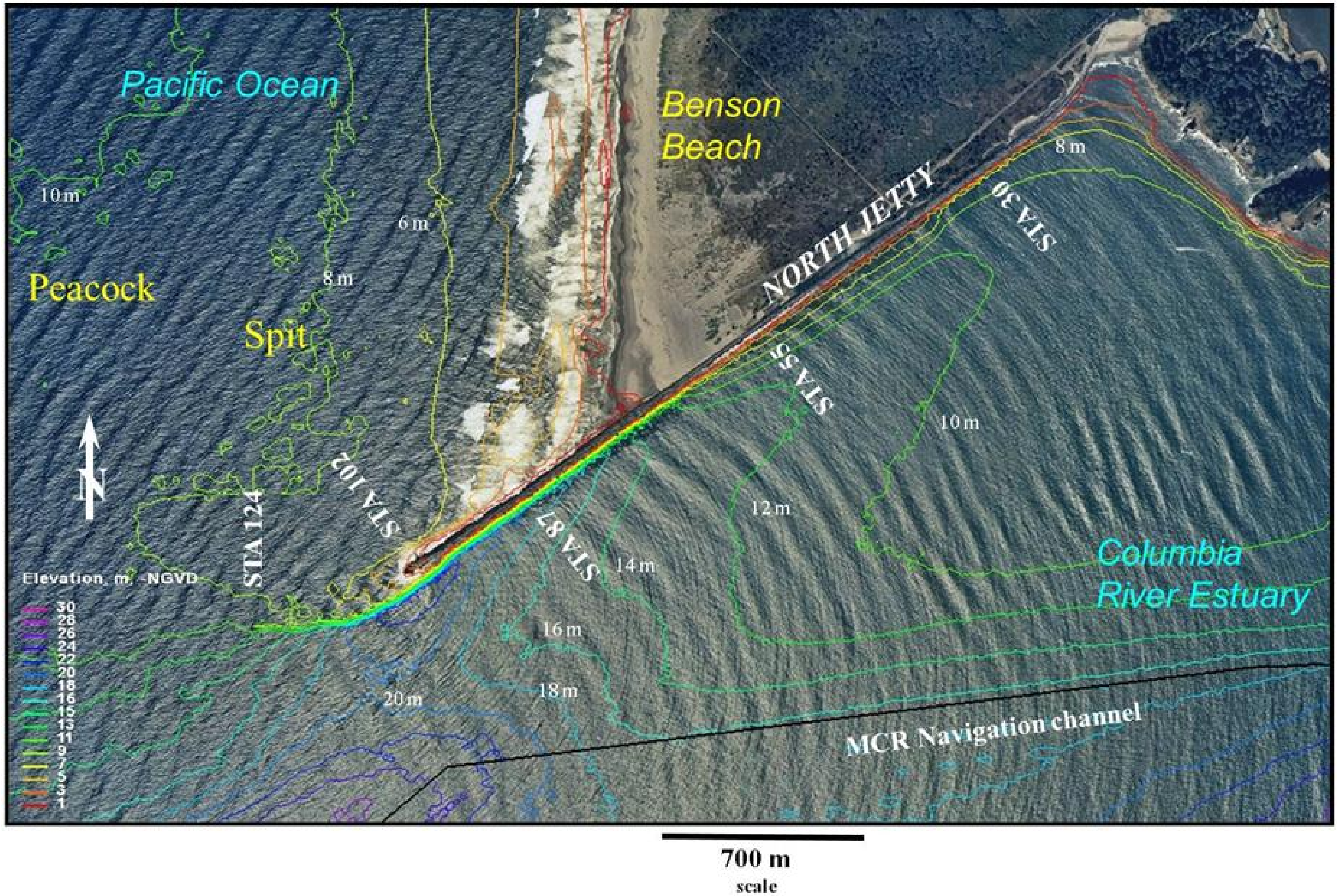


Figure A2- 3. North Side of the MCR

North jetty shown with Bathymetry 2007, elevation is in meters below NGVD. Present jetty head is located at Sta. 102. Head constructed to Sta. 124 in 1917, and re-established at Sta. 110 in 1939 and 1964. Sand shoal formed along channel side of jetty during 1999-2005 by sand being transported through the jetty from ocean side; when jetty cross-section became jeopardized by wave and scour damage.

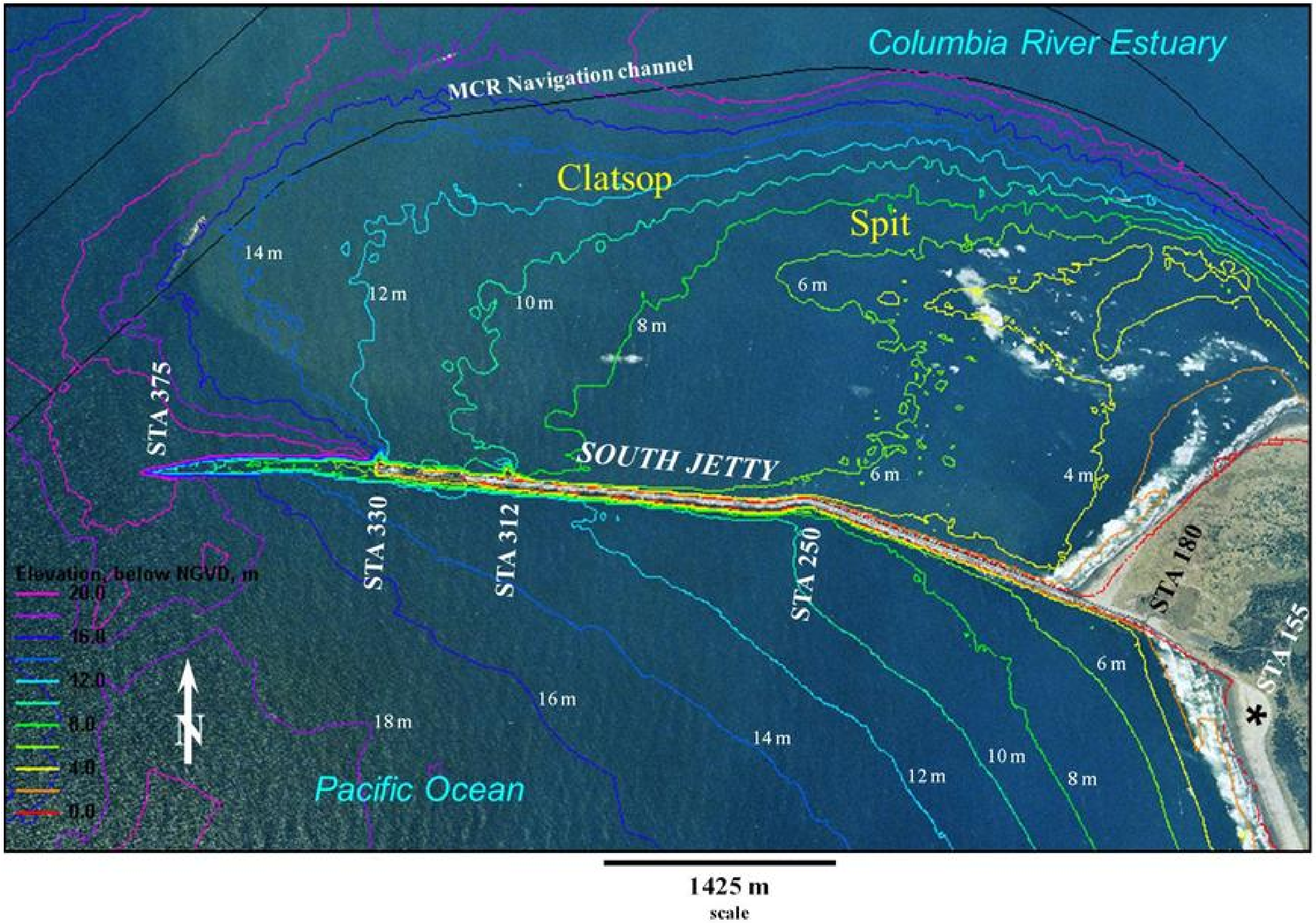


Figure A2- 4. South Side of the MCR

South jetty shown with Bathymetry (2003), elevation is in meters below NGVD. Existing spurs at Sta. 330 and 312 (channel side) reduce scour along the channel side of the jetty. The seaward end of the concrete monolith terminates at Sta. 330. Existing shore attached head of jetty is at Sta. 314. Jetty head was re-established at Sta. 354 in 1935 and Sta. 330 in 1940.

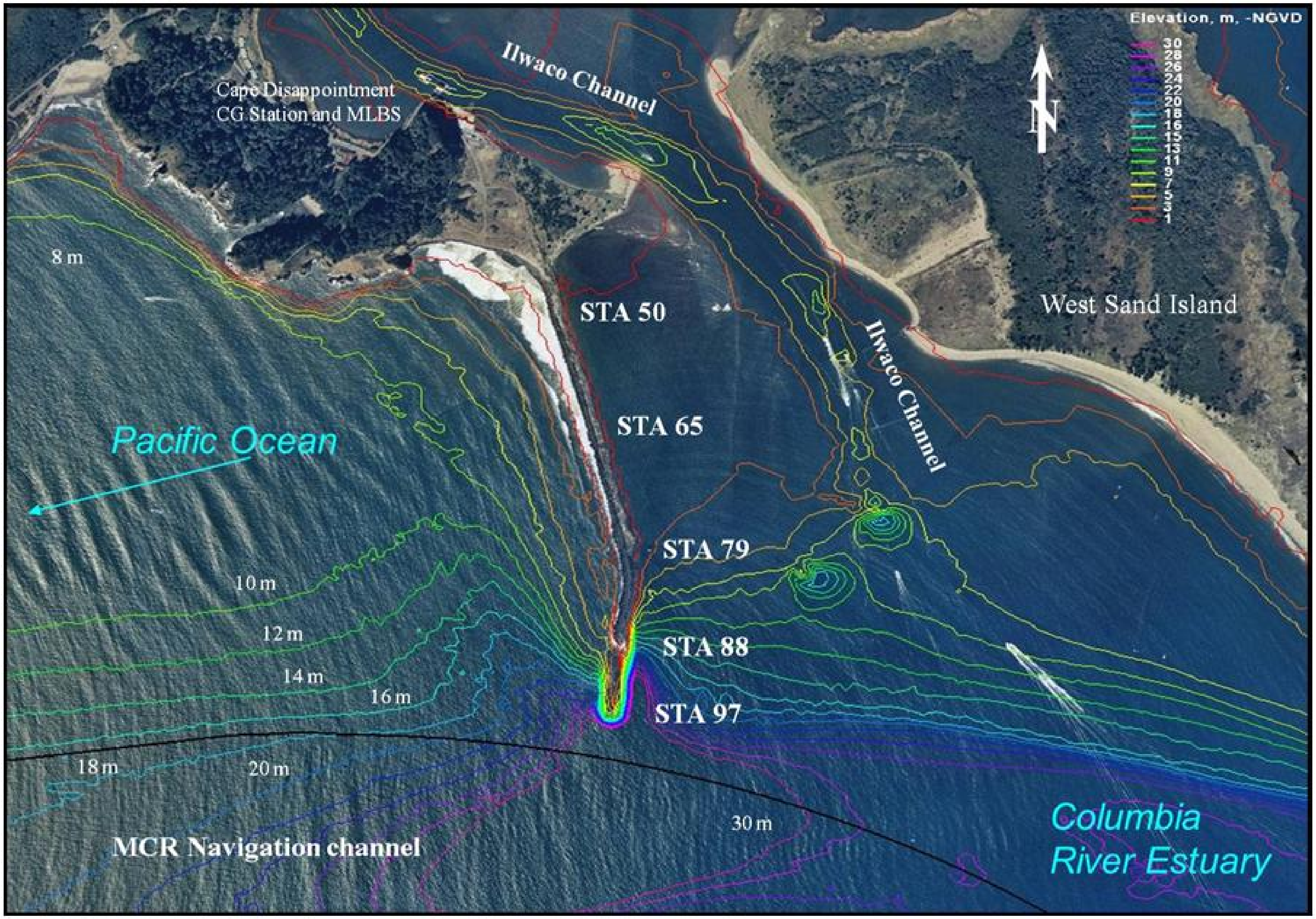


Figure A2- 5.   Jetty A Orientation with North Side of MCR

Jetty A shown with 2007 bathymetry, elevation is in meters below NGVD. Present jetty head is located at Sta. 88. Head constructed to Sta. 97 in 1939, and re-established at Sta. 90-97 during 1946 - 1962. Seaward end of Jetty A has been threatened by significant scour, while the inshore areas facing the ocean have been threatened by heavy wave action. Jetty A acts to stabilize the north side of the MCR inlet.

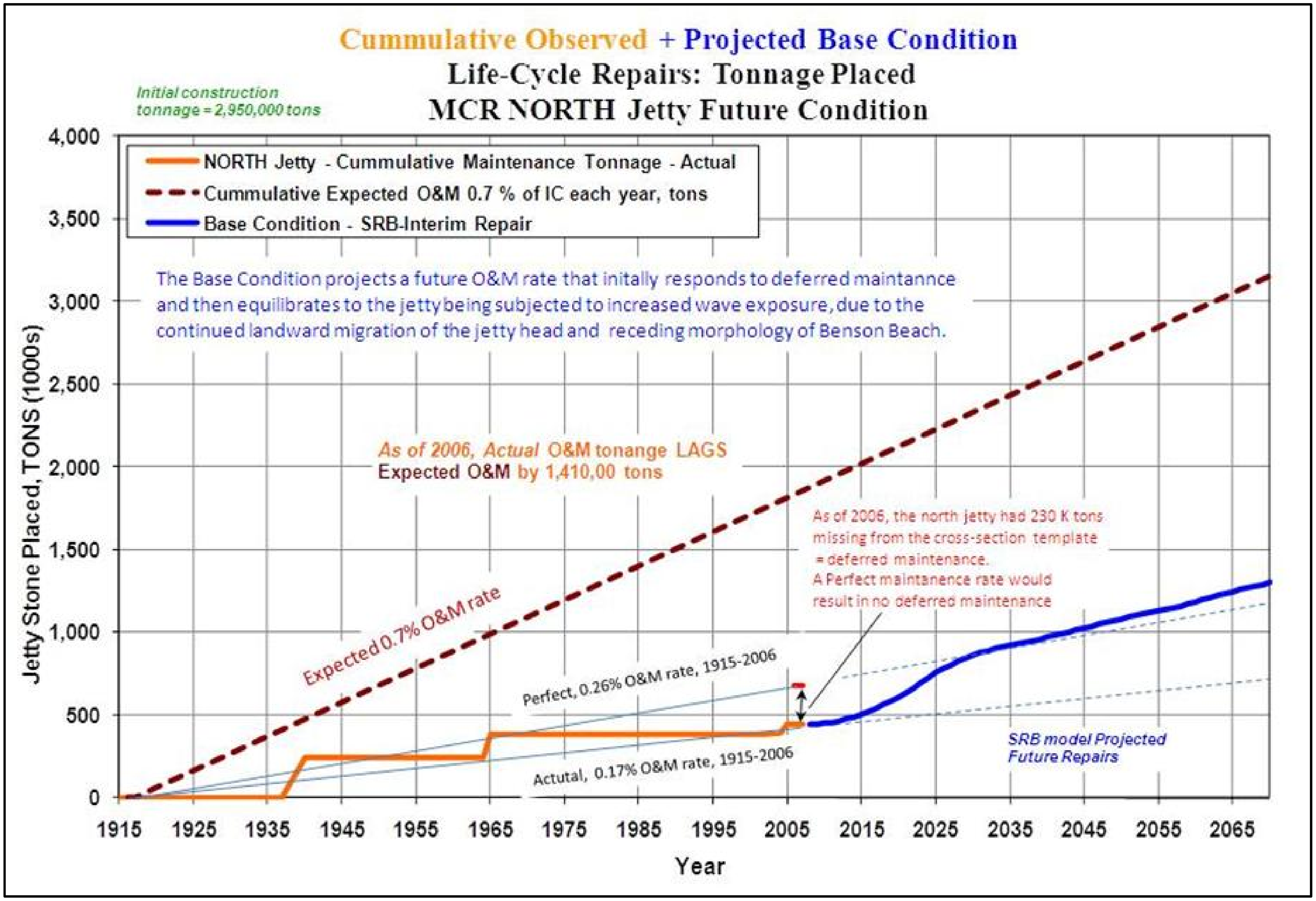


Figure A2- 6. North Jetty Maintenance Rate, Past-Observed and Future-Projected Base Condition

Repair tonnage for MCR North Jetty. Projected estimate is based on the project base condition (no action plan) and begins in 2006, which the last time that the North Jetty was fully surveyed.

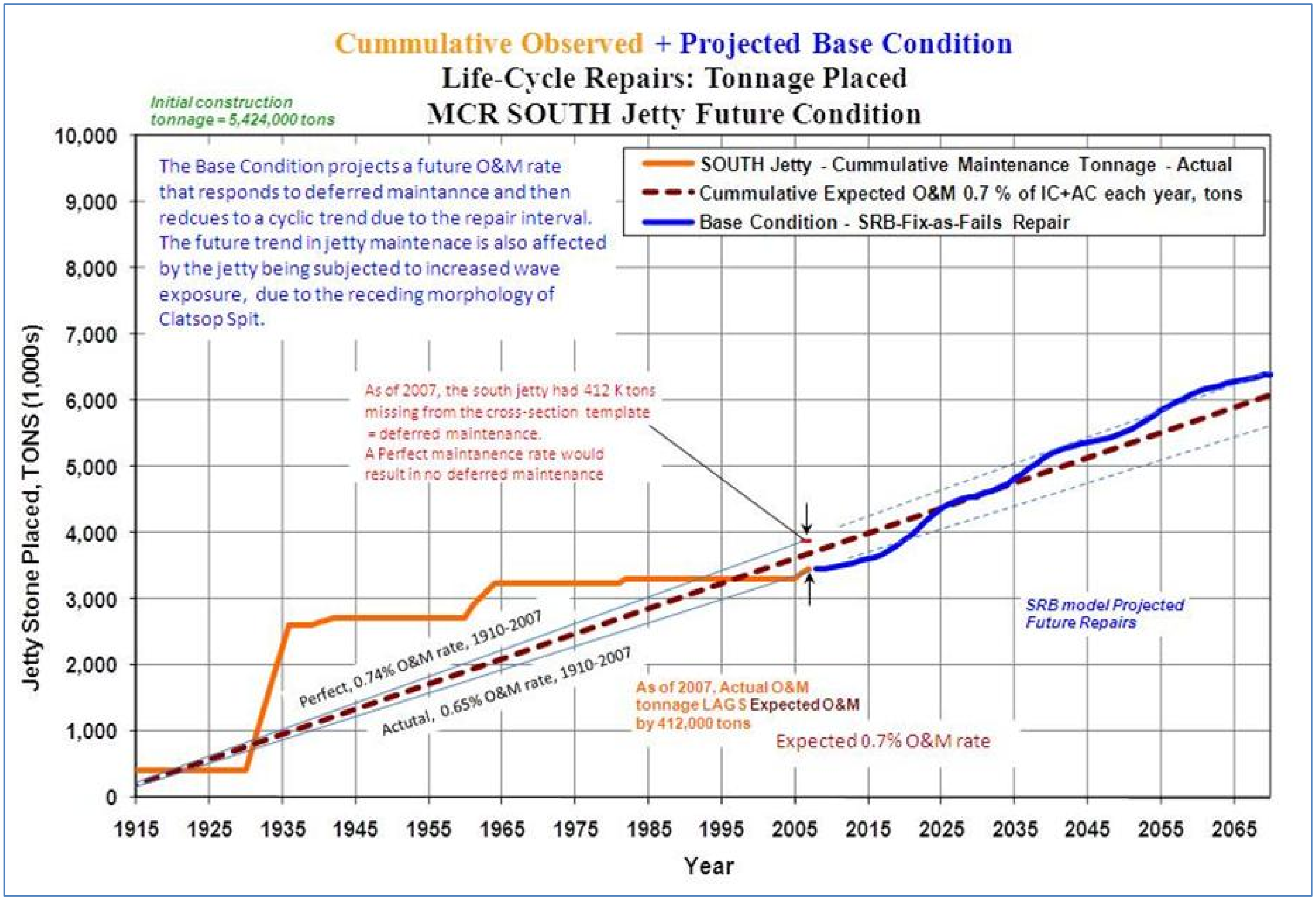


Figure A2- 7. South Jetty Maintenance Rate, Past-Observed and Future-Projected Base Condition

Repair tonnage for MCR South Jetty. Projected estimate is based on the project base condition (no action plan) and begins in 2007, which the last time that the South Jetty was fully surveyed.

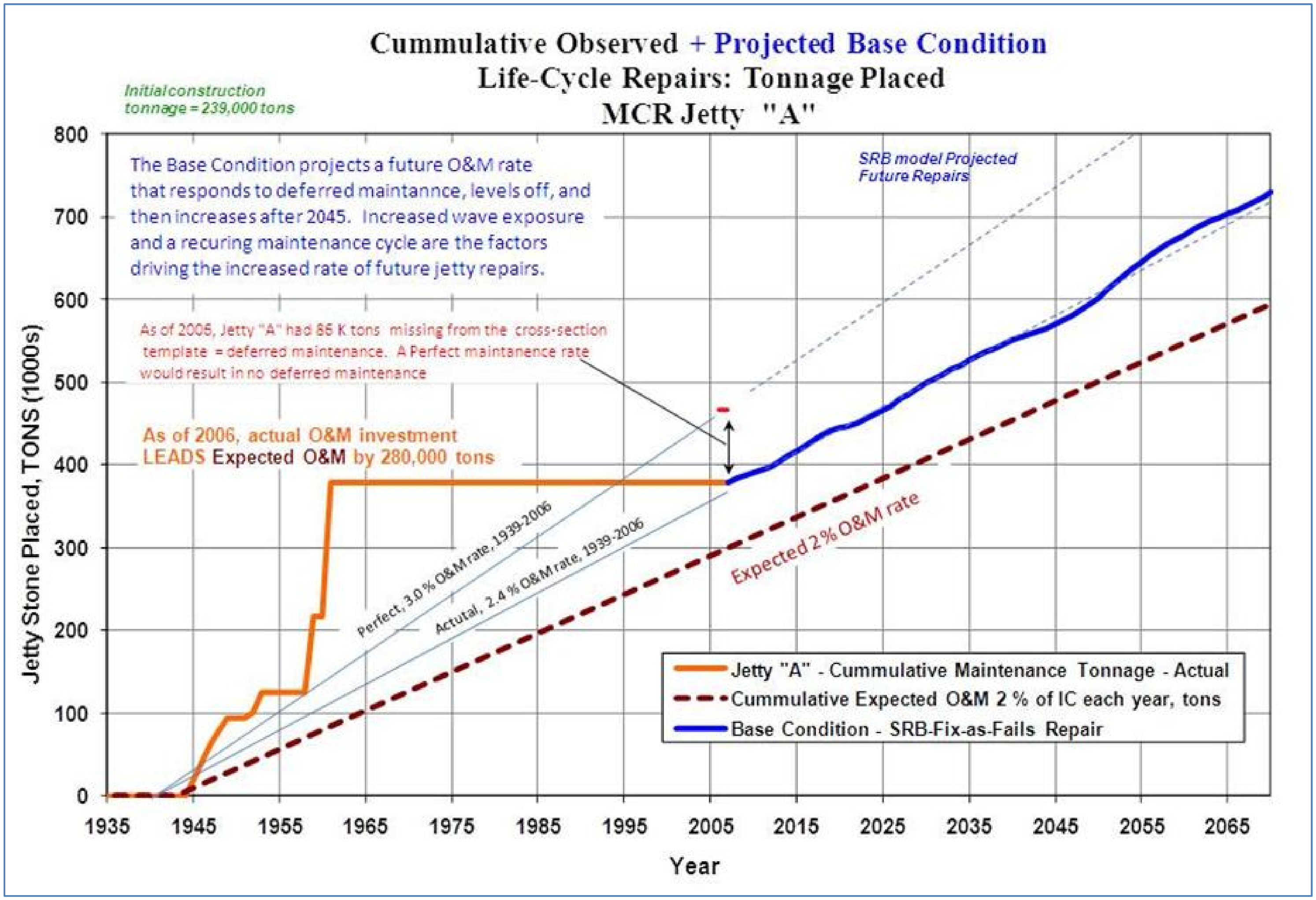


Figure A2- 8. Jetty A Maintenance Rate, Past-Observed and Future-Projected Base Condition

Repair tonnage for MCR Jetty A. Projected estimate is based on the project base condition (no action plan) and begins in 2006, which the last time that jetty "A" was fully surveyed.

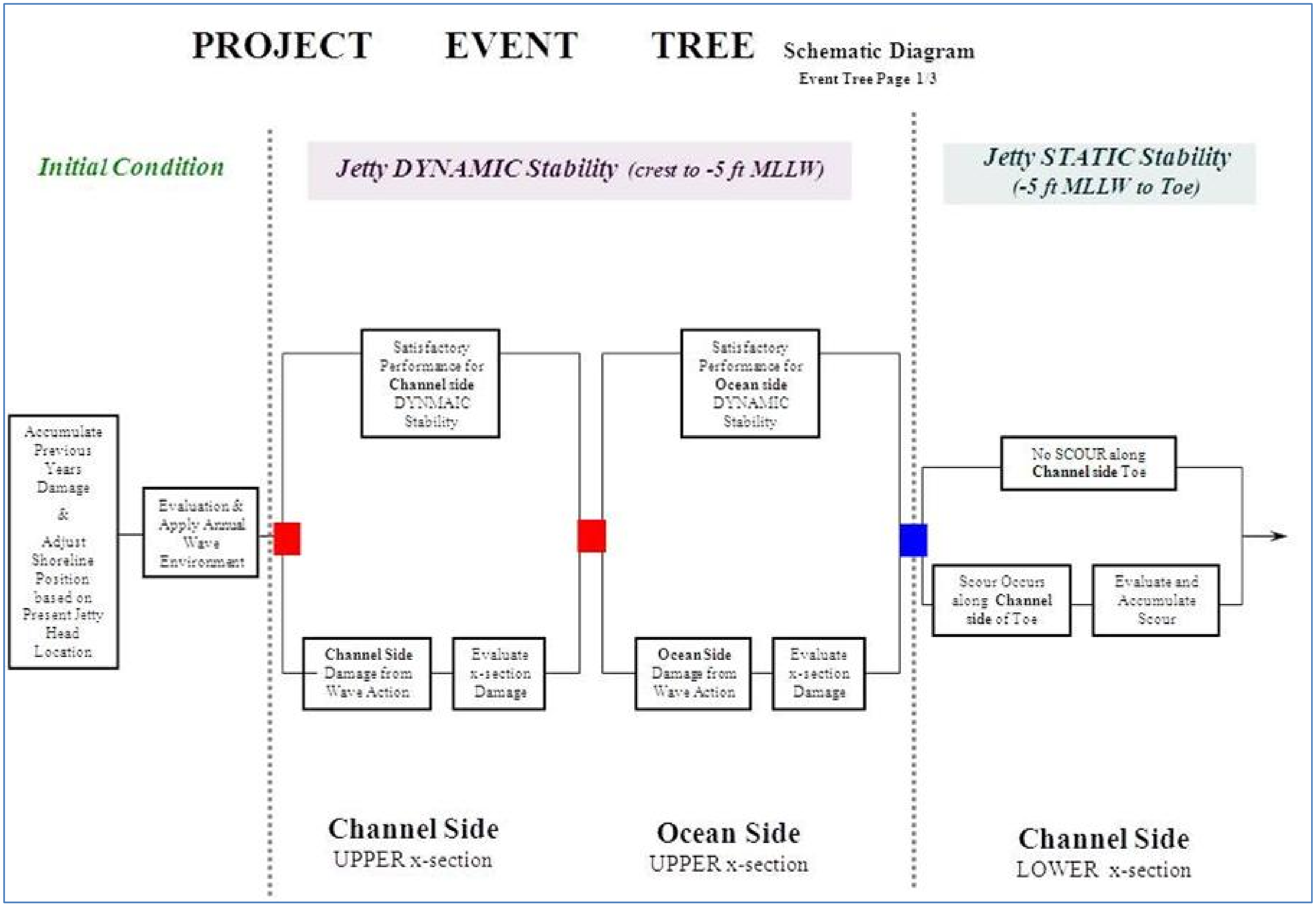


Figure A2- 9. Expanded Detail of MCR Jetty Project Event Tree, Part 1 of 3

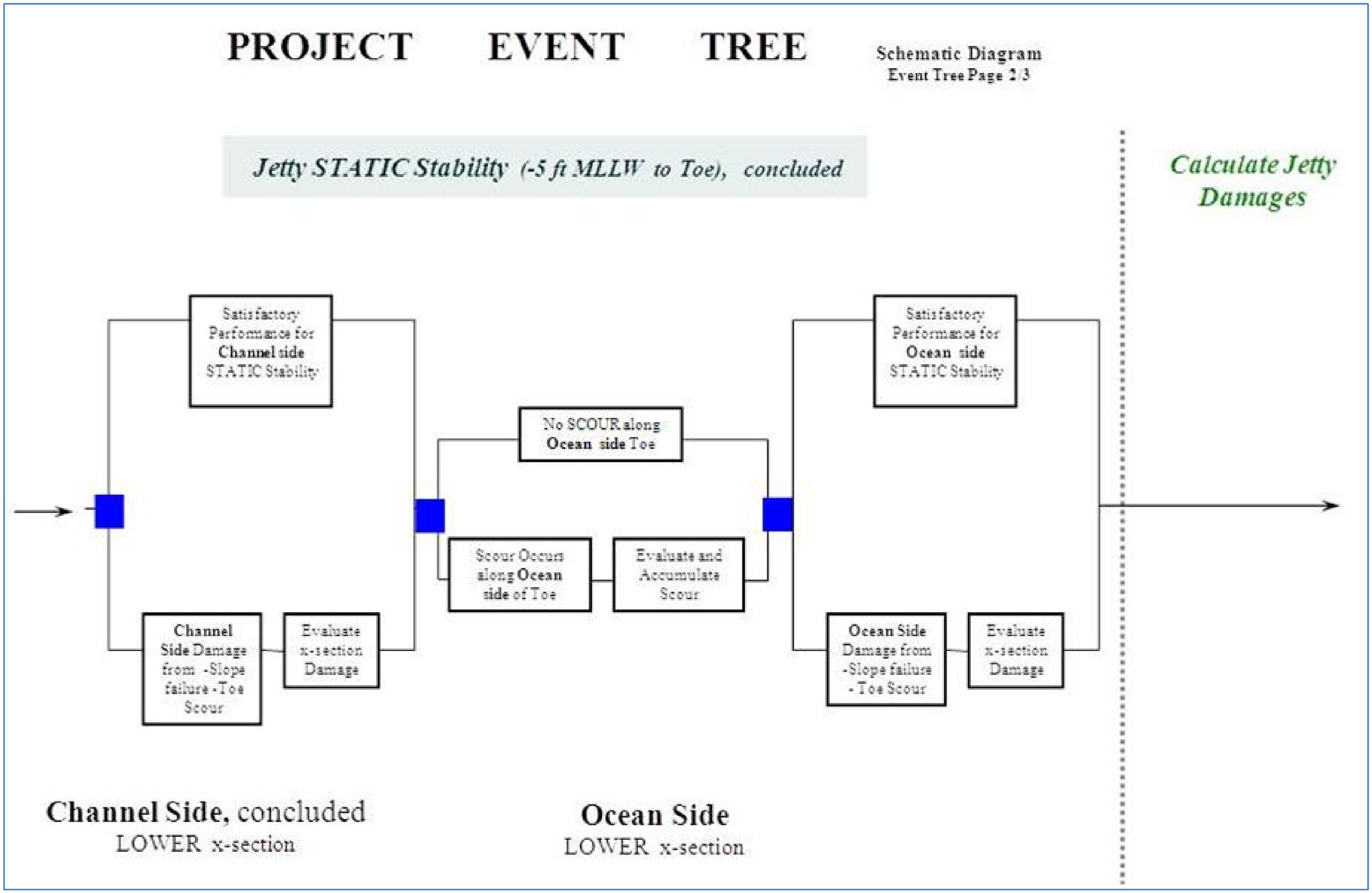


Figure A2- 10. Expanded Detail of MCR Jetty Project Event Tree, Part 2 of 3

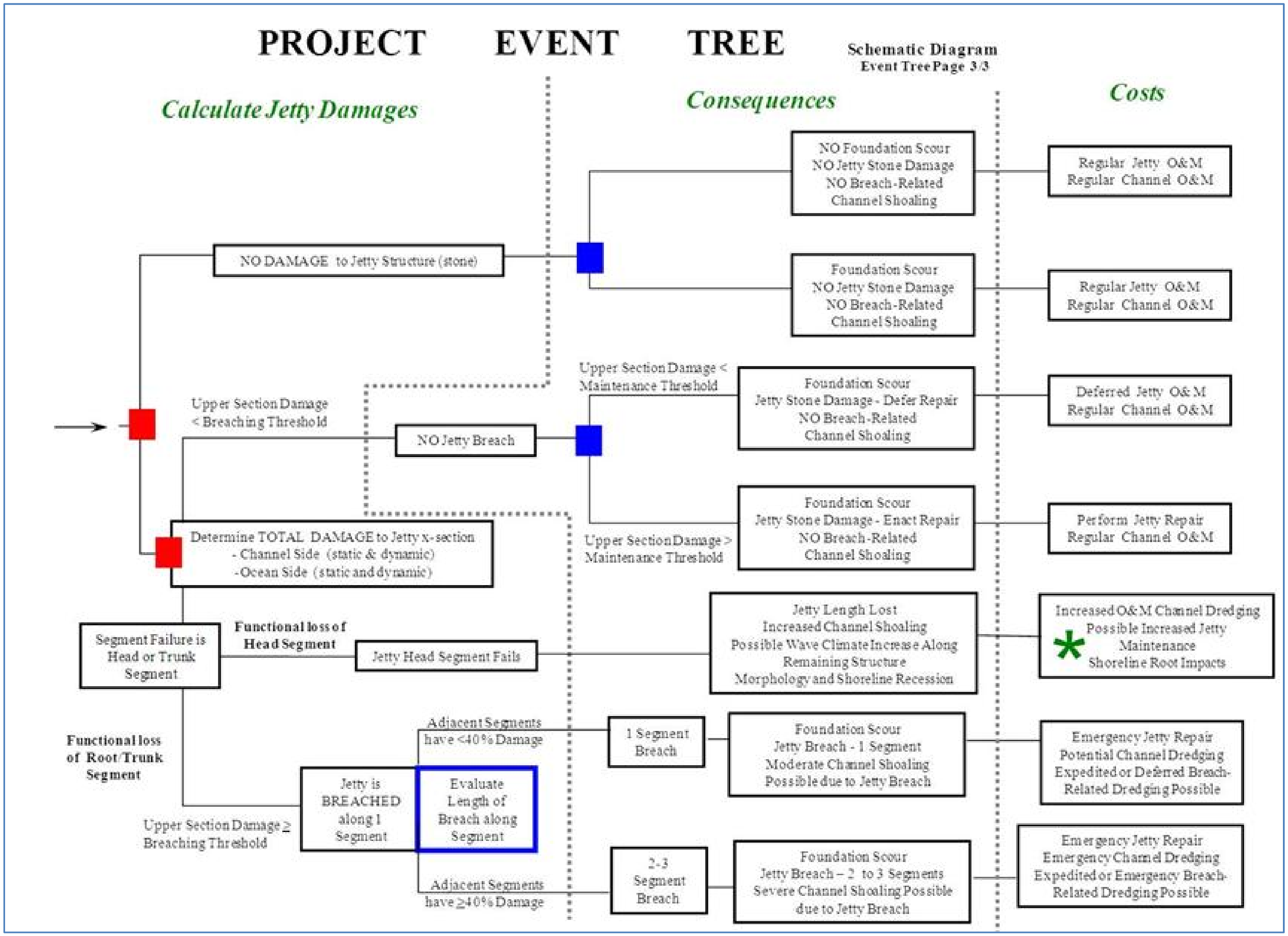


Figure A2- 11. Expanded Detail of MCR Jetties Event Tree, Part 3 of 3

1. Modeling Jetty Performance at the MCR Inlet

The three MCR jetties interact with each other and the inlet's morphology to secure the federal deep-draft navigation channel. Knowledge of these interactions is used to assess the time-varying condition of each jetty within the context of inlet evolution. A SRB model was developed for each jetty to relate environmental loading to jetty structure response and functional performance. Due to the complexities of the MCR jetty system, an integrated analysis of the life-cycle performance for all three jetties was not attempted. Rather, each jetty was analyzed independently. The SRB model for Jetty A does account for effect of scour at North Jetty, should the head of Jetty A recede landward.

The SRB model evaluates time-varying degradation of a jetty's geometry (cross-section), structural and functional reliability, location cost and timing of jetty repairs, and incremental dredging costs related to jetty degradation.

The time-varying reliability of a given jetty (or jetty segment) can be affected by the degree of cumulative damage sustained by the structure. Within the SRB model, the method used to evaluate reliability is independent from the procedure used to estimate the amount (level) of cross-section degradation. Reliability is dependent upon the degree of cross section damage.

2. Jetty Reliability and Cross-Section Damage

As stated above, calculations for jetty reliability and cross-section damage are handled separately within the SRB model. Generalized (rubble-mound armor) stability equations are evaluated to estimate the time-varying reliability for discrete areas along each jetty. Note that jetty reliability is based on both the present forcing environment and the present condition of the jetty; each of which can vary from year to year. Reliability indicates the likelihood of a jetty to resist damage (and function satisfactorily) in the presence of wave action. Reliability does not define how much jetty degradation would incur, if the jetty were damaged.

<u>Cross-Section Damage</u>. The degree and rate of structure degradation (as affected by wave action) is evaluated using damage functions which are based on incident wave height vs. incremental cross-section damage. The damage functions were developed through detailed physical model studies conducted at ERDC, featuring MCR jetty cross-section attributes [Ward et al., 2007]. Within the SRB model, wave- induced jetty damage is calculated for each storm event realized within each year, using wave-damage functions. A description of how the SRB model emulates cross-section damage is presented in Section 2 and Section 5 of this appendix.

<u>Reliability</u>. Time-varying reliability aggregate value, calculated using the mean value and standard deviation for the annual storm climate which varies for each year within the SRB simulation. An annual wave and water level environment is generated for each year within the SRB life-cycle simulation. There can be 1 to 11 storm events affecting the MCR inlet per year, having offshore significant wave height ≥ 22 ft. The annual (1-year) storm event has an

offshore significant wave height of 29 ft, and the 25-year storm event has an offshore significant wave height of 46 ft. A description of jetty reliability calculations within the SRB model is presented in Section 3 of this appendix. Refer to Section 6 of this appendix for a description of the MCR forcing environment and how it was simulated in the SRB model.

In summary, evaluation of jetty damage is performed independently of the reliability calculation. Jetty reliability can be affected by the degree of damage sustained by the structure's cross-section; however, the degree and extent of cross-section damage is not directly predicated by the structure's reliability.

c. Current Condition of MCR Jetties – Previous Life-Cycle

Despite the formidable challenges faced by the engineers to implement the original MCR jetties (severe working environment), lack of established design criteria, and limitations encountered during initial construction, the MCR jetties have performed rather well during their previous life-cycle. While the original project authorization was expected to be for a 50-year life, by default the service life of the original jetty structures has extended to an approximate life of 100 years. The present length of service for each of the MCR jetties ranges between 70 and 100 years and each jetty has been subjected to unique and severe loading induced by the region's environmental forcing. The jetties were originally constructed and repaired over the life cycle using progressively larger stone sizes and larger design templates as design criteria changed and equipment capacity evolved. At the same time, the surrounding loading climate was being altered.

If viewed strictly in terms of *realized* vs. *expected* maintenance costs (or repair tonnage), the North and South Jetties have performed as expected or better. However, what may be considered as good project performance (low O&M expenditure realized to date) may actually be an issue of deferred maintenance. Evaluation of a structure's present condition can inform whether a low maintenance expenditure rate is indicative of good structure performance or deferred maintenance. The following paragraphs provide a three-way comparison between: A) an expected rate of maintenance for MCR jetties, B) the realized maintenance rate for each jetty, and C) the present condition of each jetty. It is important to note that the stream of realized maintenance costs may not compare 1:1 with realized maintenance tonnage, if the unit cost for repairs was not consistent through time. For this reason, realized maintenance tonnage will be used to assess prior maintenance activity.

1. Expected Annual Maintenance - General Considerations vs. MCR Jetties

The annualized expenditure rate needed to maintain water resource infrastructure is typically based on an equivalent replacement value, accrued over the expected service life of the asset. In many cases, the maintenance rate is equivalent (or at least correlated) to a structure's estimated degradation rate. For a perpetual asset that is initially constructed with a 50-year service life, an expected maintenance rate would be 2%, expressed as percentage of initial structure construction tonnage (or cost, if repair unit costs are consistent). The above example assumes that the <u>entire</u> asset would be affected by some form of expected degradation. The asset would either be incrementally maintained throughout its 50-year service life or be replaced/rehabilitated after the 50-year period.

For many coastal navigation structures (jetties, breakwaters, revetments, seawalls), active degradation may be limited to an "affected" part of the structure where wave action or other active forcing is manifest. This would be the case if the structure was located in relatively deep water, where wave damage would be limited to the upper part of a structure (and there was now foundation-related degradation to affect the lower part of the structure). However, if a given structure was located in relatively shallow water and wave loading was both severe and depth-limited, then the entire cross-section could be degraded by wave action (from the structure toe to the crest). If the foundation of a structure was subjected to severe toe scour or slope instability, then much of the structure's entire cross-section could be degraded within the expected life-cycle.

2. Limited Vertical Extent of Wave Damage and Minor Toe Scour Effects:

If the structure's foundation does not experience severe degradation (scour or slope failure) and wave action does not affect the lower part of the structure, then the lower part of the structure could remain intact through a given life-cycle. Depending upon the water depth and wave action affecting the structure, only the upper 1/2 to 2/3 of the jetty cross-section may need to be replaced over the service life if the structure was <u>not</u> subjected to foundation degradation. In the absence of adverse foundation effects, the expected maintenance rate for a 50-year service life would correspond to 1% (upper 1/2 of the x-section x 2%) to 1.3% (upper 2/3 of x-section x 2%) of the initial structure construction tonnage.

3. Full Extent Wave Damage and Significant Toe Scour Effects:

If the structure's foundation were subjected to severe scour and wave action frequently affected the entire cross of the structure (from toe to crest), then the entire cross-section would be expected to degrade over a given life-cycle. The expected maintenance rate for a properly designed structure to function for a 50-year life-cycle would be 2%; the entire cross-section could require replacement within the life-cycle. If the wave action and toe scour was severe, and measures were not undertaken to mitigate either process, the maintenance rate could be 4%. This high maintenance rate may be considered unacceptable over a 50-year life-cycle, but could occur due to the entire cross-section being affected by two independent degradation processes.

Whether by design or by default, the MCR jetties have achieved an expected service life of 50-100 years. Assuming that foundation scour was not severe and that degradation due to wave action was limited to the upper half of the cross-section, the rate of maintenance needed to maintain the MCR jetties would be expected to vary from 0.5% (1/2 x 1%) to 1% (1/2 x 2%) per year. Based on this rationale, a maintenance rate of 0.7% was used to represent a favorable value for the MCR North and South Jetties. Table A2- 2summarizes annual maintenance rates for several hypothetical levels of MCR jetty performance, and compares these values to realized performance. Refer to Appendix A1 for detailed review of historical jetty cost expenditures at MCR.

Table A2- 2. Generalized Ratings for Annual Maintenance of Rubble-mound Structures Compared to Maintenance Realization for MCR Jetties Based on a 50-100 yr life-cycle

NJ & SJ ratings assume that the entire length of the structure has been adequately maintained with no deferred maintenance and that excessive foundation scour does not occur along entire structure.

MCR Project Feature	**Annualized Life Cycle Repairs Costs (in $ and tons of stone)** Expressed as a Fraction of Initial Construction*			
	Unsatisfactory 2%	**Marginal 1%**	**Excellent 0.35%**	**Actual Realization North & South Jetties**
North Jetty (cost)	$ 6.9 M/yr	$3.5 M/yr	$ 1.2 M/yr	**$ 0.5 M/yr**
(stone)	59 K tons/yr	30 K tons/yr	10 K tons/yr	**4.3 K tons/yr**
South Jetty (cost)	$ 15.7 M/yr	$7.8 M/yr	$ 2.7 M/yr	**$ 3.1 M/yr**
(stone)	108 K tons/yr	54 K tons/yr	20 K tons/yr	**33 K tons/yr**
JA ratings assume that the entire length of the structure has been adequately maintained with no deferred maintenance and that significant foundation scour occurs along much of the structure.				
	Unsatisfactory 4%	**Marginal 2%**	**Excellent 1%**	**Actual Realization Jetty A**
Jetty "A" (cost)	$ 0.76 M/yr	$0.38 M/yr	$ 0.19 M/yr	**$ 0.4 M/yr**
(stone)	9.4 K tons/yr	4.7 K tons/yr	2.3 K tons/yr	**5.7 K tons/yr**

* = Initial cost for North (South) Jetty was $345.8 million ($642.8 million). Present life cycle in 2010 for North (South) Jetty was 89 years (100 years). Initial cost for Jetty A was $19 million and life cycle during 1939-2007 was 68 years. **"Favorable" = average between marginal and excellent = 0.7 %.**

If foundation degradation was severe along the entire length of the jetty and wave action affected the entire cross-section, then the expected maintenance rate could be 1% (1 x 1%) to 2% (1 x 2%) per year. If the structure was not designed or maintained to address the severe wave of scour degradation, the (un)expected maintenance rate could be 2% (2 x 1%) to 4% (2 x 2%) per year. Based on this rationale, a maintenance rate of 1.5% was used to represent a favorable value for the MCR Jetty A. It is noted that the favorable maintenance rate for Jetty A assumes that the structure was designed to accommodate severe wave action and scour effects.

4. Realized Maintenance Rate & Current Condition of North and South Jetties

The average rate of maintenance realized to date for the North and South Jetties has been 0.15% and 0.45% per year, respectively (in terms of initial construction cost). If expressed in terms of repair *tonnage*, the realized maintenance rate for the North and South Jetties is 0.17% and 0.65% per year, respectively. Note the difference between maintenance rates based on cost vs. tonnage. This is due to unit repair costs ($/ton) being lower than initial construction costs. Realized maintenance rates were calculated by dividing the total maintenance effort (cost or tonnage) realized since jetty construction by the number of years for the present jetty life-cycle. The present life-cycle for the North Jetty is 93 years (1917-2010); and 100 years for the South Jetty (1910-2010). Figure A2- 6 and Figure A2- 7 show the actual maintenance rates (repair tonnage) for North and South Jetties, as compared to the expected rate. Based on the actual maintenance rate of 0.17%, the North jetty has performed much better than the expected maintenance rate of 0.7%. The favorable project performance is motivated by the formation of Benson Beach (Figure A1-35) protecting the North Jetty from wave action and scour along much of the ocean side of the jetty. The South Jetty has performed slightly better than expected, based on the actual maintenance rate of 0.65%; which is more than twice the maintenance rate of the North Jetty. Unlike the North Jetty, the South Jetty has been exposed to wave action and some excessive scour effects since its initial construction and consequently has a significantly higher maintenance rate than the North Jetty. But what does a low rate of maintenance say about jetty performance and the present condition of each jetty? A comparison between actual life-cycle costs realized to date and the present jetty condition can provide an indication if jetty repairs have been deferred.

During 2005-2007, interim repairs were completed "just-in-time" at specific areas of the North and South Jetties to prevent breaching at their most severely damaged areas. Many areas of each jetty remained in damaged condition following these interim repairs. Based on the most recent survey data (2006-2007), which included the post-constructed interim repairs, the amount of maintenance needed to restore each jetty to a minimal design configuration was estimated to be 237,000 tons for North Jetty and 412,000 tons for South Jetty. This tonnage deficiency represents the amount of deferred jetty maintenance, as of 2006-07. Expressed in terms of cost (2010 dollars), these deferred repair estimates translate to $46 million for North Jetty and $86 million for South Jetty. These estimates do not include additional jetty degradation since 2007, which has been documented in annual jetty monitoring reports [USACE 2011]. If the jetties had been maintained such that there was no deferred maintenance (perfect maintenance), the realized maintenance rate for the North and South Jetties would have been 0.26% and 0.74%, respectively. Actual maintenance rates for the North and South Jetties were 0.17% and 0.65%, respectively (Figure A2- 6 and Figure A2- 7). Based on the recent just-in-time repairs needed to avert imminent breaching along the North/South Jetties and the preset need for additional repairs, the difference between the actual maintenance rate vs. non-deferred maintenance rate indicates that repairs have been deferred.

5. Realized Maintenance Rate & Present Condition of Jetty A

To date, the average annual rate of maintenance actually expended on Jetty A has been 2.4% of the structure's initial construction tonnage (Figure A2- 8). This is considerably higher than a value of 0.7%, which is the expected value for MCR North and South Jetties. The expected maintenance rate for a structure such as Jetty A is 1.5%, due to the relatively large extent over which this structure is affected by both wave action and scour effects. Given the above qualifying considerations, Jetty A has performed poorer than the maintenance rate expected for this type of jetty structure.

The present life-cycle for the Jetty A is 68 years (1939-2010). The surrounding morphology was rapidly modified in response to the circulation changes induced by Jetty A construction, acting to increase wave action and scour along the jetty. As originally constructed, the entire vertical extent of the Jetty A cross-section was exposed to wave action. The jetty was initially constructed in shallow water using low resilience cross-section. A high level of maintenance was expended on Jetty A soon after construction to address extreme foundation scour along the outer 1/3 of the structure and low resiliency of initial jetty construction (to resist wave action). Repair actions implemented for Jetty A during the 1940s-1950s utilized readily available (but undersized) rock from a nearby quarry which produced a rebuilt cross-section of low resilience. The rebuilt jetty was rapidly damaged, requiring rehabilitation of the jetty during 1961-1962 following a breach event during the 1950s. The last time that Jetty A was repaired was in 1962.

Based on the most recent survey data for the MCR jetties (2006-2007), the amount of maintenance needed to restore Jetty A to a minimal design configuration is estimated to be 87,000 tons. Expressed in terms of cost (2010 dollars), this deferred repair estimate translates to $23 million. This estimate does not include additional jetty degradation since 2006, which has been documented in annual jetty monitoring reports [USACE 20011]. If Jetty A had been maintained such that there was no deferred maintenance, the realized maintenance rate would have been 3.0%, respectively (as compared to 2.4%, Figure A2- 8). Many areas along Jetty A are degraded and presently require repair, and Jetty A continues to sustain and accumulate damage each year. Based on the present condition of Jetty A, it can be concluded that maintenance has been deferred for this structure.

6. Jetties and Transient Morphology

The forcing environment affecting the jetties today is not the same as it was 70 or 100 years ago. At the time of jetty construction and shortly thereafter, the jetties were protected by the broad shallow sand shoals on which they were built. Initially, incident waves were severely depth-limited along much of each jetty and currents were reduced by the presence of shallow shoals. In some localized areas, jetty construction promoted shoaling along the jetty, further protecting it from wave and current action. In other areas, jetty construction motivated rapid dispersal of the sand shoals near the jetty, allowing larger waves and currents to affect the structure. The seaward terminus of each jetty experienced rapid deterioration immediately after initial construction due to the jetty head extending to the outer limit of the inlet's shoals, exposing the jetty head to severe current and wave action. As the seaward ends of jetties recede landward, the inlet morphology also recedes, promoting incremental shoaling of released sediment within the MCR inlet/channel, and allowing larger waves to enter the inlet's interior. Figure A2- 3 through Figure A2- 5 illustrate the integrated effect that the MCR jetties have with adjacent morphology. Note the submerged jetty heads in all three figures and differing bathymetry from one side of each jetty to the other (channel side to ocean side).

The stability of the present MCR inlet and adjacent coastal margins are dependent upon both the jetties and the tidal shoal morphology, on which the jetties were constructed. Figure A2-12 shows how the shoreline (0 MLLW) has responded due to jetty construction. Accretion of Benson Beach (in response to North Jetty construction, 1917) has protected most of the ocean side North Jetty from wave action and scour, while the jetty's channel side has been affected by morphology recession motivating scour and increased exposure to wave action.

The south side of the MCR inlet responded with both accretion and recession in response to South Jetty construction (1885-1910) protecting the inner 1/3 of the jetty from waves and scour (east of Sta 155). The shoreline and morphology along the outer 2/3 of the South Jetty has receded in response to jetty construction exposing this area of the jetty to increased scour and wave action. The shoreline and morphology response due to Jetty A construction (1939) is complicated by the overall response of the MCR inlet due to the long-term evolution of Baker Bay (1840-1939) combined with the post-construction response due to North and South Jetties. Local effects of Jetty A construction motivated significant recession of the morphology near the jetty, resulting in significant scour along the jetty and increased exposure to wave action from the ocean.

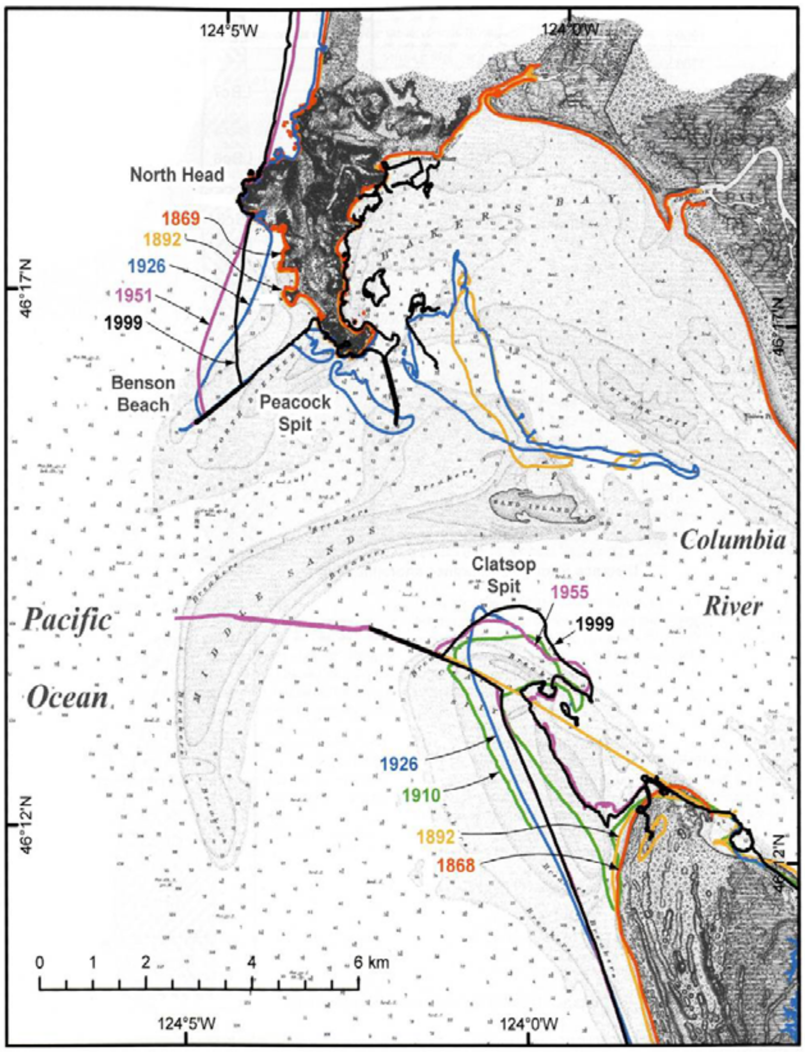


Fig. 6. 1870 U.S. Coast and Geodetic Survey – Mouth of the Columbia River, with historical shorelines.

Figure A2- 12. Historical Shoreline Response at the MCR

Mouth of the Columbia River historical shorelines. Base map is 1870 US Coast and Geodetic Survey (Kaminsky et al 2010). South Jetty constructed 1885-1910, North Jetty constructed 1913-1917, and Jetty A constructed 1938-1939.

Over time, the MCR tidal shoals, spits, and MCR jetties have evolved to function symbiotically. The interaction between jetties and morphology can be summarized by noting that the jetty is a long, thin, narrow backbone of solid material, resting upon a very doubtful foundation, against which the forces of nature have accumulated large quantities of shifting sand. These shoals break the force of the waves and protect the jetty from destruction. Jetty integrity and the permanence of the channel over the bar depend upon the amount of sand that can be accumulated [USACE 1905]. At present, each of the MCR jetties is acting to retain 10's of millions cy of sediment within and adjacent to the MCR inlet.

Due to the continual evolution of tidal shoals at MCR, the sand foundation of each jetty has receded and the resiliency of the jetties has been progressively compromised. The South Jetty has lost 4,200 ft of subareal length along its seaward end, and the seaward end of North Jetty has receded 1,800 ft due to morphology loss and erosion of the jetty foundation. Jetty A has lost 900 ft of length. The rate of morphology recession has decreased along some jetty reaches, most notably at areas near the original heads for Jetty A and South Jetty. Other areas continue to experience a constant rate of recession, such as Peacock Spit and areas of Clatsop Spit which affects the stability of the North and South Jetties. Some areas along Jetty A are showing signs of continued morphology reduction. At present, the seaward end for all MCR jetties is receding landward due to wave action. Foundation scour is also affecting the present outer end of the jetties and areas along the jetty toe.

As the seaward end of a jetty recedes landward, larger waves and stronger currents are able to attack the leeward jetty and the remaining morphology underneath; acting to increase the loss of the jetty section and foundation, leading to additional failure of each jetty. This is a self-perpetuating and coupled process of morphology loss and jetty deterioration. What this means is that the environmental loading along the MCR jetties has been increasing over time because of the evolving inlet and loss of supporting morphology. As the inlet's morphology has receded, larger waves are able to reach the inlet and attack the jetties. Depth-limited wave height along the jetties is increasing over time. The depth-limited wave height affecting the jetties has increased by greater than 30% since initial construction along many reaches of the MCR jetties. At the same time, the foundation along various reaches of each jetty has been compromised due to erosion of the shoals on which the jetty is founded. Vertical scour along the toe of the MCR jetties has exceeded 10 meters in some reaches [Moritz et al., 2007]. The extent over which the jetties continue to experience increased forcing continues to change and constitutes a non-stationary loading condition. The inlet's post-jetty morphology will continue to evolve, affecting large-scale changes for waves and circulation.

7. Alternative Measures to Address Transient Morphology

As part of the district's O&M dredging program, Regional Sediment Management (RSM) is being implemented at the MCR to abate the consequential inlet's large-scale recession, by maximizing the volume of dredged material that can be placed within the coastal near shore zone of the inlet [Moritz 2008]. The preference for near shore placement of dredged material at MCR is based on the objective to reduce the rate of morphology loss at the inlet. Abatement of localized sediment transport processes that actively degrade jetty stability was a primary objective for this study. These localized processes are addressed by alternative cross-sections for jetty rehabilitation and engineering feature alternatives (Main Report-Section 3.5, Appendix A1, and Section 5 of this Appendix). Figure A2- 3 through Figure A2- 5 illustrate how the present bathymetry and morphology adjacent to the three MCR jetties produces an elevated state of project risk. Each jetty is preventing a very large volume of sediment from entering the inlet and, ultimately, the MCR navigation channel. If prudent measures are undertaken, the heads of the jetties can be stabilized by building exclusively on the relic stone and by not over-extending jetty head reconstruction into excessive scour-prone areas.

8. Historical Breach Events for MCR Jetties

North Jetty. During 1999-2004, reaches of the North Jetty had experienced rapid deterioration. By 2002, several areas of the North Jetty were on the verge of breaching motivating interim repairs to be performed just-in-time in 2005. The jetty cross-section between stations 57-70 was degraded such that sediment was being transported through the jetty during high-tide storm wave conditions. Before completion of the North Jetty interim repairs in 2005, 100,000-200,000 cy of sand (from Benson Beach) had passed through the damaged cross section of the North Jetty. The sand deposited along the channel side of the North Jetty and was not transported toward the navigation channel due to lack of hydraulic forcing. The interim repairs were intended to last 5-10 years (from 2005) until the North Jetty could be rehabilitated. Refer to Chapter 1 of the Main Rehabilitation Evaluation Report for additional information.

South Jetty. During the 1920s, the South Jetty experienced severe degradation, resulting in a 1928 breach through the jetty cross-section near the shore connection (root) of the jetty. The consequences of the breached South Jetty were significant, a large volume of sediment passed through the breach (from south to north) and deposited within the inlet, changing the inlet's morphology. Much of the sediment along the ocean shore south of the inlet was transported by flow through the breached jetty (narrowing the margin between the ocean and Trestle Bay). Storm surge overtopped the ocean shore south of the South Jetty and passed into Trestle Bay, threatening the stability of the entire inlet. Tidal circulation through the South Jetty breach promoted the northward migration of Clatsop Spit, which changed the morphological character of the inlet, and adversely impacted navigation through the MCR.

The 1928 South Jetty breach event motivated a 9-year jetty rehabilitation program for the North and South Jetties, and included the construction of Jetty A to stabilize the MCR inlet. Refer to Chapter 1 of the Main Rehabilitation Evaluation Report for additional information. During 1999-2004, reaches of the South Jetty had experienced rapid deterioration motivating interim repairs to be performed just-in-time during 2006-2007. Due to localized areas of vulnerability along South Jetty, an advance contracting initiative (ACI) was executed in January 2006 to provide emergency repair contingency measures should the inner area of the South Jetty breach before the interim repairs could be implemented in summer 2006 (during the construction season). The outer reach of South Jetty experienced a partial breach in February 2006 and was repaired in 2007; the event was not severe enough as to motivate sand transport through the jetty. The South Jetty interim repairs were intended to last 5-10 years (from 2007) until the South Jetty could be rehabilitated.

Jetty A. Jetty A was constructed in 1939 to halt northward migration of the inlet and re-direct currents away from the North Jetty. In 1950, a 300-ft long breach developed at the mid-span of Jetty A allowing ~200,000 cy to be transported (eastward) over the jetty and toward Ilwaco channel. During 1951-61, approximately 500, 000 cy passed thru the Jetty A breach. Jetty A was rehabilitated in 1961-1962 to restore function and prevent further sediment encroachment (closure) of the Ilwaco navigation channel. Refer to Chapter 1 of the Main Rehabilitation Evaluation Report for additional information.

9. Summary of Current Jetty Vulnerability – Breaching

The current channel-side toe of the North Jetty is severely compromised due to foundation scour (note the low bathymetry elevations in Figure A2- 3), while the ocean side of the North Jetty is flanked by higher elevation bathymetry. The elevation difference of the bathymetry/topography from the ocean side to the channel of the North Jetty exceeds 10 meters along much of the jetty. Both sides of the North Jetty area exposed to large waves. The North Jetty acts as a wing dam to prevent Peacock Spit and Benson Beach from entering the inlet. More than 20 million cy of sediment is being retained by the North Jetty. Note the proximity of the MCR navigation channel to the North Jetty. The North Jetty is preventing a 10-meter high wall of sediment from entering the inlet. If the North Jetty were to be breached and hydraulic connection was established between the ocean and estuary (through the North Jetty), a substantial volume of shoal material (~2 to 8 million cy) could be released and transported into the inlet. Depending on the location and severity of a North Jetty breach, approximately 0.1 to 2 million cy of released sediment could be deposited within the navigation channel by flood tidal currents within 2-4 months of a jetty breach occurrence.

A similar breach vulnerability condition exists for the South Jetty. There is more than 30 million cy of sediment being retained by the South Jetty. The channel side of the South Jetty is in the lee of waves approaching the jetty directly from the Pacific Ocean. The channel side of the South Jetty is flanked by the high elevation bathymetry of Clatsop Spit; while the ocean side of the jetty is exposed to larger water depths and the direct attack of the Pacific Ocean wave environment. Note the proximity of the navigation channel to Clatsop Spit. If the South Jetty breaches, Clatsop Spit could be destabilized by tidal currents passing through the jetty, resulting in increased shoaling within the MCR channel. The rate and degree of channel shoaling associated with a South Jetty breach would be less than for the North Jetty. The ocean side root area of the South Jetty (sta. 165-195) is severely weakened and could be comprised (see the "*" shown in Figure A2- 4). The same is true for the present foredune along the South Jetty root location (sta. 155), that if breached could result in destabilization of the MCR inlet.

The vulnerability of Jetty A is motivated by its exposure to severe foundation scour along the outer end of the jetty (Figure A2- 5). The ocean side of Jetty A is pounded by ocean waves entering the MCR inlet, whereas the lee side sees practically no wave action. Due to the low elevation of the cross-section template used for Jetty A, the lee of the jetty can be destabilized by waves overtopping the jetty from the ocean side. Note the proximity of the navigation channel to the end of Jetty A and how the jetty anchors the entire north side morphology of the MCR inlet (from the eastern end of Sand Island to the North Jetty) Should Jetty A breach, Ilwaco channel would be compromised and the MCR channel would be impacted by increased shoaling. The stability of the North Jetty is linked to Jetty A. As the southern end of Jetty A recedes northward, Clatsop Spit migrates northward toward the MCR channel. Refer to Appendix A1 for a detailed discussion of MCR jetty vulnerability and breaching consequences.

10. Present Life-Cycle Issues for the MCR Jetties

A significant proportion of the remaining above-waterline elements of each jetty have deteriorated and the condition is worsening with time. Jetty repairs costing $26 million were recently completed in 2007 to address the most acute damage along limited reaches of the North and South Jetties. The 2007 jetty repair was required to prevent loss of jetty function (breach) and interruption of navigation through the MCR inlet. Many other locations of the all three jetties are in need of repair and degradation of the jetties continues. Continued degradation drives project reliability downward. Based on present damage trends and a lean maintenance strategy, the MCR jetties appear to be approaching a condition of continual repair. Risk-based methods were used to perform life-cycle analyses of the MCR jetties to address the following asset management concerns:

- What does the future hold for MCR jetties, in terms of expected damage trends?
- At which point will the opportunity to repair a failing jetty section before it loses function and navigation is affected be missed; what is the risk of this scenario?
- Is there an improved maintenance strategy for dealing with these aged structures?
- Is there an optimal way to increase the long-term reliability of the jetty system at MCR and minimize project cost outlays?

Evaluation of jetty damage is performed independently of the reliability calculation. In other words, cross-section degradation can affect the reliability estimate of a jetty, but changes in reliability do not affect jetty degradation; as emulated within the SRB model.

2. RELIABILITY AND RISK CONCEPTS

An engineered structure is a system of components which operate together to provide a specific function (or set of functions). Individual components must function satisfactorily in order for the overall structure to perform satisfactorily. Deep-draft navigation at the MCR inlet is secured by three MCR jetties. The three jetties act as a system; if one jetty fails to perform its function, navigation at the inlet can be compromised. Each jetty is composed of a system of structure components, each described by a performance mode. If a jetty component fails, the function of the entire jetty can be compromised, jeopardizing the function of the inlet. The MCR inlet can be considered to be a system of systems.

In engineering, *reliability* is defined as the probability of a structure (or component) to perform satisfactorily (Ps). By accounting for the randomness of system attributes, reliability-based design methods minimize the uncertainty associated with estimating engineering/design parameters and related economic projections [USACE-IWR 1992]. Judicious application of reliability-based methods can optimize project decision making by reducing the likelihood of over- or under-estimating project feature attributes required for cost-effective and reliable implementation. The consequences of implementing an over-estimated design feature can produce excessive initial cost expenditures resulting in lost opportunity for capital investment at other priority projects, and a perception of resource misallocation. Implementing an under-estimated design feature can lead to a wide range of unintended consequences, such as increased structure damage trend with unexpected higher and more frequent maintenance costs, sudden loss of project function, collateral damage to other infrastructure, and expedited corrective intervention.

Reliability-based design is intended to evaluate, reduce, or at least manage project risk. Project risk is defined as the probability of an essential project feature not performing its intended function (project failure probability) multiplied by the consequence of function loss (failure consequence). An example of project risk would be the realization of jetty function loss at a regionally important coastal inlet, resulting in the impairment of the inlet's navigation function. If the probability for jetty function loss in a given year is Pu and the consequence for the event of jetty functional loss is $-event, then project risk = Pu × $-event. An essential output provided by life-cycle analysis is time-varying project cost. Cost-related consequences that happen in the future, when discounted, are not as significant as things that happen today. In this case, reliability and other non-monetary metrics can be evaluated in conjunction with monetized data to give added insight for minimizing risk factors not explicitly defined within monetary metrics.

a. Project Event Tree – General Considerations

Complex decisions are the result of progressing through a series of sequential elementary choices and evaluating the consequences of each choice to reach a final "best" decision [USACE-IWR 1992]. An example is cast in terms of a future life-cycle scenario for the MCR North Jetty. As the North Jetty is intermittently damaged by progressive foundation scour and wave damage, areas of the jetty become weakened to the point where the structure has an elevated risk of failing. Several choices are available; continue to defer repairs, perform minimal localized repairs, perform jetty rehabilitation, and/or implement features to address processes affecting chronic damage. Each choice can produce different consequences. What is the consequence of not repairing the jetty? If repairs are to be made, how robust should the repairs be, and at what point in time should the jetty be repaired; should the jetty be rehabilitated? An event tree can be used to visually portray sequential decision problems and identify critical sequences in the life-cycle of a given structural feature or system. For the MCR jetties rehabilitation study, a project event tree was developed and used to link reliability and stochastic processes-responses to risk-based consequence.

An event tree is a schematic diagram that defines all permutations involving relevant structure performance modes and relates reliability-based outcomes to quantifiable consequences. The compilation of all consequence permutations results in an event tree. An event tree consists of decision points, probabilities of event occurrence, and conditional outcomes (composed of consequence and engineering cost assessment). The decision points within an event tree are usually defined by the reliability (or probability) for a given event realization, as affected by specific performance modes. An event realization results in a specific outcome, described by consequences and the intervention to manage the project features.

The event tree used for the life-cycle analysis of MCR jetties implemented decision points that were defined by stochastic conditional assessment, rather than a pre-determined reliability. Each decision point within the project event tree was the result of a probabilistic outcome which varied slightly from year to year and life-cycle to life-cycle. Reliability was calculated as a supplemental life-cycle metric to inform life-cycle performance for a given jetty scenario, but it was not used to define life-cycle evolution (event tree decision points).

b. Specific Considerations for the MCR Jetty Event Tree

The project event tree for the MCR jetties is shown in Figure A2- 9 through Figure A2- 11. The event tree diagram summarizes the annual functionality for a jetty in term of structural performance modes (static and dynamic), sustained damages, consequences, and costs. The event tree starts with the initial condition at year i; the forcing environment for year "i" is realized through stochastic simulation, jetty performance modes are assessed for each jetty segment "j" based on the realized forcing environment, and jetty damage for year "i" are stochastically evaluated. Cumulative damages for each segment "j" are evaluated at year "i" based on the previous years' performance. Finally, the consequences and costs for year "i" jetty damage are calculated. Consequences for year "i" can include repair activities for jetty segments, functional loss of a jetty segment, and incremental channel dredging due to segment function loss. Implementation of jetty repairs as year "i" is based on a threshold evaluation. Jetty repairs are enacted if the jetty cross-section at a given segment falls below a specified maintenance threshold, which is a random variable. If a jetty segment sustains a loss of function within a given year "i" (jetty head recession or a jetty breach), then additional adverse consequences may be realized in terms of added channel dredging costs; which is also a random variable. The event tree diagram is repeated for n-years for all jetty segments, until the entire life-cycle period is realized. As described above and shown in Figure A2- 9, the project event tree provided the basis for evaluating various life-cycle stages for each of the three (3) MCR jetties. Life-cycle stages evaluated within this report included:

A. Hindcast life-cycle (original jetty construction to present condition-2007). Dredging costs are not included in hindcast evaluations.
B. Future life-cycle (2007 to 2070) for the present jetty condition and present *baseline* maintenance strategy.
C. Future life-cycle realizations based on various optional *maintenance* strategies, which may or not include adding engineering features to a given jetty.

D. Future life-cycle realizations based on various *rehabilitation* strategies, which include additional engineering features.

The following sections describe concepts of reliability and risk and how these parameters were evaluated within the SRB model to provide life-cycle metrics for the MCR jetties.

c. Elements of Reliability

There are two general elements of reliability: structural and functional. *Structural reliability* is the likelihood that a structure will not be damaged, within a given time interval. If the structure is susceptible to damage, structural reliability indicates the relative degree of damage that could occur. In many cases, a structure or project feature can incur damage (or degradation) without affecting the overall function of the structure. The capacity for sustaining damage without failing is called *resilience*. When a structure sustains cumulative damage (deferred maintenance) to the point of exceeding its resilience, the structure can lose the ability to perform its intended function. At this point the structure fails. *Functional reliability* is the likelihood that a structure will satisfactorily perform its intended function, within a given time interval. Functional reliability is derived by combining structural reliability metrics with metrics that describe the present structure cross-section configuration. Unchecked degradation of a structure (reduction in structural reliability) leads to reduced functional reliability.

d. Life-Cycle Risk

Project life-cycle costs are affected by two risk elements. *Structural risk* is associated with consequences of a structure being damaged and is driven by structural reliability. Consequences of incurring structural risk are realized when the cumulative damage exceeds a given threshold maintenance level, motivating repairs to maintain the structure at a minimal level of resilience. The consequence of structural risk can occur frequently and usually carries a low to moderate cost per realized event, provided that the structure expresses an acceptable level of resiliency. Structure resiliency and threshold maintenance level is an important consideration governing life-cycle management of infrastructure.

Function risk is related to a structure's functional reliability, and is associated with the consequences of a structure failing to provide its intended function. Function risk and project risk are synonymous. Realization of functional failure can occur when the jetty cross-section area is reduced below a critical threshold, to a value below the maintenance threshold. In the case of the MCR jetties, a jetty breach can occur when the upper cross-section is damaged (reduced) by more than 80%. At this point, a breach occurrence is simulated as a random event having a 50% likelihood of realization in a given year. A breached jetty corresponds to function reliability = 0. Consequences of being on the wrong side of project risk (experiencing functional failure) are realized as infrequent events having a range of outcomes which can add moderate to high costs to the life-cycle. The consequences associated with function risk are usually the element of focus when investigating a structure's future life-cycle due to the high costs associated with loss of project function. Note that the cumulative aspect of incurring structure risk (damage) can add significant cost over time to a structure's life-cycle and should be considered with the same emphasis as function risk (breach).

The difference between structural and functional reliability is indicated by the ability of a structure to incur damage (expressing structure unsatisfactory performance) before losing function (functional failure). A structure that has no capacity to incur damage before losing function will express a functional reliability that is the equivalent to structural reliability. Resiliency is the marginal difference between structural and functional reliability.

e. Incremental Development of Alternatives Based on Risk and Reliability

The focus of this rehabilitation study was to identify and evaluate alternatives and recommend a course of action that balances future reliability and life-cycle cost for the system of jetties at MCR. A range of alternatives were developed through a step-wise procedure. First, the structural and functional risks affecting the present life-cycle of each jetty were identified and evaluated. Second, a range of incremental alternatives were developed to mitigate present and future risks affecting the life-cycle of each jetty. Alternatives included various without-project maintenance strategies, with-project initiatives, and several types of engineering features. Third, an implementation schedule was developed for each alternative to match construction timing with project risk over the life-cycle period.

The entire ensemble of with-project and without-project alternatives was evaluated using the SRB model to investigate the incremental improvement in project performance, as indicated by non-monetary metrics describing structural risk. In this sense, structure risk is a function of repair timing (when do repairs occur), frequency (how often), and location. The recommended plan for each jetty was selected by optimizing the initial cost of structure rehabilitation, optimizing future maintenance costs, considering the time-varying reliability of the jetty, and considering the potential for incurring pronounced channel shoaling arising from loss of jetty function. Refer to Chapter 4 of the Main Rehabilitation Evaluation Report for discussion of alternative selection.

Without-project alternatives included implementing different levels of future maintenance strategies. Evaluation of alternative maintenance strategies focused on varying the threshold level for initiating jetty repairs. Without-project alternatives avoid the initial cost of structure rehabilitation, but can incur elevated future maintenance commitment and cost by having to mitigate continual low reliability. In cases where repairs were deferred during the previous life-cycle, a proactive future maintenance strategy may require online repairs very early into the future life-cycle, emulating the magnitude of initial costs associated with structure rehabilitation.

With-project alternatives (rehabilitation) focused on reconstructing or enhancing the jetty cross-section based on a range of cross-section templates. Jetty rehab alternatives induce a high initial cost, but restore project reliability early into the future life-cycle and can reduce the future maintenance commitment. Discrete structural enhancements or engineering features were developed as a way to mitigate the chronic effects of jetty toe scour affecting jetty root degradation (jetty spur groins) and jetty head recession affecting morphology loss (jetty head cap). Engineering features are considered to be incremental with-project alternatives.

Minimum rehabilitation is appropriate in cases where the forcing-loading environment is stationary and not severe, and the structure can be adequately maintained in the future. In cases where the present loading environment is moderate to severe (or is non-stationary, increasing over time), more robust rehabilitation alternatives are required to increase project resilience and address increased structure loading. This approach may also be needed to address certain areas of a structure that cannot be easily maintained (difficult construction access). Applying engineering features along a given jetty can mitigate foundation scour and other jetty-specific degradation issues. Additional discussion concerning alternative plan development can be found in Chapters 3 and 5 of the Main Rehabilitation Evaluation Report, Appendix A1, Appendix C, and later in this appendix.

f. Estimating Structure Reliability

Composite structure reliability is based on the integration of all relevant performance modes affecting a structure. A performance mode is defined as a particular action-reaction response for a given structure component and is quantitatively described in terms of a design relationship expressed as a factor of safety. Each pertinent design parameter within the design relationship is expressed in terms of a random variable, rather than a point value, as is the case in deterministic design methods. In a simplified approach, a random variable can be bounded by a mean value, standard deviation, and prescribed statistical distribution. In a more rigorous approach, a prescribed probability density function is used to describe a given random variable. Reliability-based design is well suited to the coastal-ocean engineering discipline, where a high degree of randomness precludes accurate estimation of point-value parameters, based on incomplete data which can be biased by subjective assumptions.

A performance mode refers to a specific process affecting structure reliability, such as the loss of a jetty cross-section by wave overtopping. The “performance function” is a mathematical expression involving the random variables that govern a given performance mode. The performance function can be represented in terms of a factor of safety (FS), which is expressed in terms of capacity of the structure to resist loading (C) divided by the demand imposed on the structure due to loading (D); FS = C/D. Alternatively, the performance function can be represented in terms of the safety margin (SM); SM = C-D.

1. Reliability from Safety Factor

Figure A2- 13 illustrates how the FS is portrayed on context of random variable for C and D. The mathematical representation of the FS is called a “performance function” and was used to estimate reliability indices. The reliability index (β) for a given performance mode is defined as the number of standard deviations the mean FS is above the limit state (FS=1.0 or SM = 0). Figure A2- 14 illustrates how β, capacity (C), and demand (D) are related. Note that reliability index (β) can increase with an increase in mean FS (μ). Reliability index increases with decreasing variability of FS (standard deviation, σ), and β decreases with increasing FSσ. When $\mu_{SF} = 1.0$, $\beta=0$, and P(s) or reliability = 0.5, this condition is defined as the "limit state" [Harr 1987, USACE 1992].

All that is needed to solve for β and determine and P(s) is the mean and standard deviation for each pertinent variable within the performance function. Since capacity and demand are considered to be log-normally distributed, β can be defined from the mean (μ) and the standard deviation (σ) of the logarithm of FS (or C/D) through the following [USACE 1992]:

$$\beta_{FS} = \frac{\mu_{\ln(FS)}}{\sigma_{\ln(FS)}} \qquad \text{where,} \qquad \sigma_{\ln(FS)} = \sqrt{\{\ln[1 + (\mu_{FS}/\sigma_{FS})^2]\}}$$

$$\mu_{\ln(FS)} = \frac{\ln[\mu_{FS}] - \sigma^2_{\ln(FS)}}{2}$$

$$\sigma^2_{FS} = \sum_{i=1}^{n} [\{\partial FS/\partial Xi\} * \sigma_i]^2$$

Xi = variable of interest and n is the total number of variables in FS
ln = natural logarithm

An approximate solution for σ_{FS} was determined using an approach similar to the first order second moment method (FOSM), according to EC 1110-2-6062 [USACE 2008]. Rather than evaluating the performance functions to first order as in FOSM, the analysis featured in this appendix expanded the performance functions to third order to account for the non-linear nature of the random variables. The result (σ_{FS}) was applied within the SRB model to solve for β. This process was done for each performance mode of interest, at each jetty segment, and for each year within a given life-cycle simulation.

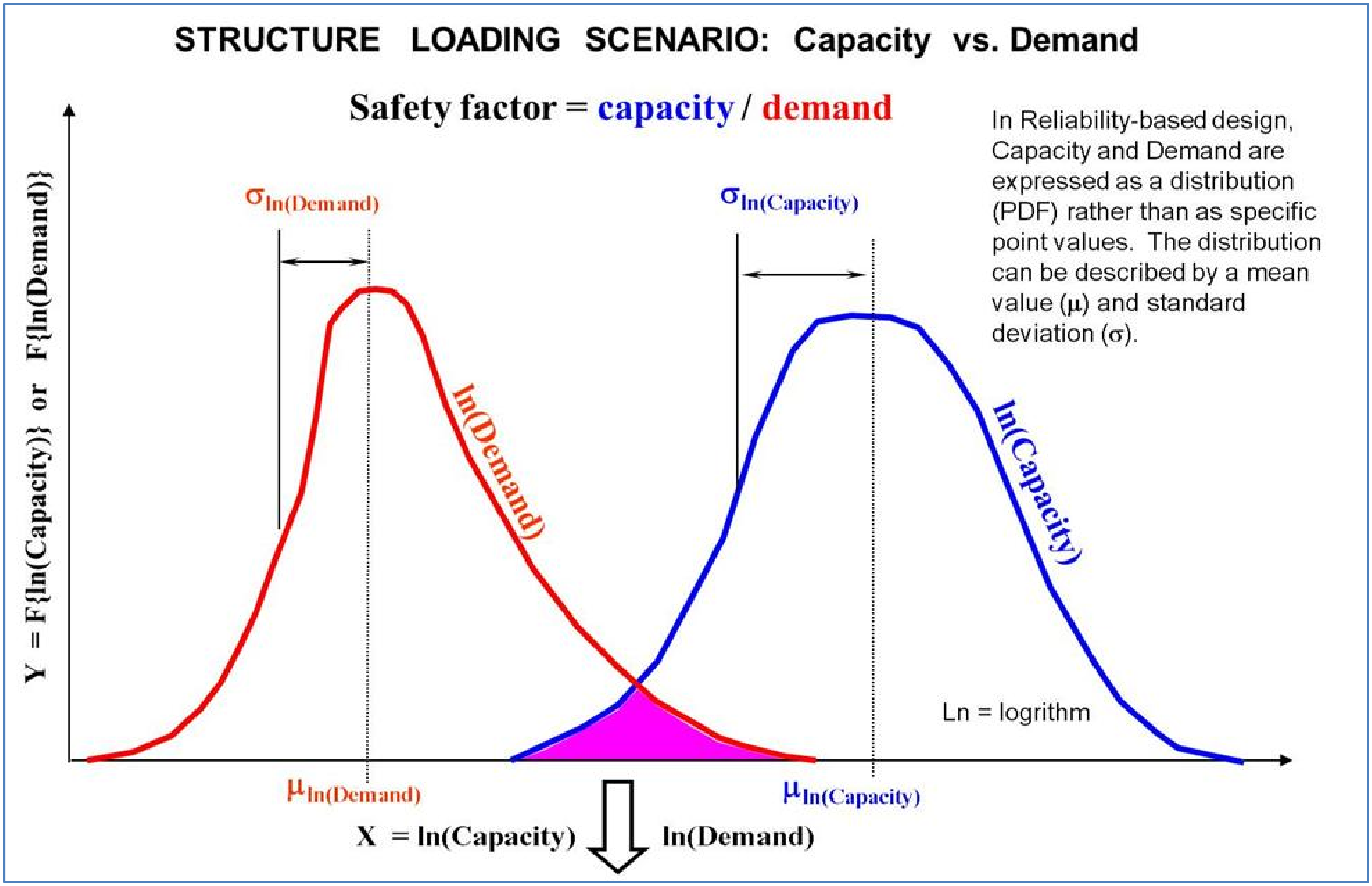


Figure A2- 13. Definition of Capacity and Demand in Reliability-Based Design

For a given structure performance mode, capacity is the ability for a structural element to resist imposed loads for a given mode of performance. Demand is the load imposed on a structural element. The region where there distribution for capacity and demand overlap identifies the potential for when demand may exceed capacity for a given performance mode.

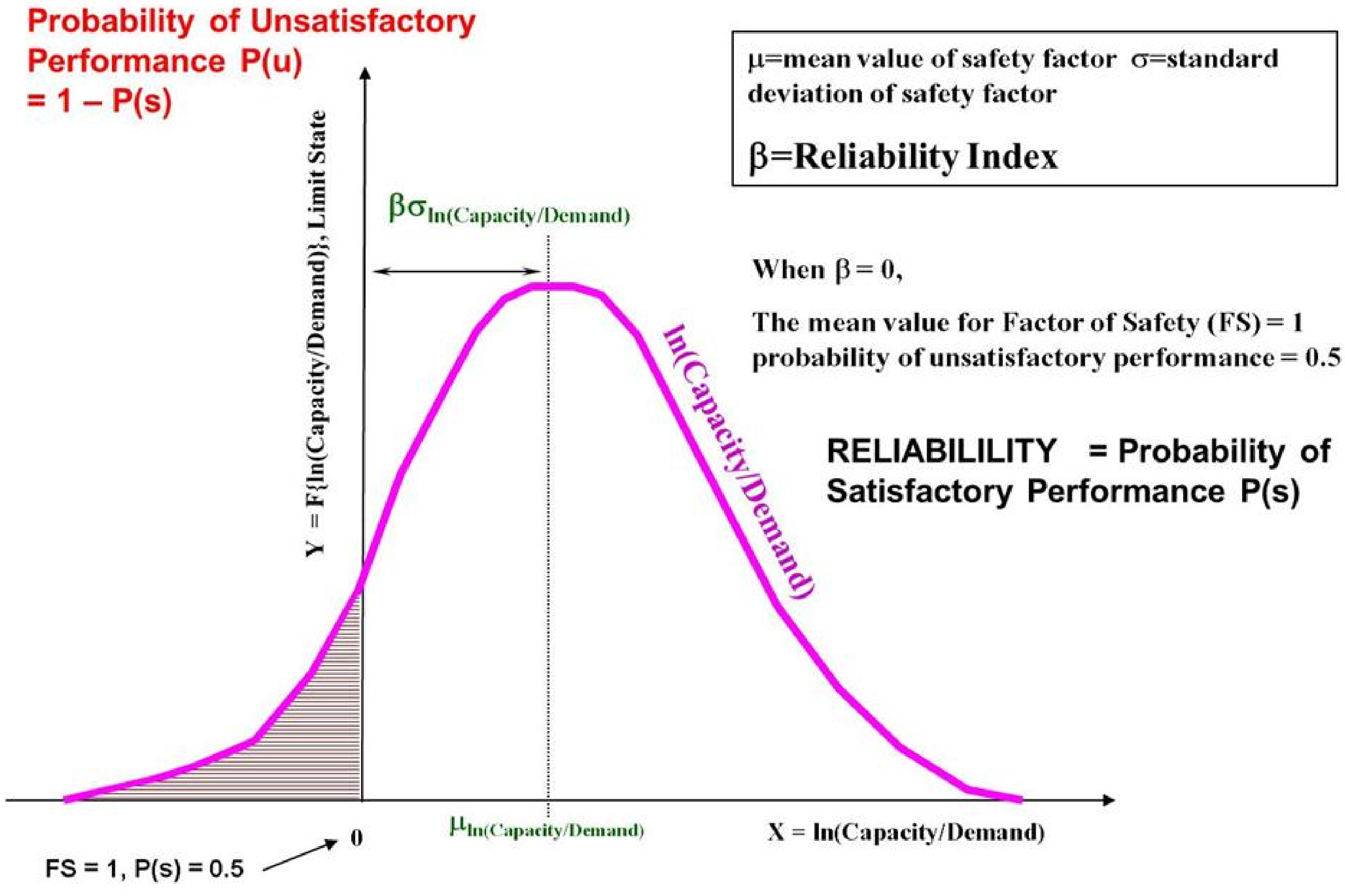


Figure A2- 14. Definition of Reliability Index for a given Structure Performance Mode

As described by the ratio of capacity to demand. In most cases, the reliability index is considered a standard normal variable, which allows direct estimation of reliability, P(s).

2. Reliability from Safety Margin

Alternatively, β can be estimated from a performance function based on the safety margin (SM = C-D) according to the relationship given below. When $\mu_{SM} = 0$, $\beta = 0$, and P(s) or reliability = 0.5, this condition is defined as the "limit state" [Harr 1987, USACE 2008]. Use of a SM-based performance function may be advantageous to stabilize the non-linear effects associated with the ratio of capacity (C) and demand (D), when D becomes less than unity. Evaluating C/D can be challenging if D is a non-linear function of random variables.

$$\beta_{SM} = \frac{\mu[C] - \mu[D]}{\sqrt{\sigma^2[C] - \sigma^2[D]}} \qquad \text{where,} \qquad \sigma[C] = \sqrt{\sum_{i=1}^{n} \sigma^2[c_i]}$$

$$\sigma[D] = \sqrt{\sum_{i=1}^{n} \sigma^2[d_i]}$$

c_i = capacity variable of interest (i) and *n* is the total number of variables in capacity
d_i = demand variable of interest (i) and *n* is the total number of variables in demand

β values were estimated using both the SM and FS methods. Comparison of SM and FS derived β-values indicated that the two methods produce similar results. There are subtle differences between the two β estimates when β approaches small negative values. To address potential uncertainty in estimating β, the SRB model combined the results from both the SM and FS methods to produce a blended estimate (root-mean square) for β. Since β is considered a standard normal random variable, it can be used to directly determine reliability in terms of P(s) for a given performance mode [Harr 1987, USACE 2008]. Time-varying βs and corresponding values for P(s) were determined for the individual performance modes for the historic and future life-cycle of each jetty. The probability of unsatisfactory performance, P(u), is the compliment of satisfactory performance and is determined by:

P(u) = Probability of unsatisfactory performance
= 1-P(s) *where* P(s) = Probability of satisfactory performance

Table A2- 3 summarizes target reliability indices and corresponding P(u) for structure performance, in reference to major rehabilitation guidance presented in ETL 1110-2-532. Note that the values shown in Table A2- 3 indicate the likelihood of a structure to exceed a given performance limit state, or the probability to experience unsatisfactory structural performance P(u). Unsatisfactory structural performance occurs when a structure incurs damage. The values shown in Table A2- 3 are intended to be used only for the MCR project; these values are not to be used for citation. Note that the values shown in Table A2- 3 do *not* indicate the likelihood for a structure to fail (lose its function), which occurs for a condition of unsatisfactory functional performance. However, continual unsatisfactory structural performance indicates that the structure is accumulating damage. At a critical threshold of structure degradation (breach threshold), there is not enough cross-section area remaining to maintain structure function. At this point, the structure can fail to perform its intended function (realization of unsatisfactory functional performance). In this sense, functional performance is related to structure reliability (performance) and the amount of cross-section area remaining on the structure.

Table A2- 3. Target Reliability Indices for Structure Performance

Values for conventional practice apply to rigid non-compliant steel structures such as bridges, lock gates, or vertical walls. Values and corresponding consequences given for rubble-mound structures are applicable for MCR jetties ONLY and are assumed to have two or more layers of armor units protecting core material.

Expected Performance Level Conventional Practice (steel structures) ETL 1110-2-532	Rubble-mound Structures @ MCR^	**Beta (β)**	**Probability of Unsatisfactory *Structure* Performance** P(u)	**Potential Structure Consequences to MCR Jetties**
High	***Excellent***	5	0.0000003	No likelihood of any structure degradation
Good	***Excellent***	4	0.00003	
Above Average	***Very High***	2	0.023	Little Likelihood of any structure degradation
Below Average	***High***	1.2	0.10	-Low likelihood for any structure degradation in response to extreme waves
Poor	***Good***	0.8	0.2	-Low likelihood for Minor structure degradation in response to extreme waves
Unsatisfactory	***Average***	0.5	0.3	-Moderate likelihood for Minor structure degradation in response to extreme waves
Hazardous	***Below Average***	0	0.5	High likelihood for Minor structure degradation in response to extreme waves
---n/a---	***Poor***	-0.2	0.6	-Low likelihood for elevated structure degradation
---n/a---	***Unsatisfactory***	-0.5	0.7	-Moderate likelihood for elevated structure degradation
---n/a---	***Hazardous***	<-0.8	>0.8	High likelihood for elevated structure degradation.

^ = This table and the values presented within are applicable ONLY to the rubble-mound MCR jetties. This table shall not be used for citation or reference.

After obtaining values of P(s) for the individual structure performance modes of a given jetty configuration, the composite structural and functional reliability for each jetty (and for each alternative configuration) can be estimated. Composite structural reliability was computed assuming the individual performance modes act in a series system. Composite reliabilities are important metrics that were used in conjunction with projected life-cycle costs to compare alternatives for future maintenance strategies and rehabilitation plans. Figure A2-15 shows how the composite structural reliability can change over time for a specific jetty location.

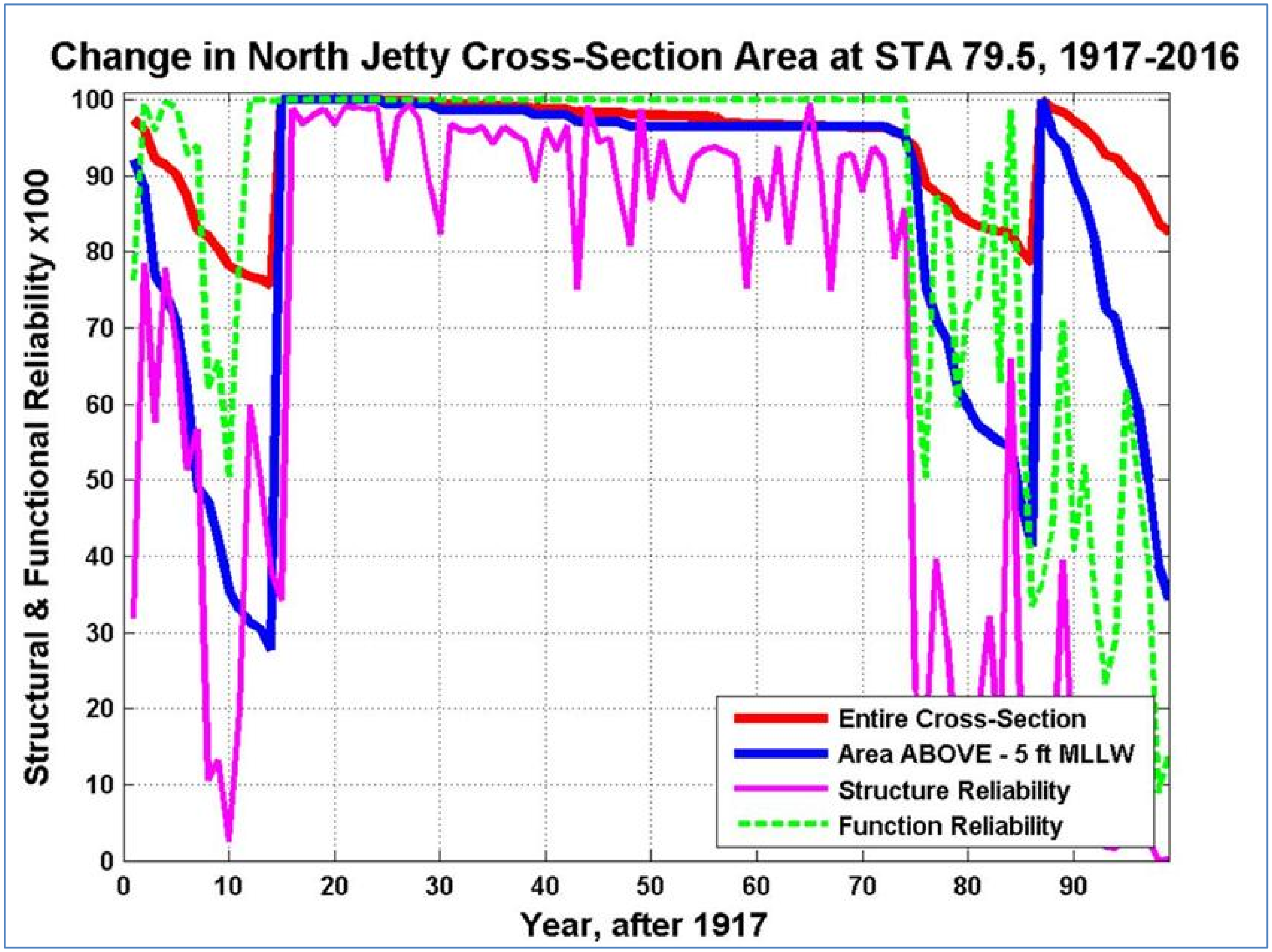


Figure A2- 15. Simulated Change in Jetty Cross-Section Area and Reliability

g. Reliability of Rubble-Mound Structures

Conventional civil engineering structures are composed of “rigid” elements; i.e., damage sustained by one component can jeopardize the functional performance of the entire structure. A rigid component possesses little margin (resilience) for sustaining damage before the element fails; if the component is damaged it can fail. In conventional civil engineering practice, load and resistance (demand and capacity) scenarios for structures such as bridges, dams, levees, and vertical walls are rarely designed with FS less than 1.2. Conventional (non-compliant) structures typically achieve a reliability index β range of 3<β<5 [USACE 1992]. This range of structural reliability is expected for design applications where structure capacity and demands are well known and have low coefficients of variation (σ/μ). Such may not be the case for many types of compliant maritime structures, where both the loading scenarios (demands) and structure response scenarios (capacity) can exhibit high coefficients of variation (0.3).

The MCR jetties are rubble-mound structures. A rubble-mound structure is composed of several layers of variable sized/shaped stone randomly placed to create the structure’s core. The core of a jetty is protected using a cover layer of selectively placed armor units of either quarry stone or specifically shaped concrete units (armor layer). Maintaining the stability of the armor layer is integral for achieving satisfactory performance of a rubble-mound structure. Yet, because the armor layer for the MCR jetties is composed of many semi-independent interlocking units, the jetties can withstand a finite amount of damage without being functionally compromised (fail). The concept of finite damage makes the jetties compliant or “resilient.” In many cases, the armor layer for rubble-mound coastal structures may be designed using performance functions (FS) which approach 1.0.

Coastal structures composed of concrete armor units (CAUs) are not compliant and possess little margin for resiliency. The same can be stated for a rubble-mound structure incorporating only one layer of armor stone. Concrete armor units rely on interlocking to achieve stability; a displaced CAU loses much of its stability and can reduce the stability of neighboring units from which the displaced armor unit originated. Most types of CAUs are fragile in that a displaced unit usually breaks, rendering it useless. Although stone armor units are more resilient on a unit basis (displaced stone armor units do not readily break and they retain some of their stability after being displaced), a 1-unit thick armor layer provides no added resiliency after the armor units have been displaced, exposing core material to wave action. In the above cases, the armor units would be designed with safety factors and reliability indices similar to conventional civil engineering practice.

Table A2- 3 compares structural reliability (β values) applicable for conventional steel frame structures to values developed for mound structures at MCR. The structure consequences for MCR jetties and corresponding reliability (β) values were developed by comparing the calculated β (Ps) to a specific loading and structural condition for a given MCR jetty segment, at a given point in time. A lower reliability index (β) indicates that the jetty has a higher likelihood to incur damage. The process of calibrating β values and structure consequences for MCR rubble-mound jetties was based on the approach used for the major rehabilitation study at Burns Harbor Breakwater [USACE 1993]. Calibrating the SRB model (and estimated reliability) was based on successful jetty life-cycle hindcast. The results shown in Table A2- 3 are site specific and applicable *only* for the MCR Jetties. The aspect of jetty resiliency is why a target β range of 0 to 0.5 (for structural performance) is acceptable for MCR jetties, at least until accumulated damage reaches a critical threshold. The limit of cross-section resiliency is reached for jetties when the core stone of a jetty becomes exposed to wave attack (or a critical percentage of the cross section has been removed). At this resilience limit, the remaining jetty can be subject to rapid cross-section loss, and the structure's cross-section may become breached. The MCR jetties are considered to lose function (fail) when the upper cross-section is breached.

Because rubble-mound structures (jetties) can afford a large degree of resiliency before being functionally compromised, less conservative maintenance strategies can be implemented to manage the structure's life-cycle, providing project risk is correctly managed. A less conservative maintenance strategy is essentially a deferred repair condition. The structure is permitted to experience significant degradation before repairs are undertaken. Deferred maintenance can suppress life-cycle expenditures, up to the point at which the structure is on the verge of losing function (failing). When this condition is reached, the damaged structure will require extensive repairs to renew the life-cycle to a point where repairs can once again be deferred.

3. PERFORMANCE FUNCTIONS AND FAILURE MODES

a. Structural Reliability

The estimation of structural reliability within the SRB model is an extension of the method employed for the analysis of a rubble-mound breakwater [USACE 1993; Moritz et al 1994]. The structural reliability of the three jetties at MCR was assessed based on the ability of each jetty's cross-section to resist the environmental loading which occurs along the jetties. Structure reliability is based on the performance of the upper region of the jetty cross-section to remain stable. Structure reliability (jetty stability) examined within the scope of this rehabilitation report is based on the two general performance modes: static stability and dynamic stability.

Static stability affects the lower part of the jetty cross-section, generally below –5 ft MLLW, on the ocean side and channel side of the jetty (Figure A2- 16). Within this analysis, static stability addresses the susceptibility of the jetty toe to be affected by wave-current scour, and resistance of the jetty slope to sliding down grade along a slip-plane. The jetty toe is the interface where the jetty intersects the morphology on which it is founded. Jetty damage motivated by static stability propagates up-slope to affect the upper region of the jetty cross-section, above -5 ft MLLW. Static stability of the lower cross-section region (below -5 ft MLLW) is evaluated stochastically within the SRB model based on jetty slope re-adjustment (creeping failure) in response to toe scour. Static stability performance is indirectly evaluated through the analysis of the upper jetty cross section, which can be affected by both static and dynamic stability performance modes.

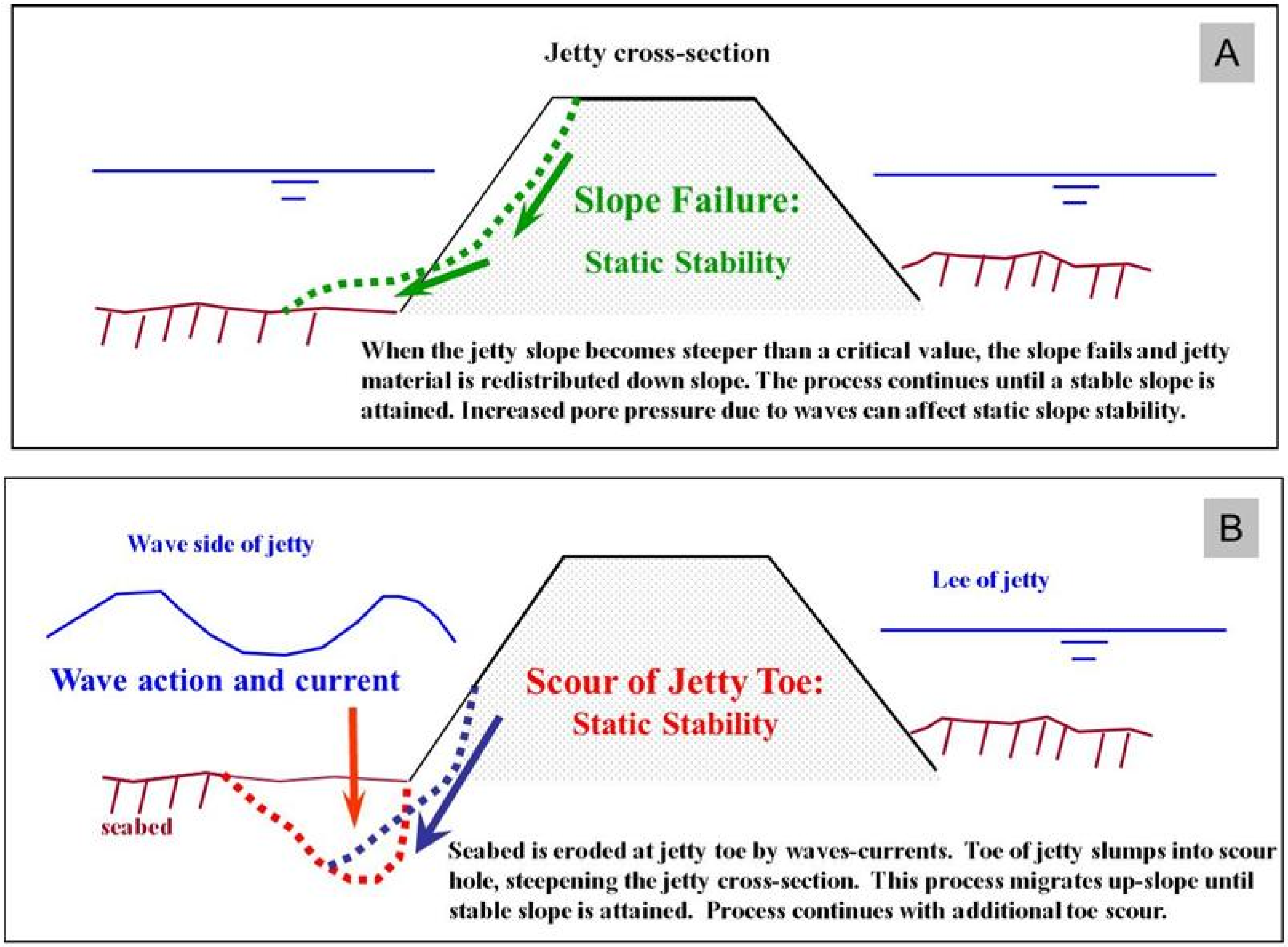


Figure A2- 16. Jetty Performance Modes for Static Stability

Dynamic stability affects the upper part of a jetty cross-section as a result of wave action, generally from –5 ft MLLW up to the jetty crest on the ocean side and channel side of a jetty (Figure A2- 17). On the side of the jetty directly exposed to wave action, dynamic stability is manifest by the direct impact of waves on the jetty and the potential displacement of individual armor units. On the lee side of the jetty, dynamic stability addresses the effect of waves overtopping the jetty crest and displacing armor or down-slope off of the jetty cross-section. There are many locations along the MCR jetties which experience direct wave attack along both sides of each jetty, in which case each side of the jetty experiences direct wave action and overtopping wave action.

The structural reliability and performance of a rubble-mound jetty can be characterized in terms of its ability to: A) resist wave attack (dynamic stability), and B) maintain a stable footprint/slope configuration on the seabed foundation (static stability). If the cross-section of a jetty exhibits chronically poor structural performance and is continually damaged, the upper part of the cross section can be reduced to a level that is less than a minimum functional configuration. The minimum functional configuration for the upper part of a jetty cross-section has been estimated to be 20% of the standard design template. At this point, the jetty cross-section can breach and the jetty will no longer perform its intended function. The function of each jetty is directly attributed to the performance of the upper region of the structure cross-section (above –5 ft MLLW). The consequences of a breached jetty cross-section are dependent upon the location of the jetty breach. Refer to *Functional Reliability* later in this section for additional information concerning functional performance.

1. Static Stability

Within the context of this analysis, static stability was considered to be a long-term performance mode with chronic (creeping) effects that can occur continuously. The long-term accumulation of these effects contributes to the incremental failure (unsatisfactory performance) of the jetty cross-section. There are two modes of performance affecting the static stability of MCR jetties: A) scour of the jetty foundation, and B) slope failure within the jetty cross-section. Static performance modes can interact to contribute to the long-term response and damage of the jetty. This process is described below.

Scour of the Jetty Toe. The MCR jetties were constructed on massive tidal shoals during 1885-1919 and the morphology of the inlet has been changing ever since. The jetties have experienced significant deterioration since construction due, in part, to foundation instability associated with the erosion of tidal shoals on which the jetties were built. This process is manifest as a jetty performance mode - scour of the jetty toe. As the seabed along the jetty toe is eroded by waves-currents, jetty stone along the toe “falls” into the scour trench. The continual loss of stone from the jetty toe can lead to enhanced degradation that migrates upward along the jetty slope, initiating a creeping slope failure within the jetty cross-section (Figure A2- 16b). Scour of marine structure foundations is a function of sediment size, current speed, wave height and period, water depth, and can be enhanced by the interaction of the seabed with structures. Due to the constantly varying interaction of waves and currents with bottom sediment at MCR, explicit specification of a scour performance function for each jetty is problematic. However, based on the rate of change in seabed elevation observed along each jetty during various time periods since jetty construction, average rates and timing for toe scour has been calculated for different locations along each jetty (refer to Table A2- 4 through Table A2- 6 and Appendix A1). The rate of historical scour along the MCR jetties has varied from 0 to 8 ft/yr, depending upon jetty location and exposure to waves and currents. The rate of scour projected for future conditions along the jetties is estimated to vary between 0 and 1 ft/yr. The present and future rate of jetty scour is less than historical values because the inlet has equilibrated to some degree with the jetties. Future jetty scour is projected to migrate inshore along the jetties, as the inlet morphology continues to adjust. It must be noted that although future scour rates are expected to be less than historical rates, toe scour can have a significant long-term effect on jetty stability. The scour rates in Table A2- 4 through Table A2- 6 were used within SRB event tree simulations to estimate jetty damage associated with cumulative scour effects. Refer to Foundation Effects in Section 6 for a discussion of how the toe scour effect is simulated within the SRB model.

Table A2- 4. North Jetty Toe Scour and Morphological Factors for Wave Height

Jetty Station	Side of Jetty	PAST Life-Cycle 1917 - 2006 Estimated	Observed	Present Seabed Elevation	FUTURE Life-Cycle 2006-2070 Estimated	Estimated
		Morphological Factor 1917 : 2006	Total Scour @ jetty (ft)	200 ft offset from toe (ft, NGVD)	Morphological Factor 2006 : 2070	Total Scour @ jetty (ft)
20+00	Ocean	0.70 : 1	deposition	*18*	-	0
50+00	Ocean	0.75 : 1	deposition	*12*	-	0
65+00	Ocean	0.77 : 1	deposition	*2*	1 : 1.1	-5
75+00	Ocean	0.79 : 1	deposition	*-5*	1 : 1.2	-10
85+00	Ocean	0.80 : 1	deposition	-16	1 : 1.3	-10
100+00	Ocean	0.75 : 1	0	-27	1 : 1.2	-15
124+00	Ocean	0.65 : 1	-15	*-31*	1 : 1.1	-10
		1917 : 2006			2006 : 2070	
20+00	Channel	0.6 : 1	0	-27	1 : 1.3	0
40+00	Channel	0.7 : 1	-5	-36	1 : 1.3	0
60+00	Channel	0.8 : 1	-10	-41	1 : 1.3	-10
80+00	Channel	0.8 : 1	-10	-50	1 : 1.3	-15
100+00	Channel	0.7 : 1	-30	-68	1 : 1.3	-10
124+00	Channel	0.65 : 1	-40	*-64*	1 : 1.2	0

NORTH Jetty morphological factors for modifying wave height along jetty and Scour depth at jetty toe. The toe scour values given for the future life cycle do not include the mitigating effect of constructing additional jetty spurs to reduce toe scour along the jetty foundation.

Table A2- 5. South Jetty Toe Scour and Morphological Factors for Wave Height

Jetty Station	Side of Jetty	PAST Life-Cycle 1910 - 2007 Estimated Morphological Factor 1917 : 2006	Observed Total Scour @ jetty (ft)	Present Seabed Elevation 200 ft offset from toe (ft, NGVD)	FUTURE Life-Cycle 2007-2070 Estimated Morphological Factor 2006 : 2070	Estimated Total Scour @ jetty (ft)
155+00	Ocean	0.67 : 1	deposition	*8*	-	-8
165+00	Ocean	0.67 : 1	0	*-10*	1 : 1.2	-8
185+00	Ocean	0.67 : 1	-5	-14	1 : 1.2	-10
205+00	Ocean	0.68 : 1	-5	-21	1 : 1.2	-12
230+00	Ocean	0.69 : 1	0	-26	1 : 1.15	-5
255+00	Ocean	0.7 : 1	-5	-33	1 : 1.1	-5
275+00	Ocean	0.71 : 1	-8	-35	1 : 1.1	-5
295+00	Ocean	0.71 : 1	-10	-40	1 : 1.05	*-5*
315+00	Ocean	0.71 : 1	-15	-41	1 : 1.05	*-10*
335+00	Ocean	0.71 : 1	-20	-45	1 : 1	0
375+00	Ocean	0.72 : 1	-45	*-70*	1 : 1	0
		1910 : 2007			2007 : 2070	
170+00	Channel	0.77 : 1	deposition	*10*	-	0
190+00	Channel	0.77 : 1	0	*-4*	1 : 1.2	-5
215+00	Channel	0.77 : 1	-5	-13	1 : 1.2	-10
235+00	Channel	0.78 : 1	0	-17	1 : 1.2	-15
250+00	Channel	0.78 : 1	0	-21	1 : 1.2	-10
275+00	Channel	0.79 : 1	0	-24	1 : 1.2	-10
295+00	Channel	0.79 : 1	0	-27	1 : 1.2	*-17*
315+00	Channel	0.79 : 1	-5	-35	1 : 1.15	*-20*
335+00	Channel	0.68 : 1	-35	-55	1 : 1.1	0
375+00	Channel	0.7 : 1	-50	*-80*	1 : 1.05	0

SOUTH Jetty morphological factors for modifying wave height along jetty and Scour depth at jetty toe. The toe scour values given for the future life cycle do not include the mitigating effect of constructing additional jetty spurs to reduce toe scour along the jetty foundation.

Table A2- 6.   Jetty A Toe Scour and Morphological Factors for Wave Height

Jetty Station	Side of Jetty	PAST Life-Cycle 1939 - 2006 Estimated Morphological Factor 1917 : 2006	Observed Total Scour @ jetty (ft)	Present Seabed Elevation 200 ft offset from toe (ft, NGVD)	FUTURE Life-Cycle 2006-2070 Estimated Morphological Factor 2006 : 2070	Estimated Total Scour @ jetty (ft)
41+00	Ocean	1 : 1	deposition	*19*	-	
45+00	Ocean	1 : 1	deposition	*17*	-	
50+00	Ocean	1 : 1	0	-6.6	1 : 1.2	0
55+00	Ocean	0.8 : 1	-10	-13.2	1 : 1.2	0
65+00	Ocean	0.7 : 1	-13	-18.3	1 : 1.1	0
75+00	Ocean	0.75 : 1	-9	-17.9	1 : 1.2	-8
90+00	Ocean	0.8 : 1	-16	-34.5	1 : 1.3	-20
95+00	Ocean	0.8 : 1	-35	*-60*	1 : 1.2	-10
97+00	Ocean	0.8 : 1	-75	*-80*	1 : 1.2	0
		1939 : 2006			2006 : 2070	
70+00	Channel	1 : 1	0	*9*	1 : 1.2	0
80+00	Channel	1 : 1	0	-16.2	1 : 1.2	-10
90+00	Channel	1 : 1	-35	-52.4	1 : 1.2	-20
97+000	Channel	1 : 1	-80	*-105*	1 : 1.2	0

Jetty A morphological factors for modifying wave height along jetty and Scour depth at jetty toe. The toe scour values given for the future life cycle do not include the mitigating effect of constructing additional jetty spurs to reduce toe scour along the jetty foundation.

Slope Stability. The performance mode of slope failure deals with the tendency of a sloping rip-rap surface to seek a more stable horizontal position in response to gravity, environmental loading, and over-steepening of the jetty surface from other failure modes. In a relatively homogeneous stratum, the surface along which slope movement (rotation) is initiated is called a failure surface and is approximated by a circular arc failure surface (Figure A2- 16a). When the rip-rap (stone) mass is on the verge of movement along the failure surface, the forces initiating and resisting the movement are in equilibrium (FS=1.0). The relationship describing this force balance is:

Equilibrium for static slope stability: $W*D = [C' + (P-U)*TAN\phi']*L*R$ where,

W=weight of sliding mass	U=pore water pressure at base of sliding mass
D=moment arm of sliding mass about center of rotation	ϕ'=material stratum friction angle – rock or sediment
C'=material cohesion = 0 for rock	R=radius of moment arm for potential sliding surface
P=normal force @ base of sliding mass	L=arc length of potential sliding surface

The slope stability equation was rearranged to form a performance function which can be used to calculate the reliability of static slope stability along the ocean and channel side slopes of jetties. This performance function is expressed in terms of a factor of safety (FS) and safety margin (SM).

$$FS = \frac{\text{CAPACITY of slope to resist shearing}}{\text{DEMAND imposed by body forces}} = \frac{[C' + (P-U)*TAN\phi']*L*R}{W*D}$$

$$SM = \text{CAPACITY} - \text{DEMAND} = [C' + (P-U)*TAN\phi']*L*R - W*D$$

Several parameters can interact to compromise this performance function. If armor units are poorly interlocked, then “R” and “L” are reduced which can reduce FS. A well interlocked stone mass can increase “R” and “L” by forcing the sliding surface deeper into the structure cross-section, and increasing the failure surface arc length. In a localized sense, “W” (armor stone size as related to armor unit stacking in the slope) can have an adverse effect on jetty slope stability. If “W” is large and the armor units are poorly interlocked with adjacent units, such that an armor elements are protruding from the local jetty slope, then W*D can make FS ≤1. If “U” becomes large, due to transient surcharging by wave or surge action, then the above FS will be reduced.

Because of the irregular geometry, varying strata within a given jetty cross-section, and the complex forcing environment, direct analysis for evaluating the above performance function is not possible. A slope stability model SLOPE-W® (Geo-slope Inc, 2004), was used to investigate the mode static stability performance based on variation analysis of nine parameters (see Appendix B, Geotechnical Studies). Each differing rock material layer contained within the jetty cross-section was described using appropriate constituent values. The evaluation of jetty static slope stability using SLOPE-W, helped to refine the overall analysis of jetty reliability by identifying key factors that affect static slope stability for jetties. Results from the slope stability analysis indicated that the most important factors affecting jetty slope stability are:

Factor 1: Wave action causing adverse pressure transients within the jetty cross-section.
Factor 2: Stone stacking patterns realized during incremental slope damage or jetty repairs.
Factor 3: Toe-scour effect initiating slop instability migrating up the cross-section.

The effect that factors 1 and 2 have on structure reliability is addressed within the SRB model evaluating the reliability if dynamic stability performance functions, as described below. Factor 3 (toe-scour) is addressed stochastically within the SRB model, and its effect on structure reliability is captured by a degradation of several parameters that affect dynamic stability. Refer to Section 5 for a description of how toe-scour can motivate cross-section damage within the SRB model.

Summary – Static Stability. Jetty toe-scour was determined to be the static stability factor which most actively affects MCR jetties. Toe scour is simulated within the SRB model to emanate within the lower region of the jetty cross-section (from the jetty toe to –5 ft MLLW). Unsatisfactory performance effects due to toe scour migrate upward along the jetty face, ultimately affecting the upper region of the jetty cross-section. The displacement (or loss) of stone off the jetty cross-section at the point of toe scour acts to steepen the structure slope above the scour area, resulting in displacement of the entire armor layer up to the jetty crest, exposing core stone within the jetty section to direct wave attack. Jetty repair (placement of armor stone onto the upper region of the cross section) reinstates the jetty to a "new" post-construction condition, in terms of the lower likelihood of slope instability. Yet the opposite may be the case, if the lower region of the cross-section (below -5 ft MLLW) is at the limit of maintaining a stable slope. Adding stone to the upper region of the cross-section may surcharge the lower slope, decreasing the reliability of the overall jetty slope. In this case, jetty repairs could represent a problematical issue if the lower slope of the jetty is at the margin of structural instability.

The SRB model emulates slope stability performance by stochastically simulating the change in jetty cross-section geometry, caused by toe-scour effects. As toe-scour motivates cross-section geometry change through time, attributes that govern dynamic stability of the jetty are affected (reduced). Refer to Foundation Effects in Section 6 for specific details.

2. Dynamic Stability

Dynamic stability is the capacity of the jetty's cross section to remain stable when affected by wave action (Figure A2- 17). Wave-driven processes affecting the dynamic stability are manifest at elevations on the upper part of a jetty's cross-section, typically above -5 ft MLLW. On the windward side of a jetty (direct exposure to ocean waves), dynamic stability is manifest by the direct impact of waves on the jetty and the resultant displacement of individual armor units. On the lee side of the jetty, dynamic stability addresses the effect of waves overtopping the jetty crest and displacing armor unit's down-slope, off of the jetty cross-section. Along many areas of the MCR jetties, dynamic stability is the primary performance mode affecting jetty response in terms of damage. Dynamic stability is a transient performance mode, exhibiting severe effects that occur infrequently as motivated by winter storm waves. In summary, two components of dynamic stability were investigated within the scope of this analysis: A) direct wave attack of the armor layer along the windward side of the jetty, and B) wave overtopping of the jetty crest and attacking the leeward side of the jetty. Both dynamic performance modes are manifested in the upper region of the jetty (from –5 ft MLLW to the crest). Incident wave height (along the jetty) is the dominant parameter affecting both dynamic performance functions.

<u>Direct Wave Attack on Armor Layer</u>. Two formations were utilized to estimate the reliability for jetty armor layer design in response to direct wave attack: the Hudson [1959] and Van der Meer [1988] equations. Comprehensive investigations were made by Hudson and Jackson during 1953-1961 to develop a formula for determining the stability of armor units on rubble-mound structures, in response to direct wave attack. The Hudson equation is based on extensive scaled physical modeling testing and verification by prototype data as presented in the Shore Protection Manual and the Coastal Engineering Manual [USACE 1984, 2003]. The Hudson equation is typically used when the crest of a structure is high enough to prevent significant overtopping by waves and the armor layer slope is not steeper than 1V:1.5H. Armor layer slopes steeper that 1V:1.5H are not recommended [USACE 2006]. A limiting attribute for the Hudson equation is that it does not directly account for wave period or wave steepness. Because the equation was developed from data that included many variations for wave period and steepness, the lack of direct specification for these parameters within the equation is not considered to be significant detriment. The Hudson equation has been successfully used to emulate the reliability of other coastal infrastructure [USACE 1993; Moritz et al., 1994]. The parameters within the Hudson equation are directly associated with the physics of wave action and armor unit stability. Note that four out of the five parameters within this equation are based on physical attributes; only on parameter (K_d, armor unit stability coefficient) is based on empirical derivation. The Hudson equation provides a limit-state or upper-bound estimate for armor stone stability. Using the Hudson equation, a mean armor stone size (weight, W) required for the wave-ward slope of a jetty to resist incident wave action is determined as follows:

Hudson Equation:

$$W = \frac{\gamma r * Hs^3}{K_d * (Sr-1)^3 * Cot\theta}$$

where

$W = W_{50}$ = mean armor unit weight, lb

γr = armor unit density, lb/ft

K_d = stability coefficient

θ = slope of armor layer from horizontal

Hs = incident significant wave height, ft

Sr = specific gravity of armor units

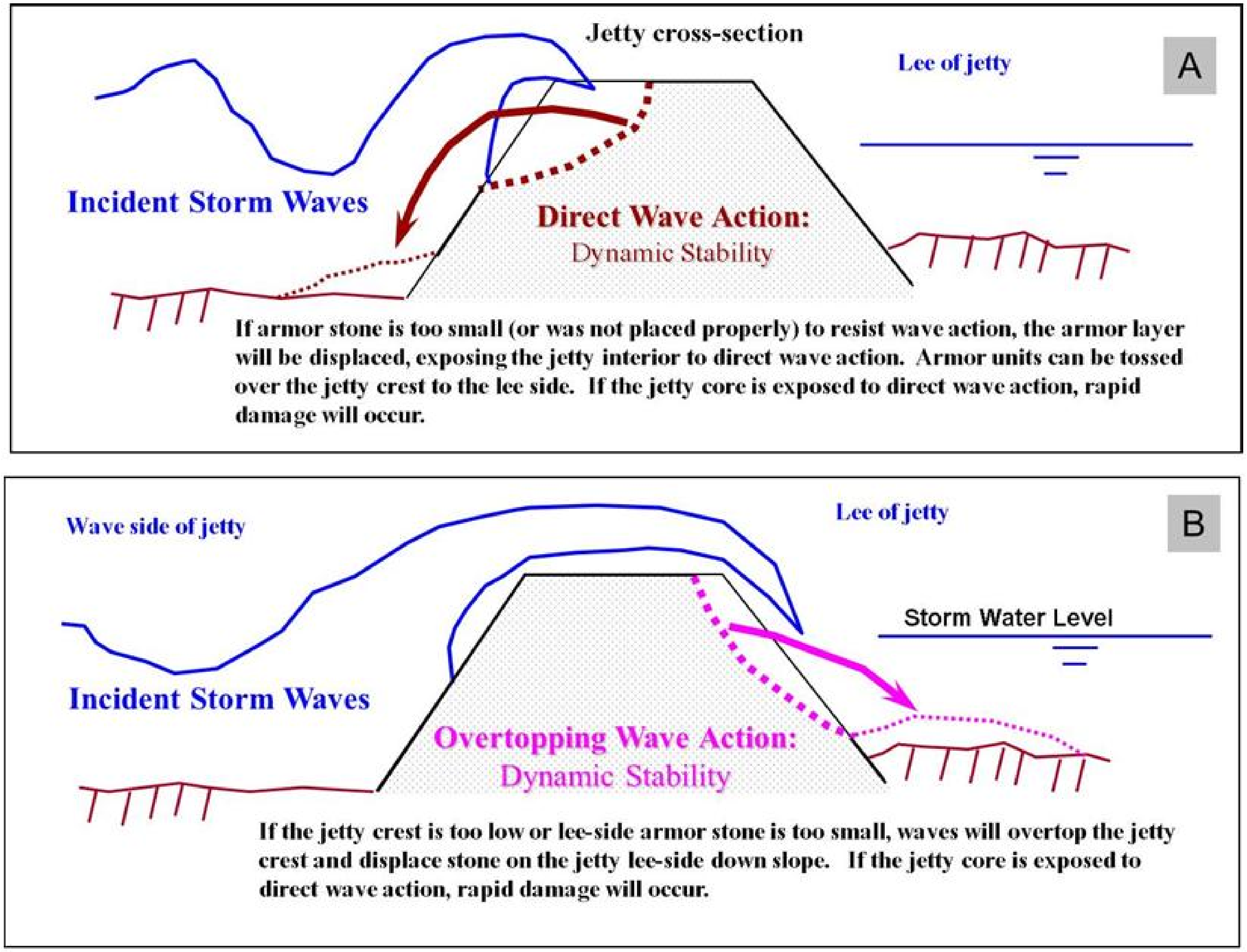


Figure A2- 17. Jetty performance Modes for Dynamic Stability

Other equations describing armor unit stability due to wave attack are documented in literature, the Van der Meer (VDM) equations being a prominent citation. The VDM equations have been used extensively throughout the international engineering community and can produce similar results as the Hudson equation [Kim and Suh 2008]. The VDM equations directly account for wave period and wave steepness within the formulation. It is noted that these equations are based on North Sea and similar prototype data. Storm waves along the U.S. Pacific Coast can have longer wave periods than many of the data sources used to develop the VDM equations. Because of this, the VDM equations may predict smaller armor stone size (W) than what is actually needed to resist a given wave height at U.S. Pacific Coast locations. Despite this potential limitation, the VDM equations offer advantages over the Hudson equation due to numerous structure and wave parameters that are directly emulated within the VDM equations. Separate VDM equations were formulated to account for wave steepness:

Van der Meer Equations:

For *plunging* waves

$$\frac{Hs}{\Delta D_{n50}} = 6.2P^{0.18}\left[\frac{S}{\sqrt{N}}\right]^{0.2} \xi_m^{0.5}$$

For *surging* waves

$$\frac{Hs}{\Delta D_{n50}} = 1.0P^{-0.13}\left[\frac{S}{\sqrt{N}}\right]^{0.2} \sqrt{\cot\alpha}\ \xi_m^{0.5}$$

The transition from *plunging to surging waves* can be calculated using a critical value for the surf similarity parameter (ξmc):

$$\xi_{mc} = [6.2P^{0.31}\sqrt{\tan\alpha}]^{1/P+0.5}$$ Critical surf similarity parameter when Cot α <= 3

The *plunging wave VDM* equation is used when ξm is less that ξmc. The *surging wave VDM* equation is used when ξm is greater that ξmc. If the structure slope is very gentle such that Cot α is greater than 3, then the following equation is to be used for evaluating the critical surf similarity parameter (ξmc).

$$\xi_{mc} = [3.58P^{0.31}]^{1/P+0.5}$$ Critical surf similarity parameter when Cot α > 3

where

Hs = significant wave height, m

Tm = mean wave period, sec

Lo = $gT_m^2/2\pi$

P = notional permeability factor (0.30-0.60)

S = damage level (varies 2-12), within this analysis varies as a function Kd for Hudson equation and structure slope

N = number of storm waves, for a given NW PAC wave event (300-900)

Cot α = structure slope (run:rise)

ξm = surf similarity parameter at structure = $\tan\alpha / \sqrt{Hs/Lo}$

ξmc = Critical surf similarity parameter; transition from plunging to surging waves

Δ = relative specific gravity for armor units = armor density/water density -1
Dn_{50} = median armor size, equivalent diameter, meters

Due to the inherent uncertainty associated with evaluating reliability for rubble-mound structures (in terms of multi-parameter empirical formulas), it was deemed prudent to use both the Hudson equation and VDM equations to evaluate the reliability of a jetty's wave-ward slope when exposed to incident waves (Figure A2- 17a). Reliability from each equation was computed. Both reliability estimates were blended together (by obtaining a mean value) to obtain an objective estimate for wave-ward reliability on each side of a jetty.

The Hudson equation and VDM equations were rearranged to form a performance function (FS=C/D), which was used to calculate the reliability of dynamic stability along the wave-ward slope of the MCR jetties. To increase the confidence of the reliability estimate, the Hudson and VDM equations were also evaluated in terms of a safe margin (SM = C-D). Comparison of the two reliability estimates (FS vs. SM methods) indicated little overall variation, except when C and D became similar in value. Reliability estimates based on FS and SM were blended to produce a confident estimate. Each parameter within the Hudson and VDM equations was treated as a random variable, prescribed by a mean value and standard deviation. The performance functions for Hudson and the VDM equations are expressed below in terms of a FS. Note the degree of sensitivity that the Hudson performance function has with wave height and armor unit density, whereas the VDM equations are linear in terms of wave height and armor size. An advantage of the VDM equations is that they express dynamic performance for jetty armor (size) in terms of a linear relationship vs. the Hudson equation which is non-linear. Linear performance functions tend to produce more stable estimates when the Taylor series FOSM method is used to estimate reliability (for factor of safety and safety margin).

FS = $\dfrac{\text{CAPACITY of armor layer to resist incident wave forces}}{\text{DEMAND imposed on armor layer by incident wave forces}}$

$$= \frac{W * K_d * (Sr-1)^3 * Cot\theta}{\gamma r * H^3} \qquad \textbf{(FS for Hudson Equation)}$$

SM = CAPACITY – DEMAND

$$= (W * K_d * (Sr-1)^3 * Cot\theta) - (\gamma r * H^3) \qquad \textbf{(SM for Hudson Equation)}$$

(VDM for plunging waves)

$$\textbf{FS} = \frac{\Delta D_{n50} 6.2P^{0.18} [S/\sqrt{N}]^{0.2} \xi_m^{0.5}}{H_s}$$

$$\textbf{SM} = \Delta D_{n50} 6.2P^{0.18} [S/\sqrt{N}]^{0.2} \xi_m^{0.5} - H_s$$

(VDM for surging waves)

$$\textbf{FS} = \frac{\Delta D_{n50}\, 1.0P^{-0.13} [S/\sqrt{N}]^{0.2} \sqrt{\cot\alpha}\, \xi_m^{0.5}}{H_s}$$

$$\textbf{SM} = \Delta D_{n50}\, 1.0P^{-0.13} [S/\sqrt{N}]^{0.2} \sqrt{\cot\alpha}\, \xi_m^{0.5} - Hs$$

Reliability for wave attack along the front side of a jetty (using the Hudson and VDM equations) was determined for each 100-ft segment along the jetties, for each year "i" within a given life-cycle simulation. There can be two components for front side dynamic stability in the case where the wave action affects a jetty on both sides of the structure (channel and ocean side). As the jetty cross section becomes damaged, the parameters of K_d, S, and W can change (decrease), further reducing the reliability of the jetty. Recall, that the upper cross-section of a jetty can be damaged by wave action and foundation effects (scour). Evaluation of jetty damage is performed independently of the reliability calculation. In other words, cross-section degradation can affect the reliability estimate of a jetty, but changes in reliability do not affect jetty degradation; as emulated within the SRB model.

Wave Overtopping on the Backslope Armor Layer. During the initial stages of jetty MCR construction (1885-1895), the crest of the South Jetty was constructed to low-mid- tide elevation (about +4 to +12 ft MLLW). The jetty was overtopped by waves resulting in rapid jetty deterioration and significant transport of sand over the jetty root. It was quickly realized that the small jetty section was being destabilized by incident and overtopping wave-action (Figure A2- 17). From the early 1900s onward, the crest elevation of MCR jetties was constructed above high tide elevation (+15 to +30 ft MLLW). A higher crest elevation was required for the jetty to remain stable and fulfill its intended function of shoal control. The performance mode for dynamic stability of a jetty's backslope (leeside) armor layer can be modeled by equations that relate structure freeboard, crest width, incident wave height and period, armor stone density, and ratio of back slope to front slope armor stone sizes. Two types of overtopping stability equations were evaluated within this appendix: the WPD equation and the Van Gent equation. The simpler of the two overtopping equations was developed by Walker et al. [1975], with results cast in terms of a stability threshold. The stability of the leeside armor units are associated with the size of the wave-ward armor units. The WPD equation assumes that the front slope (wave-ward side) armor stone has been correctly sized to be stable for the incident wave environment. The WPD overtopping stability equation is based on extensive small-scale modeling testing and verification by prototype data. Note that the WPD overtopping stability equation is very sensitive to crest elevation (freeboard, h_c), non-linearly. The higher the crest above the water surface, the more stable the leeside of the jetty; even if a smaller armor size is used on the backside of the jetty than on the frontside. Mean armor stone size for the leeside slope (weight, W_b) is determined as follows:

Walker-Palmer-Dunham Equation: $W_b = W_f * C_2 * \exp(-C_1 * h_c/H)$

where

W_b = mean stone weight on backside (lee) slope of jetty, lb
W_f = mean stone weight on frontside slope of jetty, lb
H = incident wave height ft
$C_1 = 2.061$
$C_2 = 4.554$
h_c = jetty freeboard, ft = Crest El. – WSE

The WPD overtopping stability equation does not directly account for structure slope, armor roughness, wave period, or crest width. These parameters embedded within the equation's empiricism The prototype data from which the equation was developed included applications where frontside slope differed from backside slope, in some cases by as much as factor of 3. The WPD equation also assumes that structure maintains a nominal crest width, based on an undamaged configuration. Despite the above assumptions, the WPD equation has been successfully used to emulate the reliability of other coastal infrastructure [USACE 1993; Moritz et al., 1994] and has been used to assess the design of other jetty repairs within Portland District [USACE 1994].

Through extensive prototype and scaled-physical model investigations performed by Van Gent et al, an elaborate overtopping stability equation was developed featuring paramertization similar to the VDM equations [Van Gent 2004]. The Van Gent equation directly accounts for many aspects of a structure's cross-section, and includes effects of wave period and storm duration within the formulation. Although the Van Gent equation is highly empericized, the equation accounts for many of the physics affecting rear-side armor stability. The Van Gent equation can be used to explicitly calculate rear-side armor size, unlike the WPD equation which is a threshold-based formulation dependent on the armor for the front side of the structure. The approach for evaluating rear-side armor size (overtopping) follows a three step process: A) run-up elevations onto the structure are estimated based on wave conditions at the structure toe; B) wave overtopping parameters are calculated based on the run-up estimate from step A; and C) the requisite size of rear-side armor units is calculated based on wave overtopping parameters estimated in step B.

Van Gent Equation: $$D_{n50} = 0.008 \left(\frac{S}{\sqrt{N}}\right)^{-1/6} \left(\frac{u_{1\%}\, T_{m-1,0}}{\Delta^{0.5}}\right) (\cot\varphi)^{-2.5/6}\, (1 + 10 \cdot \exp(-R_{c-rear} / H_s))^{1/6}$$

where

$$z_{1\%} / (\gamma H_s) = c_0\, \xi_{s,-1} \qquad \text{for } \xi_{s,-1} \leq p$$
$$z_{1\%} / (\gamma H_s) = c_1 - c_2 / \xi_{s,-1} \qquad \text{for } \xi_{s,-1} \geq p$$

$$\frac{u_{1\%}}{\sqrt{gH_s}} = 1.7\ (\gamma_{f-c})^{0.5} \left(\frac{z_{1\%} - R_c}{\gamma_f H_s}\right)^{0.5} \Big/ \left(1 + 0.1\frac{B_c}{H_s}\right)$$

$Z_{1\%}$ = 1% exceedance value for wave run-up elevation onto the structure, m
H_s = significant wave height, m
γ = run-up reduction factor, account for oblique wave attach & armor roughness = 0.5
$C_o = 1.45$, $C_1 = 5.1$, $C_2 = (0.25C_1)/C_o$
ξm = surf similarity parameter at structure = $\tan\alpha / \sqrt{Hs/Lo}$
$p = 0.5\ C_1/ C_o$
$U_{1\%}$ = 1% exceedance value for velocity of overtopping onto backside of structure, m/s
R_c = structure crest height above water surface, freeboard, m
B_c = Structure crest width, m

γ_f ,γ_{f-c} = armor unit density, kg/m3
Δ = relative specific gravity for armor units = armor density/water density -1
S = damage level (varies 2-12), within this analysis varies as a function Kd for Hudson equation and structure slope
Tm = mean wave period, sec
Lo = $gT_m^2/2\pi$
N = number of storm waves, for a given NW PAC wave event (300-900)
Cot α = structure slope (run:rise), limiting slope for Van Gent application is 1.5:1

The WPD and Van Gent wave-overtopping equations were rearranged to form performance functions that were used to assess the reliability of dynamic stability along the leeside face of MCR jetties. Each non-constant parameter within the overtopping equations was treated as a random variable, prescribed by a mean value and standard deviation. Recall that a performance function is expressed as a FS in terms of capacity (capacity of armor units to resist movement) and demand (load caused by wave overtopping). To increase the confidence of the reliability estimate, the overtopping performance functions were also evaluated in terms of a SM (SM = C-D). Reliability estimates based on FS and SM were blended to produce a confident estimate. The performance functions (FS and SM) for overtopping dynamic stability are:

$$FS = \frac{\text{CAPACITY of leeside armor to resist overtopping}}{\text{DEMAND imposed by overtopping waves}}$$

$$= \frac{Wb}{W_f * C_2 * \exp(-C_1 * h_c/H)} \qquad \textbf{(FS for Walker-Palmer-Dunham)}$$

$$SM = \text{CAPACITY - DEMAND}$$

$$= Wb - W_f * C_2 * \exp(-C_1 * h_c/H) \qquad \textbf{(SM for Walker-Palmer-Dunham)}$$

$$FS = \frac{D_{n50}}{0.008\left(\frac{S}{\sqrt{N}}\right)^{-1/6}\left(\frac{u_{1\%}\,T_{m-1,0}}{\Delta^{0.5}}\right)(\cot\varphi)^{-2.5/6}\,(1+10\cdot\exp(-R_{c-rear}/H_s))^{1/6}} \qquad \textbf{(SF for Van Gent)}$$

$$SM = D_{n50} - 0.008\left(\frac{S}{\sqrt{N}}\right)^{-1/6}\left(\frac{u_{1\%}\,T_{m-1,0}}{\Delta^{0.5}}\right)(\cot\varphi)^{-2.5/6}\,(1+10\cdot\exp(-R_{c-rear}/H_s))^{1/6}$$

(SM for Van Gent)

Based on peer review recommendation and comparing the reliability results between WPD and Van Gent, it was determined that the Van Gent equation produces superior reliability estimates. Evaluation of armor stability due to wave overtopping was performed exclusively using the Van Gent equation. Time-varying reliability for wave overtopping (using the Van Gent equation) was determined for each 100-ft segment along the jetties. There can be two components for overtopping (leeside dynamic stability) in the case where the wave action affects a jetty on both sides of the structure (channel and ocean side). Recall that reliability indicates the likelihood of a jetty to resist damage (and function satisfactorily) in the presence of wave action; reliability does not define how much jetty degradation would incur if the jetty were damaged.

3. Structure Reliability - Each Segment

Structure reliability is calculated for each 100-ft segment of jetty (j), for each year within a given life-cycle simulation (i). Because a jetty can have wave action affecting both sides of the structure (channel side and ocean side), there can be two components of structure reliability for a given jetty segment. Each component has two modes of dynamic performance: direct wave attack and wave overtopping. When wave action affects the *ocean* side of the jetty, the ocean side is subject to direct wave attack and the channel side of the jetty can be affected by wave overtopping. When wave action affects the *channel* side of the jetty, the channel side is subject to direct wave attack and the ocean side of the jetty can be affected by wave overtopping. Taken together, there can be up to four individual components of structure reliability affecting the upper cross-section region of each 100-ft jetty segment (Figure A2- 18). The individual components are combined, using a series combination of probabilities, to calculate structure reliability for each jetty segment for each year within a given life-cycle. Note that the structure reliability for a given segment is limited by the lowest value of the individual component reliabilities.

Structure reliability at a given jetty *segment-j*, for *each year* in life-cycle-*i*

$$= P_{i,j}(s)_{\text{overtopping wave action}} \times P_{i,j}(s)_{\text{direct wave attack}}$$

where

$$P_{i,j}(s)_{\text{overtopping wave action}} = P_{i,j}(s)_{\text{overtopping – channel side}} \times P_{i,j}(s)_{\text{overtopping – channel side}}$$

$$P_{i,j}(s)_{\text{direct wave attack}} = P_{i,j}(s)_{\text{direct wave attack – channel side}} \times P_{i,j}(s)_{\text{direct wave attack – channel side}}$$

Recall that the process of active toe scour can destabilize the entire side slope of the jetty cross-section, reducing the resiliency and the reliability of the upper cross-section. The above estimate for segment structure reliability incorporates static and dynamic stability performance modes.

Table A2- 7 through Table A2- 9 summarize design parameters and associated reliability at specific locations along each MCR jetty. The design parameters (and reliabilities) are based on the various construction/repair sequences realized during a given jetty's life-cycle. These include initial construction, historical repairs, and future alternative repair/rehab scenarios. Reliability components for each construction sequence are calculated based on an undamaged cross-section exposed to the forcing environment applicable for the time period of interest, and includes the effects of time-varying morphology change.

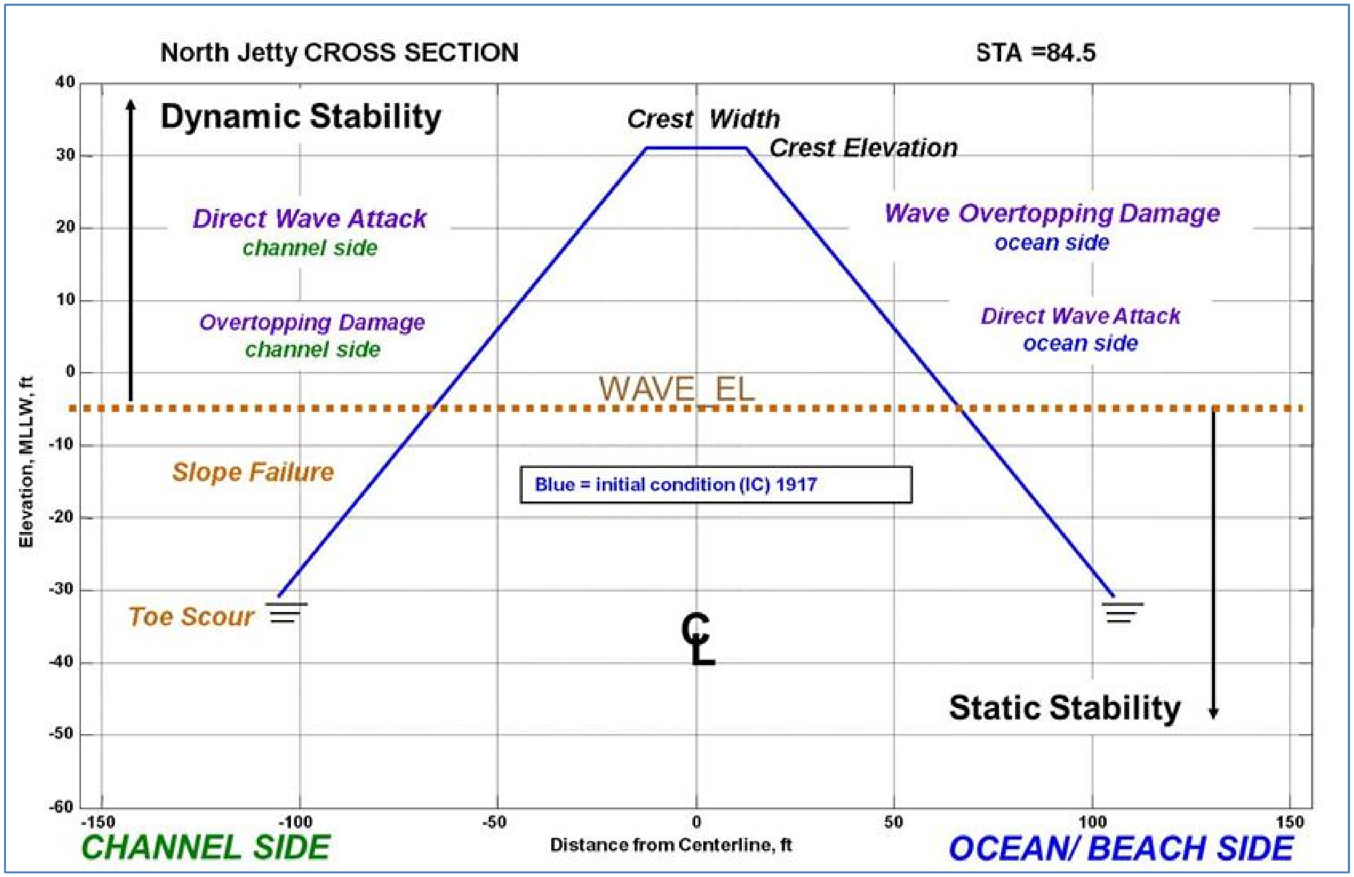


Figure A2- 18. Representation of a Jetty Cross-Section as Emulated by SRB Model

For every 100-ft of jetty. The jetty is bisected horizontally by the centerline (CL) and vertically by the elevation (WAV_EL) at which wave damage becomes the driving process for structure degradation. Below WAV_EL, scour and static slope stability performance modes govern jetty degradation. Jetty degradation is simulated separately for each side of the jetty.

Table A2- 7. Design Parameters and Reliability (Ps) for North Jetty

JETTY CROSS -SECTION	"A" TYPE	MEAN Value	W50, tons Ocean	W50, tons Channel	γ lb/ft³	Kd Ocean	Kd Channel	COT(θ) Ocean	COT(θ) Channel	CE ft	CW ft	Hsig, ft Mean/STD @ year Chan Side	Channel Side Structural Reliability, P(s) Incident/Overtopping	Hsig, ft Mean/STD @ year Ocean Side	Ocean Side Structural Reliability, P(s) Incident/Overtopping	Composite Structural Reliability, P(s) for jetty segment
Previous Repair Template	COV		0.167	0.167	0.03	0.22	0.22	0.09	0.09	0.08	0.08	variable		variable		
1917 - Original STA 85			10	10	167	2.5	2.5	1.5	1.5	30	25	9.4/1.0	0.97/0.99	12.1/1.1	0.97/0.99	**0.59**
	COV		0.15	0.15	0.03	0.22	0.22	0.09	0.09	0.08	0.08	variable		variable		
1939 Rehab STA 95			15	15	160	3.5	3.5	1.5	1.5	26	30	10.0/1.0	1.0/1.0	0	1.0/1.0	**0.99**
1964 Rehab Head STA 105			18	18	167	4	4	1.5	1.5	24	30	12.4/1.4	0.98/0.93	16.0/1.8	0.98/0.93	**0.65**
2006 Repair STA 85			10	9	167	4	4	1.5	1.5	25	30	11.8/1.2	0.89/0.74	15.2/1.4	0.89/0.74	**0.26**
Future Repair Template	COV		0.15	0.15	0.03	0.22	0.22	0.09	0.09	0.08	0.08	variable		variable		
Fix-as-Fails																
STA 85			12	12	167	3	3	1.5	1.5	25	30	11.8/1.2	0.89/0.78	15.2/1.4	0.89/0.78	**0.23**
Interim-Repair/ Scheduled Repair																
STA 85			16	16	171	4	4	1.5	1.5	25	30	11.8/1.2	0.99/0.97	15.2/1.4	0.99/0.97	**0.80**
Rehabilitation Template	COV		0.15	0.15	0.03	0.22	0.22	0.09	0.09	0.08	0.08	variable		variable		
Minimum																
STA 85			18	18	171	4	4	1.5	1.5	25	30	11.8/1.2	0.99/0.98	15.2/1.4	0.99/0.98	**0.85**
Moderate - Small Toe Berm																
STA 85			22	22	171	4	4	2	2	25	30	11.8/1.2	0.99/0.99	15.2/1.4	0.95/1.0	**0.93**
Large - Big Toe Berm																
STA 85			22	22	171	4	4	2	2	25	30	11.8/1.2	0.99/0.99	15.2/1.4	0.95/1.0	**0.93**
Jetty Head *	COV		0.11	0.11	0.03	0.22	0.22	0.09	0.09	0.08	0.08	variable		variable		
STA 100-102			32	32	171	4	4	3 and 2.5	3 and 2.5	20	40	14.6/1.6	0.99/1.0	18.8/2.1	0.98/1.0	**0.97**

* Jetty Head has a compound slope, 1v:3h from crest to + 10 ft MLLW, and 1v:2.5h down to Toe.

Mean wave height = annual average storm Hsig at time of construction or repair, STD = standard Deviation of annual Hsig Reliability. Reliability is calculated using mean WSE = 5.6 ft NGVD, STD = 1.1 ft

COV = coefficient of variation = mean value / standard deviation. ALL values assumed to have normal distribution about mean value, unless otherwise noted.

W50 = Mean armor stone weight, γ = weight density of armor units, COT(θ) = slope angle of armor layer (1.5 = 1v:1.5H)

CE = X-section crest elevation, CW = X-section crest width

Kd = Hudson Stability Coefficient: values can range from 2.5 (for dumped, random placement armor units) to 6 (for special placemat stone armor units).

Alternative Cross-Section development for this study was based on a Kd value that varied between 4 and 6, for rough armor stone.

W50 was calculated using Kd = 5 for the Repair/Maintenance Template and Kd = 6 for Rehab and Jetty Head templates

Reliability for alternative plans was evaluated using a Kd value of 3 and 4, where noted above; using Hudson equation, Van der Meer equation, and Van Gent equation

Reliability (Ps) was calculated using SM and SF performance functions, solved by Taylor series expansion, FOSM; to obtain Beta factor and P(s). Calculations based on Undamaged Structure

Table A2- 8. Design Parameters and Reliability (Ps) for South Jetty

JETTY CROSS -SECTION	"A" TYPE	MEAN Value	W50, tons Ocean	W50, tons Channel	γ lb/ft³	Kd Ocean	Kd Channel	COT(θ) Ocean	COT(θ) Channel	CE ft	CW ft	Hsig, ft Mean/STD @ year Estuary Side	Estuary Side Structural Reliability, P(s) Incident/Overtopping	Hsig, ft Mean/STD @ year Ocean Side	Ocean Side Structural Reliability, P(s) Incident/Overtopping	Composite Structural Reliability, P(s) for jetty segment
Previous Repair Template	COV		0.167	0.167	0.03	0.22	0.22	0.09	0.09	0.08	0.08	variable		variable		
1910 - Original STA 230			7	7	180	2.5	2.5	1.5	1.5	12	30	8.7/2.3	0.92/0.10	12.4/0.93	0.51/0.36	**0.02**
	COV		0.15	0.15	0.03	0.22	0.22	0.09	0.09	0.08	0.08	variable		variable		
1935 Rehab STA 230			9	9	171	3	3	1.5	1.5	24	40	9.4/2.6	0.93/0.73	13.5/1.1	0.49/0.99	**0.32**
1962 Rehab STA 230			10	10	180	4	4	1.5	1.25	28	30	10.0/2.7	0.97/0.92	15.8/1.2	0.55/1.0	**0.49**
1982 Repair STA 230			13	13	168	4	4	1.5	1.5	25	30	10.5/2.9	0.96/0.68	17.7/1.3	0.24/0.99	**0.16**
2006 Repair STA 230			15	10	180	4	4	2	1.5	25	30	11.1/3.0	0.94/0.61	18.6/1.4	0.77/1.0	**0.44**
Future Repair Template	COV		0.15	0.15	0.03	0.22	0.22	0.09	0.09	0.08	0.08			variable		
Fix-as-Fails																
STA 230			14	8	167	3	3	2	1.5	25	30	11.1/3.0	0.71/0.32	18.6/1.4	0.18/1.0	**0.44**
Interim-Repair/ Scheduled Repair																
STA 230			16	10	171	4	4	2	1.5	25	30	11.1/3.0	0.91/0.56	18.6/1.4	0.65/1.0	**0.33**
Rehabilitation Template	COV		0.15	0.15	0.03	0.22	0.22	0.09	0.09	0.08	0.08			variable		
Minimum																
STA 230			15	8	171	4	4	2	1.5	25	40	11.1/3.0	0.84/0.39	18.6/1.4	0.58/1.0	**0.19**
Small																
STA 230			24	17	171	4	4	2	2	25	30	11.1/3.0	0.99/0.98	18.6/1.4	0.89/1.0	**0.86**
Moderate																
STA 230			24	17	171	4	4	2	2	25	40	11.1/3.0	0.99/0.98	18.6/1.4	0.89/1.0	**0.86**
Large - Composite Slope																
STA 230			24	17	171	4	4	2	2	25	30	11.1/3.0	0.99/0.98	18.6/1.4	0.89/1.0	**0.86**
Jetty Head *	COV		0.11	0.11	0.03	0.22	0.22	0.09	0.09	0.08	0.08	variable		variable		
STA 311-313			35	35	171	4	4	3 and 2.5	3 and 2.5	20	40	10.1/3.0	0.99 / 0.99	23.7/3.0	0.88/1.0	**0.86**

* Jetty Head has a compound slope, 1v:3h from crest to + 10 ft MLLW, and 1v:2.5h down to Toe.

Mean wave height = annual average storm Hsig at time of construction or repair, STD = standard Deviation of annual Hsig Reliability. Reliability is calculated using mean WSE = 5.6 ft NGVD, STD = 1.1 ft

COV = coefficient of variation = mean value / standard deviation. ALL values assumed to have normal distribution about mean value, unless otherwise noted.

W50 = Mean armor stone weight, γ = weight density of armor units, COT(θ) = slope angle of armor layer (1.5 = 1v:1.5H)

CE = X-section crest elevation, CW = X-section crest width

Kd = Hudson Stability Coefficient: values can range from 2.5 (for dumped, random placement armor units) to 6 (for special placemat stone armor units).

Alternative Cross-Section development for this study was based on a Kd value that varied between 4 and 6, for rough armor stone.

W50 was calculated using Kd = 5 for the Repair/Maintenance Template and Kd = 6 for Rehab and Jetty Head templates

Reliability for alternative plans was evaluated using a Kd value of 3 and 4, where noted above; using Hudson equation, Van der Meer equation, and Van Gent equation

Reliability (Ps) was calculated using SM and SF performance functions, solved by Taylor series expansion, FOSM; to obtain Beta factor and P(s). Calculations based on Undamaged Structure

Table A2- 9. Design Parameters and Reliability (Ps) for Jetty A

JETTY "A" CROSS -SECTION TYPE	MEAN Value	W50, tons Ocean	W50, tons Channel	γ lb/ft^3	Kd Ocean	Kd Channel	COT(θ) Ocean	COT(θ) Channel	CE ft	CW ft	Hsig, ft Mean/STD @ year Estuary Side	Estuary Side Structural Reliability, P(s) Incident/Overtopping	Hsig, ft Mean/STD @ year Ocean Side	Ocean Side Structural Reliability, P(s) Incident/Overtopping	Composite Structural Reliability, P(s) for jetty segment
Previous Repair Template	COV	0.167	0.167	0.03	0.22	0.22	0.09	0.09	0.08	0.08			variable		
1939 - Original STA 78		5	3	160	2.5	2.5	1.5	1.5	18	30	0	1.0 / 0.21	9.3 / 1.2	0.60 / 1.0	**0.13**
	COV	0.15	0.15	0.03	0.22	0.22	0.09	0.09	0.08	0.08			variable		
1946 Rehab STA 78		5	1	160	2.5	2.5	1.5	1.5	20	40	0	1.0 / 0.04	9.9 / 1.2	0.46 / 1.0	**0.02**
1958 Repair STA 78		10	3	145	2.5	2.5	1.5	1.5	24	30	0	1.0 / 0.37	10.5 / 1.3	0.53 / 1.0	**0.2**
1962 Repair STA 78		10	3	145	3	3	2	1.5	24	30	0	1.0 / 0.76	10.9 / 1.4	0.72 / 1.0	**0.55**
Future Repair Template	COV	0.15	0.15	0.03	0.22	0.22	0.09	0.09	0.08	0.08			variable		
Fix-as-Fails															
STA 78		10	6	167	3	3	2	1.5	20	30	0	1.0 / 0.78	12.4 / 1.6	0.95 / 1.0	**0.74**
Interim-Repair/ Scheduled Repair															
STA 78		12	8	171	4	4	2	1.5	20	30	0	1.0 / 0.91	12.4 / 1.6	0.98 / 1.0	**0.89**
Rehabilitation Template	COV	0.15	0.15	0.03	0.22	0.22	0.09	0.09	0.08	0.08			variable		
Minimum - Low Profile (wide crest)															
STA 78		15	15	171	4	4	2	2	20	40	0	1.0 / 0.99	12.4 / 1.6	0.99 / 1.0	**0.98**
Minimum - Standard Crest Aspect															
STA 78		15	15	171	4	4	2	2	25	30	0	1.0 / 0.99	12.4 / 1.6	0.99 / 1.0	**0.98**
Jetty Head *	COV	0.11	0.11	0.03	0.22	0.22	0.09	0.09	0.08	0.08	variable		variable		
STA 90-92		25	25	171	4	4	2 and 1.5	2 and 1.5	15	40	6.1 / 2.4	0.99 / 0.99	11.1 / 1.4	0.99 / 1.0	**0.97**

* Jetty Head has a compound slope, 1v:3h from crest to + 10 ft MLLW, and 1v:2.5h down to Toe.
Mean wave height = annual average storm Hsig at time of construction or repair, STD = standard Deviation of annual Hsig Reliability. Reliability is calculated using mean WSE = 5.6 ft NGVD, STD = 1.1 ft
COV = coefficient of variation = mean value / standard deviation. ALL values assumed to have normal distribution about mean value, unless otherwise noted.
W50 = Mean armor stone weight, γ = weight density of armor units, COT(θ) = slope angle of armor layer (1.5 = 1v:1.5H)
CE = X-section crest elevation, CW = X-section crest width
Kd = Hudson Stability Coefficient: values can range from 2.5 (for dumped, random placement armor units) to 6 (for special placemat stone armor units).
Alternative Cross-Section development for this study was based on a Kd value that varied between 4 and 6, for rough armor stone.
W50 was calculated using Kd = 5 for the Repair/Maintenance Template and Kd = 6 for Rehab and Jetty Head templates
Reliability for alternative plans was evaluated using a Kd value of 3 and 4, where noted above; using Hudson equation, Van der Meer equation, and Van Gent equation
Reliability (Ps) was calculated using SM and SF performance functions, solved by Taylor series expansion, FOSM; to obtain Beta factor and P(s). Calculations based on Undamaged Structure

North Jetty: The first row in Table A2- 7 documents the design parameters and associated reliability for the North Jetty initial construction template. In 1917, the structure reliability at Station 85 was 0.59 and was affected by the modest performance of the ocean side of the jetty to resist direct wave action. During 1917 to the mid 1930s, significant accretion occurred along the ocean side of the North Jetty resulting in the formation of Benson Beach. The accretion prevented wave action from affecting much of the ocean side of the jetty, acting to improve the reliability for most of segments along the North Jetty. As Peacock Spit receded (1939-present), wave action increased along the ocean side of the North Jetty, acting to reduce reliability of exposed jetty areas. This is the reason for the low structure reliability for North Jetty repairs conducted after 1939.

South Jetty: The South Jetty was initially constructed using a relatively small cross-section allowing significant overtopping of the jetty. The first row in Table A2- 8 documents the design parameters and associated reliability for the South Jetty initial construction template. Upon full completion in 1910, the extremely low reliability for the South Jetty at Station 230 (0.020) was affected by poor reliability for overtopping performance modes. As the jetty was repaired during the 1930s and 1960s, a larger (higher and wider) cross-section was used which significantly improved the jetty's overtopping reliability. The 1982 repair featured a less robust cross-section (steeper side slopes) and lower rock density than previous repairs, which lowered the reliability for this repair action.

Jetty A: Jetty A was initially constructed to function more as a revetment and breakwater than as a jetty. Initially, only the outer 1/5 of the jetty (~1,000 ft) functioned as a true jetty. The first row in Table A2- 9 documents the design parameters and associated reliability for Jetty A's initial construction template. The low reliability for the initially constructed Jetty A was due to the small sized size armor stone used along most of its length and low crest elevation. The initial meager cross-section was quickly damaged by wave action and scour, and was repaired using cross-section and construction materials that were not resilient (1940s and 1950s). Consequently, the first series of repairs for Jetty A had very low initial reliability. The third series of repairs (1960s) was performed using a more robust cross-section and larger armor stone size, resulting in improved structure reliability.

Structure Reliability for the Entire Jetty

For each year (i) in a given life-cycle, the overall structure reliability (PS-i) for the *entire* jetty is calculated as the mean value of the structure reliability over all active segments. For hindcast simulations, the overall structure reliability for each year is calculated using all jetty segments extending to the initial jetty head location. In forecast *simulations*, the overall structural reliability, for each year (i), is based on jetty segments that extend to the location of the current jetty head.

4. Structure Reliability and Jetty Cross-Section Damage

Structure reliability indicates the likelihood for a given jetty segment to incur damage. The structural reliability for each jetty (segment) is calculated based on the spatial variation of the forcing environment affecting the jetty and the condition of a structure, at a given point in time. Structure reliability does not define the extent of structure damage.

If the jetty cross-section continues to degrade over time, the parameters affecting structure reliability (crest elevation, armor stone size, armor stone stability number) will change, resulting in reliability reduction. Within the SRB model, degradation of jetty cross-section can be motivated by two processes:

1. Slope instability of the lower cross-section of the jetty, induced by toe scour – static stability performance (affects lower and upper cross-section region).
2. Wave induced damage to the upper cross section of the jetty – dynamic stability performance (affects upper cross-section region).

The cross-section of the jetty is modified in response to incident (and overtopping) wave action by a prescribed set of damage functions. Physical model studies were conducted by ERDC [Ward and Melby 2007] to define damage functions for various jetty cross-section configurations. These damage functions were used within the SRB life-cycle model to emulate jetty damage when the simulated wave height incident to the jetty exceeded the threshold condition for initiating damage (zero-damage wave height, $H_{D=0}$). When the armor layer for a given jetty segment is damaged, the value for $H_{D=0}$ is reduced to account for the presence of smaller and less stable stone exposed to wave forcing. As the armor layer and side slope of a jetty is progressively damaged, the geometry of the jetty's upper cross-section is reduced; eventually lowering the crest elevation of the jetty. As the crest elevation is reduced, the leeward slope becomes increasingly susceptible to damage from wave overtopping. The reliability of a jetty segment is cast in terms of the upper cross-section region (and physical attributes) being reduced as the segment becomes progressively more damaged. Damages sustained by the upper region of a jetty are expressed as a percent reduction in terms of the total upper cross-section area. As the parameters that describe dynamic performance (of the jetty upper region) are reduced, jetty reliability is also reduced.

The concept of jetty degradation affecting reliability is illustrated in Figure A2- 15, which shows how the change in jetty cross-section area can drive structure and functional reliability at a given jetty segment. The result shown in Figure A2- 15 is based on one realization from a SRB model hindcast simulation, for the MCR North Jetty at station 84+50. Based on the hindcast realization, the cross-section at station 84+50 was repaired 2 times during 1917-2006; note how the reliability is reduced as the cross-section area is reduced and how the reliability is restored as the cross-section is repaired. The relationship between upper cross-section change (above -5 ft MLLW) and total cross-section change is affected by wave action and jetty toe scour. When the jetty damage is primarily due to wave action, the structural response is manifested in terms of upper cross-section degradation.

Excessive erosion of the morphology, on which a jetty is founded, causes downward displacement of the jetty toe (toe scour). Continual toe scour leads to slope re-adjustment, which affects of the entire jetty cross-section. Refer to Structural Reliability below for additional details. If the jetty is affected by toe scour, the structural reliability of the entire structure will be compromised regardless of the dynamic reliability of the upper cross-section region. If the likelihood exists for significant toe scour, its abatement must be addressed when considering repairs or improvements for the upper cross-section.

b. Functional Reliability & Satisfactory Project Performance

All three rubble-mound MCR jetties perform in different ways to provide the same basic function: secure and maintain the configuration of the authorized channel through the coastal inlet. Without the present function of each jetty, year-round deep-draft navigation would not be possible at the MCR inlet. An essential objective for each jetty is to prevent rapid shoaling within the MCR navigation channel. The prevention of pronounced channel shoaling during winter is especially important, when large ocean waves can significantly degrade navigability within a shoaled channel due to the under-keel clearance requirements of MCR deep-draft navigation. The northerly 2,000 ft of the MCR channel is maintained at -55 ft MLLW (plus 5 ft for over-dredging to -60 ft), and the southerly 640 ft of the channel to be maintained at -48 ft MLLW (plus 5 ft for over-dredging to -53 ft).

If the upper region of the cross-section of a jetty is damaged beyond a minimum configuration, it will no longer perform its intended function; the jetty will experience unacceptable performance (the segment fails, functional reliability = 0). The minimum configuration that a Pacific Northwest seacoast jetty can remain functional was estimated to be 15% of a standard design template (Table A2- 10). At this point, the jetty section can be breached allowing for a separate flowpath to be established through the jetty, motivating sediment transported into the inlet and possibly into the navigation channel. Depending upon the condition of the jetty, and location along a given jetty, the consequences of functional failure can range from: A) a minor increase in the annual maintenance dredging requirement, to B) aggressive or emergency actions required to prevent rapid and significant shoaling within the MCR navigation channel. If the northern 1/2 of the channel experienced shoaling above -50 ft MLLW, deep-draft navigation would be significantly impaired during the fall-winter-spring time frame. Refer to Section 4 for a description of jetty breach scenarios associated with each MCR jetty.

Table A2- 10. Target Reliability for Functional Performance, Reliability = 1-P(u)

Jetty is assumed to have two more layers of armor units protecting core material. Values and corresponding consequences are applicable for MCR jetties ONLY.

Expected Performance Level Rubble-mound Structures @ MCR	Probability of Unsatisfactory *Functional* Performance P(u)	Potential Functional Consequences to MCR Jetties and Channel Shoaling [1/]
Excellent	0.005	Essentially no likelihood of jetty breach.[1] No sustained structure degradation.
Very High	0.02	Very little likelihood of jetty breach.[1] Minor sustained structure degradation.
High	0.05	Very little likelihood of jetty breach.[1/] Nominal sustained structure degradation.
Good	0.10	Little likelihood of jetty breach. Notable sustained structure degradation. Active structure monitoring required.
Average	0.15	Low likelihood for jetty breaching;[1] breaching potential exists for an extreme storm year. Notable sustained structure degradation. Active structure monitoring required.
Below Average	0.20	Potential for jetty breaching,[1] in response to severe storm activity. High level of structure degradation. Jetty repairs should be in active state of planning.
Poor	0.30	Elevated Likelihood for jetty breach,[1] in response to severe storm activity. Excessive structure degradation. Jetty should be in process of being repaired.
Unsatisfactory	0.40 to 0.50	High likelihood for jetty breach,[1] in response to severe storm activity. Significant structure degradation. Expedited jetty repairs are needed to avert a jetty breach. Moderate potential for priority dredging, if sediment is available for transport into channel.
Hazardous	>0.50	Jetty breach is likely. High degree of structure sustained degradation. Immediate action needed to prevent jetty breach. High likelihood for priority dredging to avert significant channel shoaling, if sediment is available for transport into channel.

1 = In the case of a jetty breach, likely to occur in winter when wave loading is highest: "Priority dredging" refers to dredging that would be needed to maintain MCR navigation channel during winter at authorized depth (-55 ft) due to significant channel shoaling due to the jetty breach. If a jetty breach event does not have the capacity to mobile more than 250,000 cy into the MCR channel during the winter season, then dredging is deferred until the following summer.

1. Calculation of Functional Reliability

The time-varying functional reliability for each jetty segment is estimated for each year (i) by combining the segment's upper cross-section with the four components of structure (dynamic) reliability to obtain weighted estimate for functional reliability for each year in the simulation. The weighting parameters are based on the fraction of cross-section remaining at year (i). The weighting function is modified to give more influence to segments having a higher or lower than average percentage of remaining cross-section. The "average remaining cross-section" is expressed in terms of an upper cross-section template that has been reduced to 57% of its full template area. For a given segment to have unsatisfactory function reliability, the cross-sectional area must be highly degraded and the structural reliability must be poor. In this sense, functional reliability is indicative of jetty resilience.

Figure A2- 15 shows how the functional reliability can change over time with respect to the cross-section area for a specific jetty location. Recall that structure reliability can be affected by the degree of damage a given segment has sustained, as can functional reliability. However, functional reliability displays less irregularity than structural reliability due to the buffering effect of the cross-sectional area. The sensitivity of functional reliability to changes in cross-section area (and structural reliability) can be observed in Figure A2- 15. If the cross-section area for a given reach of a jetty becomes diminished, the functional reliability may be affected more by cross-section area change than by the change in structure reliability. The complex interaction between cross-section area change, structure reliability, and the averaging of the two parameters along the entire jetty (when discrete areas of the jetty are being "repaired") can lead to instances when average structural reliability (for the entire jetty) is improving while the functional reliability is neutral or decreases. This means that the effect of the jetty being damaged (loss of cross-section) is greater than the effort to repair the jetty, in an overall average-jetty sense. In this case, the effort of repairing a jetty (restoring the cross-section) has less influence on affecting the functional reliability, than does the structure reliability. The jetty cross-section is being restored, but it has low reliability to resist damage.

Table A2- 10 gives the expected performance level and potential functional consequence for a range of unsatisfactory functional performance probability, p(u). A low value for functional performance p(u) indicates that a jetty segment has high resilience and can accept a finite amount of structure degradation and still have a high likelihood of functional performance.

4. MOTIVATION AND CONSEQUENCES OF JETTY FUNCTION FAILURE

Each jetty at MCR functions in a unique way to maintain the present inlet and navigation channel configuration. Jetty components include the head, trunk, and root. The morphology on which a given jetty is founded can also be considered a jetty component, and is included with the life-cycle analysis. In the vertical sense, a given jetty is composed of a lower section which re-directs subsurface currents and provides a foundation to support the upper part of the jetty. The upper part of the jetty re-directs surface currents, intercepts wave action, stabilizes the morphology adjacent to the jetty, and controls the (re)formation of shoals within the channel. Each MCR jetty is now acting to stabilize 10's of millions cy of sediment at the MCR inlet. Figure A2- 19 describes the functional components of a jetty and the related consequence for a given jetty component to lose its function (fail, functional reliability = 0). The MCR jetties and adjacent morphology have evolved to function together as s system. In this sense, each jetty can be thought of as a system of components working together to provide an overall jetty function.

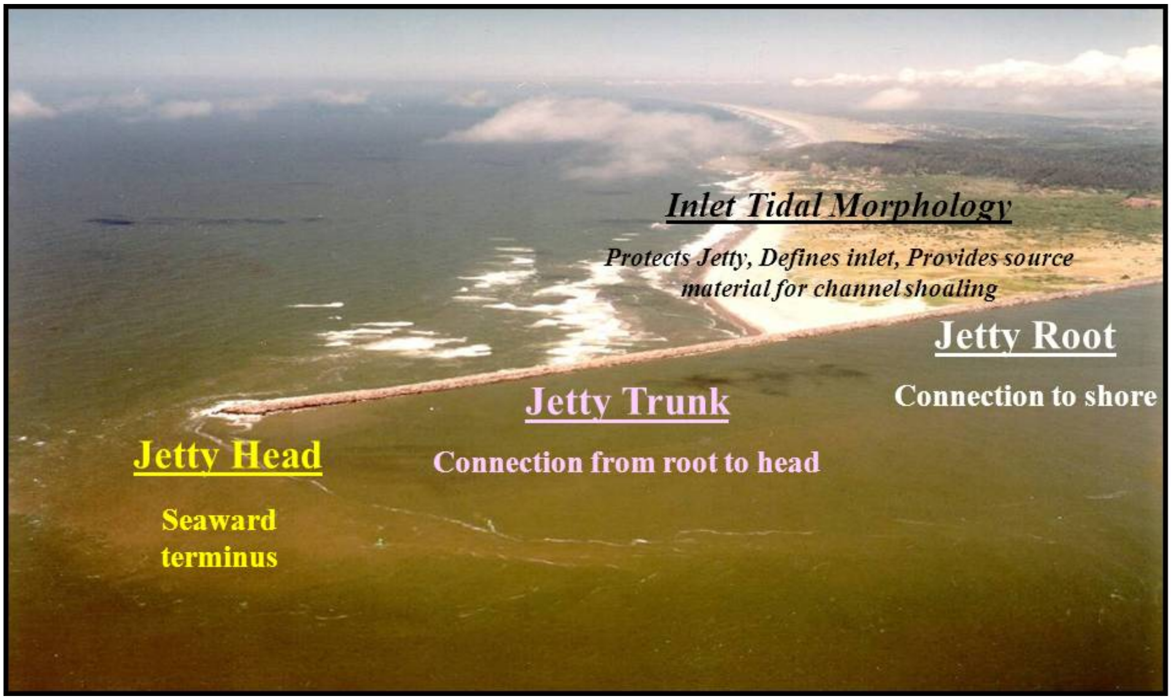


Figure A2- 19. General Components of a Coastal Jetty and Damage Consequences

MCR North jetty, view to the north. Jetty Head recession leads to progressive loss of jetty function and release of inlet morphology, which can impact inlet dredging requirements and stability of other jetty areas. Cumulative jetty Trunk damage can result in a trunk breach which can have functional consequences on the inlet. Cumulative jetty root damage can result in a root breach which can have serious functional consequences on the inlet. Note plume of suspended sediment transported past the jetty head and into the MCR inlet. Tide stage is at peak of flood tide.

Due to the complexities of the MCR jetty system, it is problematic to analyze life-cycle performance of all three jetties collectively. Rather, each jetty was analyzed independently using the SRB model and it was important to account for the primary and secondary processes, which affect future life-cycle performance and consequences on the MCR navigation project, and to discount the other process and related consequences that do not govern the life-cycle performance of the MCR jetty system. It is crucial to understand how each jetty presently functions, how each is affected by the forcing environment, how each jetty can fail, and the consequences of jetty failure.

North Jetty Function. Construction of the North Jetty was motivated by the northward evolution of the inlet in response to South Jetty construction. The North Jetty was the second to be constructed at MCR, to stabilize a series of ebb tidal shoals along the northern half of the inlet that were disrupted by the South Jetty. North Jetty construction constricted the center area of the inlet, resulting in the seaward displacement of ebb tidal shoals and establishment of a secured jetty inlet. Much of the shoals displaced by the North Jetty reformed along the north side of the inlet adjacent to and offshore of the North Jetty to form the modern day configuration of Peacock Spit. The North Jetty now anchors Peacock Spit along the northern flank of the MCR inlet. Without the functional aspect of the North Jetty, Peacock Spit would re-enter the inlet, devolving into a large flood tidal shoal spread across the inlet. The inlet would cease to support deep-draft navigation. Incremental loss of North Jetty function can produce consequences that have a moderate to high level of immediate impact intensity for a given location, and could accrue over time to have significant affect over the inlet.

<u>South Jetty Function</u>. The South Jetty was the first to be constructed at MCR. It is the longest of all three jetties and has had the largest effect on reforming the MCR inlet to the present condition. The South Jetty's present ocean exposure is three miles. The jetty continues to have a profound effect on the inlet; protecting the inlet and Clatsop Spit from destabilizing wave action and currents associated with regional-scale near shore circulation and coastal tidal flow. Clatsop Spit functions in conjunction with the South Jetty with refract wave energy within the inlet away from the navigation channel. Without the functional aspect of the South Jetty, Clatsop Spit would be dispersed within the inlet, devolving into a large flood tidal shoal spread across the inlet. The inlet would cease to support deep-draft navigation. Incremental loss of South Jetty function can produce consequences that have a low to moderate level of immediate impact intensity for a given location, but could accrue over time to have large affect over the inlet.

<u>Jetty A Function</u>. Construction of Jetty A was in part motivated by the breaching of South Jetty during the late 1920s. Jetty A was the last to be constructed at MCR, to minimize northward encroachment of Clatsop Spit, reduce the scour effect on North Jetty, stabilize the inlet's thalweg along the northing margin of the inlet, and to stabilize the morphology of Sand Island and Baker Bay. Jetty A anchors the interior (eastern) side of the inlet. Without the functional aspect of the Jetty A, Clatsop Spit would migrate northward into the inlet thalweg destabilizing Sand Island and the foundation of the North Jetty. The entrance into Baker Bay, through the Ilwaco channel, would not be passable without Jetty A. The inlet would cease to support deep-draft navigation at its current level. Incremental loss of Jetty A function can produce consequences that have a low to moderate level of immediate impact intensity for a given location, and could accrue over time to have large affect over the inlet.

This section of Appendix A2 describes the consequences that can arise when the MCR jetties fail due to breaching, head recession, or foundation scour-root erosion. The SRB model implements jetty response on similar basis (as described below) for life cycle simulations. SRB simulations for future conditions *do* account for consequences related to jetty repair and incremental dredging caused by jetty function loss. Recall that the SRB model assesses only jetty repair costs for hindcast simulations; incremental dredging costs associated with jetty deterioration are *not* included in hindcast simulations.

a. Jetty Head Recession

Figure A2- 20 identifies eight areas of MCR where the morphology is affected by landward recession of the jetty head. Figure A2- 21 shows schematically how jetty head recession can affect the inlet's morphology. As the jetties recede landward, the adjacent morphology is destabilized and the inlet and jetties become increasingly exposed to wave and current action. Sediment mobilized from the destabilized morphology can increase the MCR O&M dredging requirement. Figure A2- 19 and Figure A2- 22 describe how jetty head recession and adjacent morphology change are related. The SRB model incorporates these values into future life-cycle simulations. The incremental and long-term reduction of the inlet's morphology (and related increase in O&M dredging) due to jetty head recession is a complex process; one which defies definitive quantification. The SRB accounts for the first order jetty recession/morphology change processes, which can be estimated. As represented within the SRB model, the jetty recession/morphology change process is based solely on the incremental lateral reduction (cut) of the present tidal shoals (over a finite length), in relation to the incremental recession of the jetty heads. There are other morphological change processes that likely occur, but estimating these are problematic, refer to Jetty Head Recession Impacts Not Represented within the SRB Model. Implementation of engineering features such as jetty head "caps" at the terminus of a given jetty can arrest the landward migration of the jetty head. Refer to Jetty Rehabilitation and Engineering Features for a description of how Jetty head cap engineering features are emulated within the SRB model.

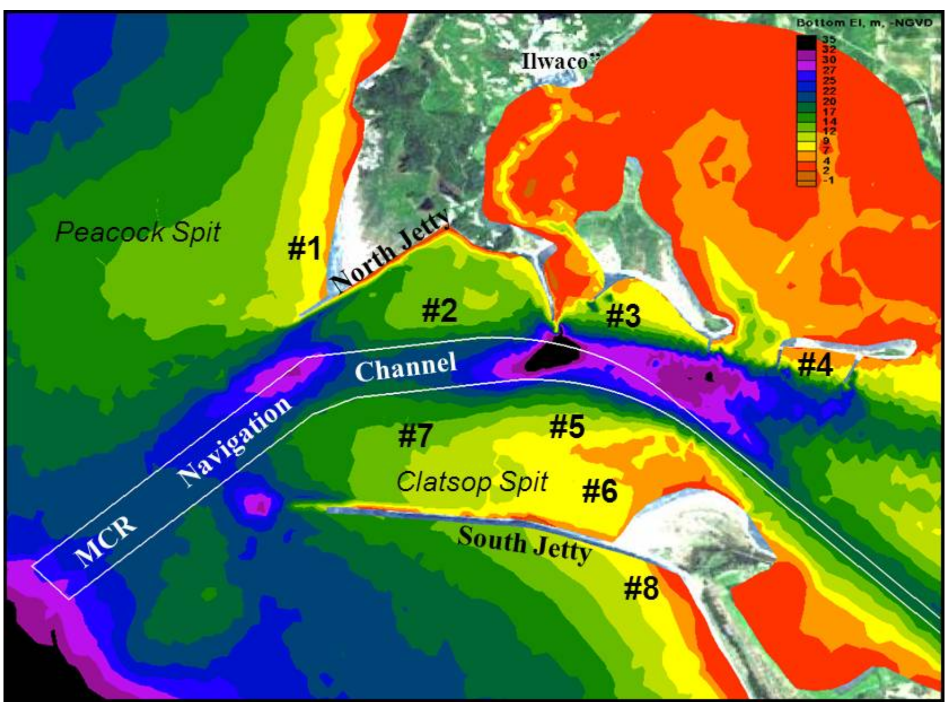


Figure A2- 20. Areas of MCR Morphology (1-8) Affected by Jetty Deterioration

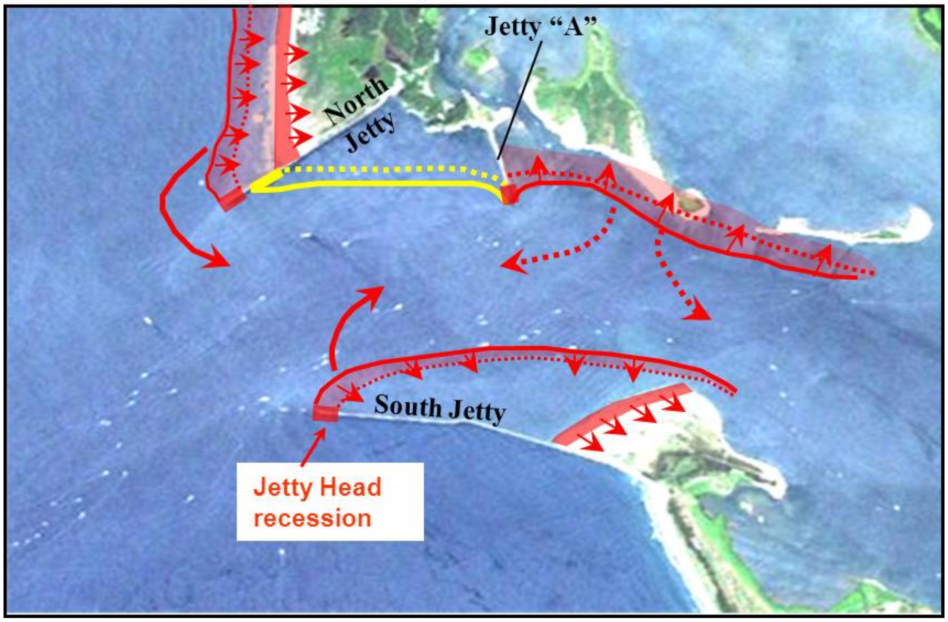


Figure A2- 21. Schematic of Jetty Head Recession Impacts

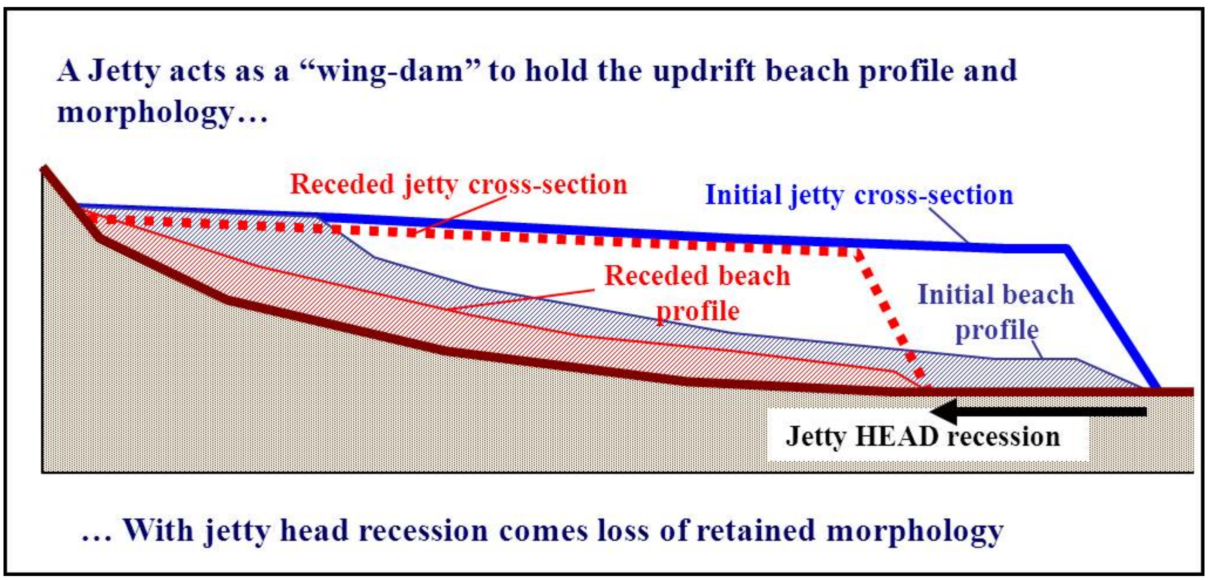


Figure A2- 22. Schematic Showing Profile of a Jetty as the Jetty Head Recedes Landward

1. **North Jetty – Head Recession**

North Jetty essentially acts as a wing dam to hold the morphology of Peacock Spit and prevent the spit from migrating into the MCR inlet (see Figure A2- 3 and Figure A2- 21). As the North Jetty head recedes landward, sand from Peacock Spit and the adjacent ocean shore is transported past the receding jetty and deposits within the MCR channel. When sediment is lost from Peacock Spit, the bathymetry deepens and the ocean shoreline recedes, exposing North Jetty to increased wave action. The ocean shoreline adjacent to North Jetty is controlled by the position of the North Jetty head. The morphology identified by area 1 (Figure A2- 21 and Table A2- 11) is affected by North Jetty head recession. The incremental increase in shoaling within the MCR channel (due to North Jetty head recession) would add to the volume of dredging routinely performed under the present O&M dredging program. As the North Jetty head recedes landward, the combined recession effect of Peacock Spit and North Jetty modifies the wave climate along the North Jetty such that the waves attacking the present head of the North Jetty remain constant while the waves along the inshore reaches of the North Jetty increase with respect to the changing distance to the North Jetty head. As the North Jetty head recedes landward from its 2007 position, the wave environment shoreward of the receding jetty head will increase. This wave climate vs. head recession effect is emulated within the SRB model only for areas along the North Jetty. Modification of the wave climate beyond the North Jetty for other inlet areas (due to North Jetty head recession), is not emulated with the SRB model.\

2. South Jetty - Head Recession

South Jetty stabilizes Clatsop Spit, preventing its northward and landward encroachment on the MCR navigation channel (Figure A2- 4). As the head of the South Jetty recedes landward, sand from the northern flank of Clatsop Spit is exposed to increased wave and current action. Sediment mobilized from Clatsop Spit is deposited within the MCR channel; similar to encroachment of a cut-bank shoal. The morphology identified by areas 5-8 (Figure A2- 22 and Table A2- 11) is affected by South Jetty head recession. The incremental increase in shoaling within the MCR channel (due to South Jetty head recession) would add to the volume of dredging routinely performed under the present O&M dredging program.

3. Jetty A - Head Recession

Jetty A protects the North Jetty from erosive ebb current and prevents northward migration of the MCR inlet (see Figure A2- 5). Jetty A also protects Sand Island from ocean waves and flood current. As Jetty A recedes, the North Jetty is exposed to an increased ebb current acting to destabilize the foundation of the North Jetty. The MCR inlet will translate northward as Jetty A recedes, destabilizing and increasing the erosion of Sand Island. The navigation entrance into Baker Bay through Ilwaco Channel would experience increased O&M dredging requirements. Sediment eroded from Sand Island would be deposited within the MCR channel. The morphology identified by areas 5-8 (Figure A2- 21) is affected by Jetty A head recession. The incremental increase in shoaling within the MCR or Ilwaco Channel (due to Jetty A head recession) would add to the volume of dredging routinely performed under the present O&M dredging program.

Table A2- 11. Effect of Jetty Head Ersion on Mobilizing Sediment Transport

Morphological Area	1 ft of Receding Jetty Head	Morphologcal Expression Affected by 1 ft of Jetty Head Recesion	VOLUME of Sediment Eroded from Morphology Area for Every 1 ft of Jetty Head Recession		Corresponding Volume of Eroded Sediment Transported into Navigation Channel	
		Elevation Extent of recession cut X Shore parallel extent of morphology recession	Erosion Below intertidal, CY	Erosion Above intertidal, CY	From Erosion Below intertidal, CY	From Erosion Above intertidal, CY
1	North Jetty	morpholgy recession from -30 to -20 ft along shore reach of 10,000 ft, 75% into inlet	3,700		2,700	
		morpholgy recession from -20 to 7 ft along shore reach of 9,000 ft, 75% into inlet	6,700	2,300	5,000	1,800
		morpholgy recession from 7 ft 13 along shore reach of 6,000 ft, 75% into inlet		1,300		900
2	Jetty "A"	morpholgy recession from -52 to -32 ft along shore reach of 8,200 ft, 70% into inlet	6,100		4,200	
3	Jetty "A"	morpholgy recession from -82 to -22 along shore reach of 6,200 ft, 60% into inlet	14,200		8,500	
		morpholgy recession from -16 ft -3 along shore reach of 1,300 ft, 70% into inlet	600		400	
4	Jetty "A"	morpholgy recession from -82 to -22 along shore reach of 6,200 ft, 50% into inlet	6,900		3,500	
5	Jetty "A"	morpholgy recession from -40 to -16 along shore reach of 7,800 ft, 40% into inlet	5,200		2,100	
6	South Jetty	(0.7)morpholgy recession from -10 to 7 along shore reach of 5,000 ft, 80% into inlet	1,300	900	1,000	700
		(0.7)morpholgy recession from 7 to 13 along shore reach of 5,000 ft, 80% into inlet		700		600
7	South Jetty	morpholgy recession from -32 to -13 along shore reach of 9,200 ft, 80% into inlet	6,500		5,200	
8	South Jetty	(0.3)morpholgy recession from -10 to 7 along shore reach of 3,000 ft, 10% into inlet	200	100	20	10
		Armor Stone Displaced from North Jetty due to 1 ft of Jetty"A" Head Recession	Above values for morphology erosion estimates due to jetty head recession are based NO added jetties spurs (engineering features) being constructed.			
North Jetty Degradation	Jetty "A"	60 Tons				

b. Jetty Head Recession Impacts Not Represented in SRB Model – Residual Risk

Vertical Deflation of Morphology. As represented in the SRB model, the jetty recession/ morphology change process is based solely on the incremental lateral reduction (cut) of the present tidal shoals (over a finite length), in relation to the incremental recession of the jetty heads. The vertical deflation of the inlet's shoals in response to jetty head recession is not included in the SRB model. There is a likelihood that this process actually occurs in response to jetty head recession. The added volume of sediment lost from the inlet's shoals due to vertical deflation of the shoals (incremental increase in O&M dredging) could approach the volume of sediment lost from the shoals by lateral reduction. The SRB model did not account for the vertical deflation of the inlet's shoals (due to jetty head recession) because there was a high degree of uncertainty as to if this effect would occur or how to best estimate the areal extent of the process.

Littoral Sediment Inflow. It is likely that as the heads of the MCR North and South Jetties recede landward, the volume of littoral sediment entering the inlet from the adjacent coastal areas will increase (along with O&M dredging). This process was not emulated within the SRB model. Combining the omission of this littoral shoaling process with the omission of the vertical component of morphology deflation within the inlet, it is likely that the SRB model is not accounting for a significant contribution of additional channel infilling (or omission of added O&M dredging cost) associated with jetty head recession. It was deemed more prudent to error on underestimating increased channel O&M dredging (and related cost) by omitting the above speculative effects, as opposed to overestimating O&M dredging costs by including the aforementioned effects. This rationale introduces residual risk of understating the O&M dredging costs (lost benefit) for not stabilizing the jetty heads. Alternatives that do not include head stabilization (head cap engineering feature) will have residual risk as described above.

Impacts to Inlet Stability. Without stabilization of the jetty heads at MCR, the morphology within and adjacent to the inlet will recede at a significantly higher rate as compared to the case where the jetty heads were stabilized. Long-term reduction (erosion) of morphology within a coastal-estuarine inlet such as MCR will act to increase wave action and modify current patterns within the inlet. Without the present function of MCR jetties, these changes would occur because the inlet would be preferentially deepened along its shallow flanks due to morphology erosion. Thalweg depth will remain approximately the same as the present condition. With depths increased along the inlet's interior margins, larger ocean waves can penetrate further into the inlet and current action becomes less aligned with the thalweg. The occurrence of such changes within the interior margins of the MCR inlet are likely to adversely affect sensitive ecology that normally resides within the inlet flanks or passes through the inlet. The SRB model does not account for the potential changes in environmental (ecological) conditions that would occur due to morphological deflation within the inlet.

Impacts to Navigation. As larger waves propagate further through the inlet (due to jetty head recession), under-keel clearance for ships can be reduced and the persistence of strong cross-currents will reduce ship handling through the MCR channel. The end result of an increased incremental rate of morphology loss within the MCR will be an incremental loss of deep-draft navigability through the inlet. Ship handing and keel clearance will be reduced through the more confined areas of the inlet due to increased wave and cross-current action, specifically along RM 1 to 4. The realized effect on navigability will be an increased occurrence of conditions at MCR when ship maneuverability is reduced, such that the frequency and duration of delay periods will increase for ships passing through the MCR. Bar pilots will have a harder time controlling the vessels during what are now deemed as nominal storm wave and tidal conditions, and the threshold for closing the bar (based on offshore storm wave height and tidal window) will be reduced. The end result will be more frequent inbound/outbound delays due to adverse wave action and tidal conditions, increasing the days per year when the MCR bar is closed to shipping. The cause and effect process between morphology loss and reduction of deep-draft navigability has been confirmed by the MCR Bar Pilots based on observed changes in ship handling characteristics correlated to bathymetry change during 1997-2007 [Jordan 2007]. The SRB model does not account for the reduction in deep-draft navigability that would occur due to morphological deflation within the inlet.

In summary, if the jetty heads are not stabilized (capped), the functional performance of the MCR inlet will be compromised by the residual risk of morphology deflation.

c. Jetty Rip Currents - Toe Scour and Root Erosion

Waves and currents constantly churn along the base of jetties and at the shoreface where the jetty root interfaces with adjacent topography, acting to create secondary circulation (eddies and counter currents). The secondary circulation along the jetties produces rip currents which erode sediment away from the jetty foundation (toe scour). Jetty toe-scour is a localized process that affects a finite volume of sediment along the seabed interface with the jetty. The toe scour zone along a jetty typically extends less than 200 ft away from the jetty toe-seabed interface. The volume of sediment directly affected by the toe scour process (within the scour zone) is relatively small, yet the degree to which toe-scour can affect jetty stability is large. Secondary circulation, motivated by jetties interacting with regional circulation, can mobilize sediment along the shore face adjacent to the jetties, resulting in shoreface recession. In many cases, the shore edge recession effect can extend for a considerable distance away from a given jetty and produce a large quantity of mobilized sediment.

Once mobilized and injected into the jetty rip current system, much of this shore edge sediment (50% to 80%, depending on jetty location) is transported by rip-currents that flow along each jetty, and deposited into the MCR channel. In general, annual O&M dredging at MCR is affected by 10% to 20% by the processes that govern shoreline retreat and rip-currents formation along the North and South Jetties. Figure A2- 23 shows schematically how jetty toe scour and shore recession are related and contribute to shoaling with the MCR channel. Implementation of engineering features such as spur-groins along a given jetty can mitigate the scour of the jetty toe and reduce shoreface recession along the root of a jetty, reducing the rip currents that form along a jetty. Jetty rip currents are responsible for both promoting jetty toe scour and for transporting eroded shoreface sediment into the navigation channel. Refer to Jetty Rehabilitation and Engineering Features and Table A2- 12) for a description of how jetty spur-groin engineering features are emulated within the SRB model.

Table A2- 12. Channel Shoaling Volume Attributed to the Processes of Shore Recession and Jetty Head Retreat on Morphology

Part I: Process Affecting Sediment Transport into MCR Channel	**North Jetty** CY	**South Jetty** CY	**Jetty "A"** CY *
A) Shoreface Recession Affected by Present Evolution of MCR Inlet (channel and ocean side) - Not associated with Jetty Head Loss *Volume into Channel Expressed in CY for every 100 ft of shoreline recession*	**300,000**	**340,000**	**0** 0 *
B) Shoreface Recession Affected by Jetty Head Loss (channel and ocean side) *Volume into Channel Expressed in CY for every 100 ft of Jetty Head Loss*	**1,040,000**	**750,000**	**1,870,000** 100,000 *
Part II: Process Mitigated by Implementation of Proposed Jetty SPURS **	**North Jetty** % Mitigation	**South Jetty** % Mitigation	**Jetty "A"** % Mitigation
1) Erosion of Jetty Foundation Affected by Toe Scour			
Ocean Side	**0.3**	**0.3**	**0.3**
Channel Side	**0.3**	**0.3**	**0.3**
2) Shore Face Recession Affected by Background Erosion & Related Channel Shoaling = Mitigates Part I-A			
Ocean Side	**0.3**	**0.5**	0
Channel Side	0	**0.3**	0
3) Shoreface Recession Affected by Jetty Head Loss & Related channel Shoaling = Mitigates Part I-B			
Ocean Side (below intertidal / above intertidal)	**0.7 / 0.9**	0	**0.8**
Channel Side (below intertidal / above intertidal)	0	**0.6 / 0.7**	**0.5 / 0.8**
Part III: Process Mitigated by Implementation of Jetty Head Extension	**North Jetty** CY	**South Jetty** CY	**Jetty "A"** CY *
Shoaling Reduced by Constructing Head Cap or Jetty Extension *Volume Expressed in CY for every 100 ft of Jetty Head Cap (or re-extension) Constructed* *= accomodation space on morphology to accumulate added sediment*	**1,040,000**	**870,000**	**970,000**

* = Shoaling into Ilwaco Channel associated with Jetty "A" processes
** = Four (4) North jetty Spurs: NJ1-Channel(50), NJ2-Channel(70), NJ-3Ocean(80),NJ4-Channel(90)
** = Five (5) South Jetty spurs: SJ1-Ocean(165), SJ2-Channel(210), SJ3-Channel(230), SJ4-Channel(265), SJ5-Ocean(305)
** = Two (2) Jetty "A" spurs: JA1-Channel(90), JA2-Ocean(84)

1. North Jetty - Toe Scour and Root Erosion

As the ocean shoreline adjacent to the North Jetty recedes, the North Jetty root is exposed to increased wave action. Since the 1930s (after Peacock Spit attained its largest subareal extent), the shoreface along the North Jetty has been receding landward by 4-8 ft per year, not including the effect of jetty head recession. Much of the eroded sediment is transported into the MCR inlet by rip-currents forming along the jetty, adding to the O&M dredging required to maintain the channel. Table A2- 12 gives the estimated volume of sediment entering the MCR channel for every 100-ft of shore edge recession that occurs along the ocean side (Peacock Spit) of the North Jetty. The compounding effect of rip currents is to erode sand away from the submerged part of the jetty. Table A2- 13 gives values for scour along the North Jetty. Storm wave and surge/run-up action can destabilize the jetty slope and toe along the beach side of the North Jetty leading to degradation of the jetty root area.

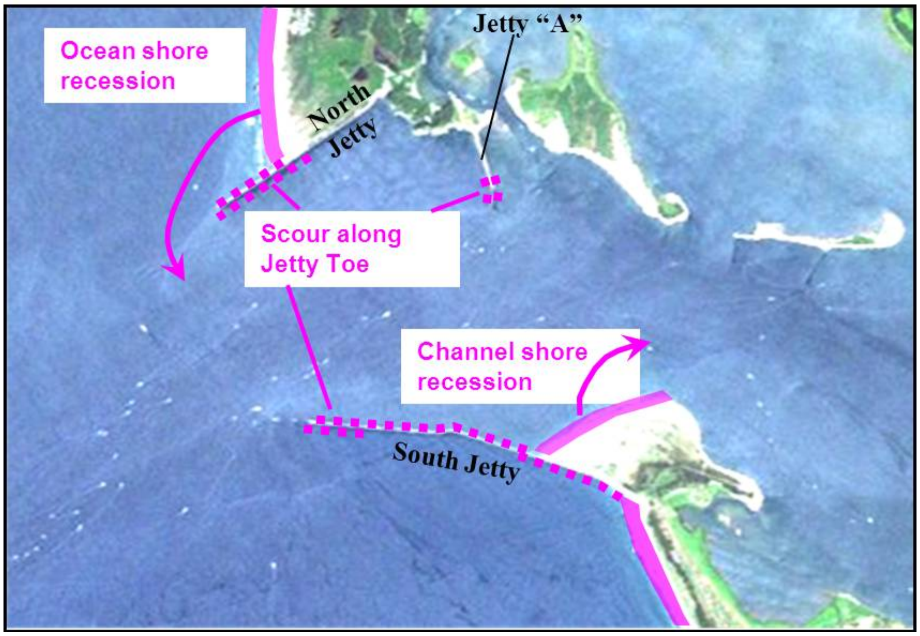


Figure A2- 23. Effects of Jetty Scour/Rip Current at MCR Inlet for Shoaling and Jetty Stability

Table A2- 13. NORTH Jetty Morphological Factors for Modifying Wave Height

Jetty Station	Side of Jetty	PAST Life-Cycle 1917 - 2006 Estimated	PAST Life-Cycle 1917 - 2006 Observed	Present Seabed Elevation	FUTURE Life-Cycle 2006-2070 Estimated	FUTURE Life-Cycle 2006-2070 Estimated
		Morphological Factor	Total Scour @ jetty	200 ft offset from toe	Morphological Factor	Total Scour @ jetty
		1917 : 2006	(ft)	(ft, NGVD)	2006 : 2070	(ft)
20+00	Ocean	0.70 : 1	deposition	*18*	-	0
50+00	Ocean	0.75 : 1	deposition	*12*	-	0
65+00	Ocean	0.77 : 1	deposition	*2*	1 : 1.1	-5
75+00	Ocean	0.79 : 1	deposition	*-5*	1 : 1.2	-10
85+00	Ocean	0.80 : 1	deposition	-16	1 : 1.3	-10
100+00	Ocean	0.75 : 1	0	-27	1 : 1.2	-15
124+00	Ocean	0.65 : 1	-15	*-31*	1 : 1.1	-10
		1917 : 2006			2006 : 2070	
20+00	Channel	0.6 : 1	0	-27	1 : 1.3	0
40+00	Channel	0.7 : 1	-5	-36	1 : 1.3	0
60+00	Channel	0.8 : 1	-10	-41	1 : 1.3	-10
80+00	Channel	0.8 : 1	-10	-50	1 : 1.3	-15
100+00	Channel	0.7 : 1	-30	-68	1 : 1.3	-10
124+00	Channel	0.65 : 1	-40	*-64*	1 : 1.2	0

2. South Jetty- Toe Scour and Root Erosion

The channel side shoreline along the (north side) root of the jetty is receding landward at 2-5 ft per year, not including the effect of jetty head recession. Currently, the eroded sediment is transported into the MCR channel and the channel side of the South Jetty is exposed to increased wave action. Table A2- 12 gives the estimated volume of sediment entering the MCR channel for every 100-ft of shore edge recession that occurs along the channel side (Clatsop Spit) of the South Jetty. As the ocean shoreline south of South Jetty recedes landward (2-5 ft per year), the ocean side root of the South Jetty is exposed to increased wave action. The sediment eroded away from the ocean side of the South Jetty root is not considered to enter the MCR channel. Table A2- 14 gives values for scour along the South Jetty. Storm wave and surge/run-up action can destabilize the jetty slope and toe along both sides of the South Jetty, where the jetty connects to shore, leading to degradation of the jetty root area.

Table A2- 14. SOUTH Jetty Morphological Factors for Modifying Wave Height

Jetty Station	Side of Jetty	PAST Life-Cycle 1910 - 2007 Estimated	PAST Life-Cycle 1910 - 2007 Observed	Present Seabed Elevation	FUTURE Life-Cycle 2007-2070 Estimated	FUTURE Life-Cycle 2007-2070 Estimated
		Morphological Factor	Total Scour @ jetty	200 ft offset from toe	Morphological Factor	Total Scour @ jetty
		1917 : 2006	(ft)	(ft, NGVD)	2006 : 2070	(ft)
155+00	Ocean	0.67 : 1	deposition	*8*	-	-8
165+00	Ocean	0.67 : 1	0	*-10*	1 : 1.2	-8
185+00	Ocean	0.67 : 1	-5	-14	1 : 1.2	-10
205+00	Ocean	0.68 : 1	-5	-21	1 : 1.2	-12
230+00	Ocean	0.69 : 1	0	-26	1 : 1.15	-5
255+00	Ocean	0.7 : 1	-5	-33	1 : 1.1	-5
275+00	Ocean	0.71 : 1	-8	-35	1 : 1.1	-5
295+00	Ocean	0.71 : 1	-10	-40	1 : 1.05	*-5*
315+00	Ocean	0.71 : 1	-15	-41	1 : 1.05	*-10*
335+00	Ocean	0.71 : 1	-20	-45	1 : 1	0
375+00	Ocean	0.72 : 1	-45	*-70*	1 : 1	0
		1910 : 2007			2007 : 2070	
170+00	Channel	0.77 : 1	deposition	*10*	-	0
190+00	Channel	0.77 : 1	0	*-4*	1 : 1.2	-5
215+00	Channel	0.77 : 1	-5	-13	1 : 1.2	-10
235+00	Channel	0.78 : 1	0	-17	1 : 1.2	-15
250+00	Channel	0.78 : 1	0	-21	1 : 1.2	-10
275+00	Channel	0.79 : 1	0	-24	1 : 1.2	-10
295+00	Channel	0.79 : 1	0	-27	1 : 1.2	*-17*
315+00	Channel	0.79 : 1	-5	-35	1 : 1.15	*-20*
335+00	Channel	0.68 : 1	-35	-55	1 : 1.1	0
375+00	Channel	0.7 : 1	-50	*-80*	1 : 1.05	0

3. Jetty A - Toe Scour and Root Erosion

The present condition of the shoreface along each side along the root of Jetty A is highly resistant to erosion (stable) due to armoring from previous jetty repairs. Consequently, there is no sediment estimated to enter either the MCR or Ilwaco Channel due to the ambient recession of the shoreline on either side of Jetty A, not including the effect of jetty head recession. The jetty toe along the most of the outer half of Jetty A (ocean and estuary side) continues to experience scour due to rip currents that form along the jetty due to enhanced circulation motivated by flood and ebb tide action. Future scour along the outer-most part of Jetty A (> sta. 95) is expected to stabilize, while scour along areas between sta. 65-95 will continue. Table A2- 15 gives values for scour along Jetty A.

Table A2- 15. JETTY A Morphological Factors for Modifying Wave Height

Jetty Station	Side of Jetty	PAST Life-Cycle 1939 - 2006 Estimated	Observed	Present Seabed Elevation	FUTURE Life-Cycle 2006-2070 Estimated	Estimated
		Morphological Factor	Total Scour @ jetty	200 ft offset from toe	Morphological Factor	Total Scour @ jetty
		1917 : 2006	(ft)	(ft, NGVD)	2006 : 2070	(ft)
41+00	Ocean	1 : 1	deposition	*19*	-	
45+00	Ocean	1 : 1	deposition	*17*	-	
50+00	Ocean	1 : 1	0	-6.6	1 : 1.2	0
55+00	Ocean	0.8 : 1	-10	-13.2	1 : 1.2	0
65+00	Ocean	0.7 : 1	-13	-18.3	1 : 1.1	0
75+00	Ocean	0.75 : 1	-9	-17.9	1 : 1.2	-8
90+00	Ocean	0.8 : 1	-16	-34.5	1 : 1.3	-20
95+00	Ocean	0.8 : 1	-35	*-60*	1 : 1.2	-10
97+00	Ocean	0.8 : 1	-75	*-80*	1 : 1.2	0
		1939 : 2006			2006 : 2070	
70+00	Channel	1 : 1	0	*9*	1 : 1.2	0
80+00	Channel	1 : 1	0	-16.2	1 : 1.2	-10
90+00	Channel	1 : 1	-35	-52.4	1 : 1.2	-20
97+000	Channel	1 : 1	-80	*-105*	1 : 1.2	0

d. Jetty Breaching

The function of each MCR jetty has evolved through time. When initially constructed, the jetties functioned to diffuse (or flush) the inlet's shallow broad tidal shoals which had significantly restricted navigation across the bar at the MCR. Once the inlet's tidal shoals were re-oriented by the flushing action of the MCR jetties, the function for the jetties was to maintain a stable deep thalweg through the inlet. Through time, the function of the MCR jetties has evolved to include an additional objective - to hold sediment (morphology) in place along the inlet's interior and exterior margins. Each MCR jetty now acts to retain 10's of millions of cy of tidal shoal sediment.

The most efficient way to release sediment back into the MCR inlet is to "punch a hole" (breach) through the jetty along an area where waves and currents can quickly mobilize a large volume of sediment. The likelihood of a jetty breach is low, but can increase with decreasing jetty resilience. If the jetties are not maintained, then unchecked degradation of the cross-section will lead to reduced jetty resilience and the rate of jetty deterioration will increase. Jetty resilience can also decrease if the loading conditions increase, if the regional wave environment becomes more severe (non-stationary climate), or the inlet's morphology is reduced (non-stationary morphology). See Section 5 and Figure A2- 24 for additional discussion regarding jetty cross-section deterioration rates as a function of maintenance strategy and other life-cycle considerations. Figure A2- 25 shows schematically how a jetty breach can contribute to shoaling with the MCR channel.

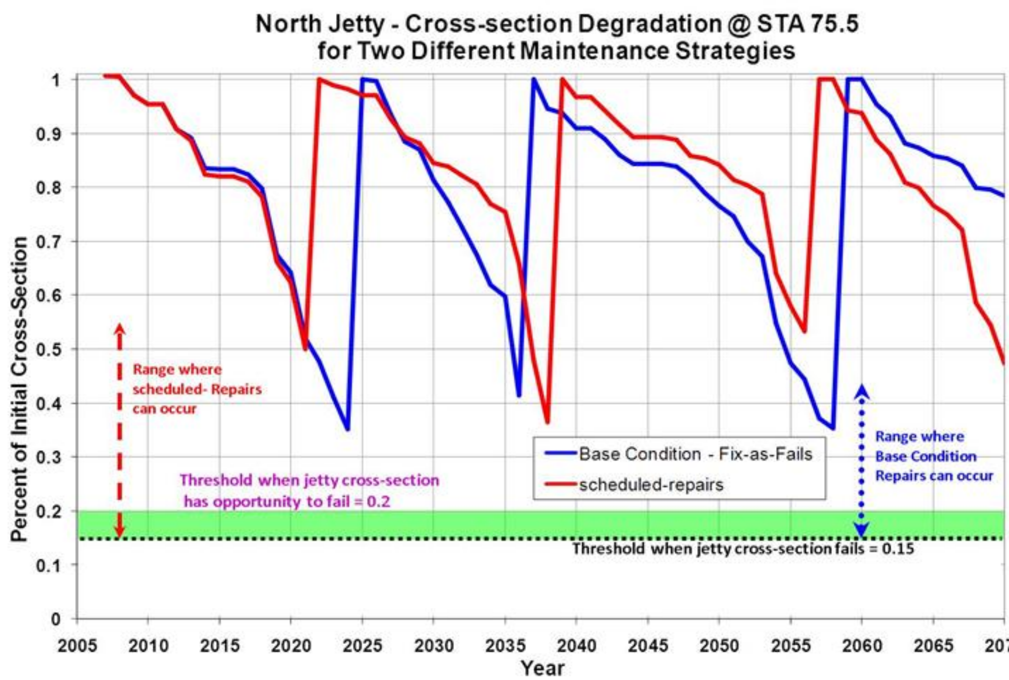


Figure A2- 24. Jetty Cross-Section Degradation Rate and Repair Timing

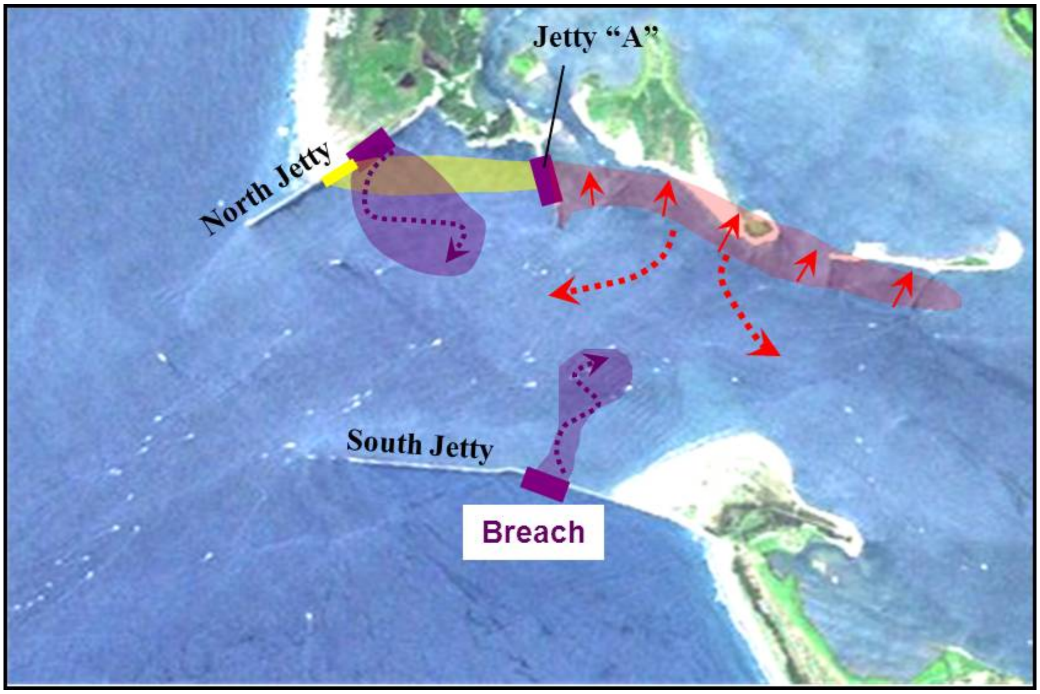


Figure A2- 25. Effects of Jetty Breaching at MCR Inlet for Shoaling and Jetty Stability

e. Tsunami

The specter of a tsunami is a reality for the coastal margin along the Pacific Northwest of North America. The last Cascadia Subduction Zone (CSZ) earthquake to affect the northwest coast of North America occurred in 1700 (8-9 magnitude, 50-150 miles offshore). It is estimated that the re-occurrence interval for these events is approximately 400 years. The USGS has speculated that there is a 1:6 chance that such an event will occur within the next 50 years. The tsunami generated from an 8-9 magnitude Cascadia earthquake could range from 5 ft to 30 ft high along the present shoreface. Co-seismic subsidence (due to strain release of the earth's tectonics) may induce immediate lowering of the coastal margin by 2-8 ft [Atwater and Hemphill-Haley 1997]. The effect of a 5-30 ft tsunami on the MCR jetties would be significant and transient, likely to destabilize the roots of all the jetties due to overland flow eroding the morphology along the jetty roots. The jetty roots may be flanked. Immediate repairs would be needed to re-secure the jetty roots. The seaward ends of the jetties could be affected by significant scour due to the volume of water transported into and out of the inlet in response to tsunami passage. A significant volume of sediment may be mobilized and deposited within the MCR inlet. Violent shaking of the jetties would likely destabilize many areas having a side slope steeper than 1V:2H. Liquefaction of the jetty foundation may occur and initiate jetty settlement and toe failure. If vertical co-subsidence occurred with the CSZ temblor, the long-term effects on the jetties and existing land margin being lowered by 2-8 ft may be more profound than the earthquake and tsunami. Jetty freeboard could be significantly reduced and depth-limited wave height would be significantly increased. This effect would significantly increase the rate of jetty degradation and expose the landward areas of each jetty to increased wave loading and overtopping. Jetties that were in a good state of repair (or recently rehabbed) would be more resistant to earthquake-related damages as opposed to jetties that were in a condition of deferred repair. The effect of a tsunami is presently not addressed within the SRB model.

5. COMPONENTS AND PROCESSES OF SRB LIFE-CYCLE MODEL

The SRB model is a computer simulation which integrates many simple interacting considerations governing jetty response and performance. The modeling objective is to simulate time varying condition of the jetty and estimate costs associated with the functional performance of the jetty. A key limitation that must be understood is that the SRB model simulates outcomes based on many assumed input conditions; most are cast in terms of uncertainty. Models provide insight, not answers. The SRB model produces bounded estimates. By using Monte Carlo simulation within the SRB model, these estimates can be given a specified level of certainty (or uncertainty).

a. SRB Model Structure

The SRB model uses a project event tree (Figure A2- 9 through Figure A2- 11) as the basis for conditional logic, decision making, and consequence evaluation for assessing jetty life-cycle performance. The SRB model was developed within Portland District based on a similar approach used to evaluate rehabilitation of Burns Harbor breakwater at Portage Indiana [USACE 1993]. The SRB model simulates a jetty life-cycle in a series of one year increments. A model year begins June of calendar year 1 and ends May of year 2. This timing captures the storm climate during fall-spring within the same year and repair structure damages the following year (during summer construction season). The coding structure and organization of the SRB model is schematically shown in Figure A2- 9 through Figure A2- 11. The primary actions undertaken during SRB model development were to:

1) Adequately describe the forcing environment affecting the jetty cross-section,
2) Simulate jetty cross-section response to environmental forcing,
3) Estimate consequence of jetty breaching, should it occur, and
4) Emulate jetty maintenance intervention.

The SRB model was written in MATLAB and is composed of a number of script (.mat) files and modules (functions), each to perform specialized tasks. The modules independently deal with generating realizations of life-cycle wave and water level environment, interpolating the realized wave environment continuously along the jetty, calculating reliability, performing cross-section geometry calculations due to damages, and other tasks. A more detailed description of the model structure is provided in the *User's Manual*.

The SRB model considerations include: (1) existing condition of structure; (2) previous repairs of structure; (3) foundation conditions; (4) failure modes; (5) structure function; (6) exposure to changing wave conditions; and (7) coupling between jetty function and morphology evolution of the tidal shoal(s) directly adjacent to each jetty. Physical and numerical modeling was conducted to evaluate the forcing environment (waves and currents) along each jetty and the response characteristics of various jetty design sections.

Each SRB model assumes a pre-specified nominal evolution in environmental forcing as related to the expected long-term morphological change of the MCR inlet (refer to Foundation Effects in Section 6). Localized changes in environmental forcing along each jetty, attributed to progressive specific changes in function of a given jetty, are also included in each SRB model. The SRB model for Jetty A accounts for subsequent effects on the inlet, should the function of Jetty A be compromised. Recall that Jetty A is functionally linked to the North Jetty by reducing the ebb current (scour) that would affect the North Jetty, in the absence of Jetty A. Jetty A also stabilizes the morphology along the north side, and to a lesser extent, the south side of the inlet thalweg. The Jetty A SRB model accounts for the one-way localized interaction of Jetty A with the North Jetty, and for localized interaction of Jetty A with Clatsop Spit. The SRB models for the North and South Jetties do not account for interaction with Jetty A, nor do the models interact with each other.

In general, the SRB jetty models do not simulate the consequences of interaction between the jetties. If the SRB model for the South Jetty predicts severe jetty degradation (head recession or jetty breach) such that Clatsop Spit would devolve significantly over time, there is no inlet-wide effect implemented within the SRB model to account for related impacts that may be realized by the North Jetty, Jetty A, or within the inlet itself. Additionally, if all three MCR jetties were (independently) predicted to significantly degrade over time such that the respective morphology affected by each jetty devolved, it is likely that the regional wave and current environment in the MCR inlet would be modified to adversely affect: A) navigation passing though the inlet; and B) each jetty by more vigorous regional environmental loading than estimated in the SRB models. These regional effects are not simulated in the SRB models due to the uncertainty involved in attempting to evaluate such large-scale effects within the complex MCR system. The above scenarios demonstrate the level of residual risk not captured by the models and is further discussed in *Engineering Feature Analysis*.

b. Input and Output Data Definition

Parameters utilized within the SRB model include: time-varying shoreline evolution along each side of the jetty, time- and spatially-varying scour rates along each side of the jetty, time- and spatially-varying wave conditions along each side of the jetty, time-varying water levels, variable jetty root degradation rates, spatially-variable and time-varying jetty cross-section attributes (for each side of the jetty).

Two stand-alone scripts are used to convert Excel-based data into MATLAB (.mat) files for input to the SRB model. The input data conversion process (from Excel to MATLAB) deals with data that defines the present physical condition of the jetty, STWAVE model output, wave damage functions, and rehabilitation and engineering feature costs per jetty segment. The data file conversion is performed only one time; after which the SRB model automatically reads the input data from the MATLAB (.mat) data file every time the SRB model is run. Other data types and SRB model control parameters are specified directly within the model script. Most of the model control parameters are located within the first 175 lines of the SRB model. All parameters (model control and data definition) are described within the SRB model through commenting of the code.

When executing a hindcast SRB simulation, the initial condition geometry, jetty armor/core stone attributes, and jetty foundation scour rates are defined for the entire jetty, on a segment by segment basis. A jetty segment is 100-ft long. The historical repair sequence is defined within the model to define the number of times segments can be rebuilt, repair cross-section attributes, and the applicable threshold to initiate repairs. Future life-cycle simulations use the ending jetty condition from the hindcast to describe the initial jetty condition (geometry and armor stone characteristics) in the forecast. This means that a calibrated hindcast simulation must be completed (with hindcast MATLAB [.mat] output files saved), prior to initiating a future life-cycle simulation.

The SRB model does allow for the use of observed geometry data (present jetty survey) to override the simulated end-state jetty geometry obtained from model hindcast. In this case, the SRB model would use "observed" survey data to define the initial forecast condition when conducting future simulations. The "observed" geometry option was used to define the initial condition for jetty geometry for all SRB life-cycle forecasts conducted in this study. Because there is no objective way to estimate the armor layer characteristics for the forecast initial (present day) condition along each jetty, the calibrated SRB hindcast solution was utilized to define initial conditions for armor stone characteristics along each jetty, when forecasts where conducted. For additional information on hindcasting performed to support this study, refer to Section 7.

Various types of SRB model output can be saved to files, depending upon SRB parameters set within the model. Output produced by the SRB model includes ACSII text-based data files (for life-cycle repair tonnage and incremental dredging volume) expressed in a mean value and standard deviation. Multiple graphical summaries are produced for pertinent model metrics describing the spatial and time-varying conditions of a given jetty. The entire MATLAB simulation environment, containing all variables accessed or created by the SRB model, can be saved as a .mat file.

1. Future Life-cycle Simulations

Future Jetty Repairs. Jetty repairs may be enacted at three different levels of response, depending on the urgency for repairs. In a normal O&M level, jetty repair areas are identified and executed in a methodical manner (multi-year planning effort). In an expedited level, jetty repairs are fast-tracked and made within one year of problem identification. Expedited repairs may be made to prevent the onset of a breach, when the jetty is in an advance state of degradation. Expedited repairs are enacted for the South Jetty and Jetty A in response to a jetty breach. In an emergency level, jetty repairs are executed within 2-6 months, in response to a serious breach along the North Jetty. Within the SRB model, jetty repair costs associated with normal O&M and expedited repair efforts are tracked separately from emergency repairs, which are associated with significant breach events.

Rehabilitation and Engineering Features. Within the SRB model, tonnage for jetty rehab elements or engineering features was pre-determined based on design template cut and fill volume computations. A design template (cross-section and profile) was developed for each alternative, and the existing jetty surface or seabed grade elevation was subtracted from the template surface to determine the volume of "new" work. This volume was converted to jetty stone tonnage per jetty segment (100 ft). Rehab cost per jetty segment was determined by multiplying tonnage/segment by the unit cost for the rehab alternative ($/ton). Unit costs (including mob-demob, mitigation, and other cost factors) for various rehabilitation alternatives were estimated by the NWD regional cost estimating team within the MII framework. The material tonnage and cost for engineering features was determined in a similar manner. Within the SRB model, rehab alternatives and engineering features are sequentially implemented along a jetty according to a pre-specified schedule. This process emulates the "real life" implementation schedule. If degradation of the jetty cross-section occurs before a given rehab alternative is implemented, then the tonnage for the rehab alternative is increased to account for additional cross-section replacement. If future jetty repairs occur at a given location before a rehab alternative is implemented (due to cross-section degradation), then the tonnage of the rehab alternative is reduced to account for cross-section being supplemented through the repair action. Within the SRB model, costs associated with implementing jetty rehabilitation and engineering features are tracked separately from jetty repair costs.

Incremental Dredging Costs. The SRB model can estimate the volume associated with increased channel dredging (due to loss of jetty function) that are incrementally within the normal O&M program, or that exceed normal O&M outlays. Incremental O&M dredging volume can occur through: A) landward retreat of the jetty head; B) landward recession of shoreface along the ocean side or channel side of the jetty; and C) scour of the tidal shoal along the jetty toe. Dredging costs that exceed the normal O&M outlay are the occurrence of a jetty breach allowing the progressive migration of tidal shoal sediment into the estuary and navigation channel. At some locations along the North Jetty, a jetty breach can result in the rapid release of sediment into the navigation channel. In this case, emergency dredging may be required to mitigate shoaling within the MCR navigation channel. Within the SRB model, dredging associated with incremental impairment of jetty function (head recession and local scour effects) are tracked as O&M dredging volume. Dredging motivated by jetty breach events are tracked separately from O&M dredging volume.

c. Jetty Segmentation

Within the SRB model, a jetty is divided into 100-ft long semi-independent responding segments. Segmentation allows for the jetty to be modeled as a system of interacting components, the response of each being described by a specific performance mode relating to head recession, foundation erosion, slope stability, and wave-induced damage. The SRB model uses these performance modes to simulate jetty response over a specified period of time (a given life-cycle), by evaluating the cumulative structural response of the jetty cross-section in 1-year time steps. Jetty damage is simulated to occur in winter (damage being motivated by storm wave action) and, if needed, jetty repairs are simulated to occur the following summer (when construction activities are normally executed). If a jetty fails during winter, before normally programmed repairs can be activated the following summer, the jetty response is described as "breached." A breached jetty may require implementation of an emergency or expedited repair action, depending upon the impending severity of the breaching consequences. Expedited repairs are more costly to execute (cost per ton of placed jetty stone) than normal repairs, and emergency repairs are more costly than expedited repairs.

For this study, application of the SRB life-cycle model is initiated by first simulating the structure's previous life cycle history (hindcast). Correct simulation of the jetty's previous life-cycle produces a calibrated model that can be used to evaluate structure performance in the project environment. The calibrated SRB model is then used to project the existing jetty condition into the future. Future life-cycle simulations were performed for variable maintenance strategies and a range of graduated rehabilitation alternatives.

d. Lateral Subdivision of Jetty Cross Sections

Recall that within the SRB model, the entire jetty is segmented into 100-ft long semi-independent responding segments. The initial condition for each segment is described by specific cross-section geometry and armor-core stone attributes, which can vary along segments and on each side of the jetty (oceanside vs. channel side). The centerline of the present jetty crest serves as the boundary to split the segment cross-section into channel vs. ocean side. Refer to Figure A2- 18 for jetty cross-section element definition. Segment attributes include toe elevation, crest elevation, crest width, jetty side slope, armor stone characteristics (size-tons, stability number, density), and core stone presence. All segment attributes are described in terms of a mean value and standard deviation to enable segment-based reliability calculations.

e. Vertical Subdivision of Jetty Cross Sections

Each segment is divided into two vertical areas (upper section and lower section) based on an elevation of -5 ft MLLW. Above this elevation (WAV_EL) wave damage generally controls jetty cross-section evolution; below WAV_EL the cross-section evolution is generally controlled by scour or static slope instability issues. If the jetty toe elevation is higher than -7 ft MLLW, then the demarcation between upper and lower sections is set at jetty toe elevation, plus 2 ft. This allows for the vertical subdivision of a jetty cross-section in shallow water regions, where the jetty toe may be higher than -5 ft MLLW. The 2-ft offset is the minimum vertical distance required to represent geometric changes in the lower section of a jetty (within the SRB model) as motivated by slope/foundation adjustment processes associated with jetty toe scour.

f. Cross-Section Damage Process – Lower Section

The lower cross-section of each jetty segment can be affected by foundation (toe) scour which motivates slope stability issues (static failure modes). The initial condition for the lower slope along the jetty is assumed to be constructed to a statically stable configuration (slope is equal to or flatter than 1.5H:1V). The degree of damage sustained by the lower cross-section each year of the simulation is based on how much jetty toe can be lowered due to scour, before the lower slope is steepened beyond a limiting value (slope steeper than 1.3H:1V). The limiting value (of 1.3H:1V) for the lower slope was based on results from a slope stability analysis reported in Appendix B, *Geotechnical Studies*. If the limiting slope value is exceeded, the lower slope "fails" at the new toe elevation (hinge point) and the steepened slope rotates into the jetty cross-section until a stable slope is attained (1.4H:1V). This process emulates a creeping failure of the lower section slope where the jetty toe incrementally follows the vertical progression of foundation scour. This creeping slope adjustment, due to jetty toe scour, is what has been observed to occur along jetties subjected to foundation scour. Adjustment of the lower cross-section can affect the upper slope if geometry conditions allow (Figure A2- 18). The displaced jetty section (stone) falls downslope leaving non inter-locked and unstable stone behind. The displaced stone provides little function to the jetty. The area of damage associated with the toe elevation and slope re-adjustment is calculated based on geometry change for the upper and lower cross-section. The damage areas are then subtracted from the area remaining within the segment (upper and lower sections).

g. Cross-Section Damage Process – Upper Section

Reliable simulation of jetty performance requires accurate and consistent accounting of cross-section damage. Considerable effort was invested in SRB model development to ensure continuity in cross-section area change, with respect to changes in jetty crest width and crest elevation. Accurate tracking of damages sustain by the jetty cross-section and related changes in structure configuration are crucial for several reasons:

- Jetty crest width reduction indicates the degree to which the armor layer is disturbed and indicates the extent to which core material is exposed to wave action. Reducing the crest width on a given side of the structure lowers the threshold for wave damage and decreases the reliability of the jetty segment by lowering the stability number (Kd) for the disturbed armor stone remaining on the cross-section. If sufficient armor stone is displaced off the jetty cross-section such that core stone is subjected to direct wave action, then the effective size (W) of the "armor" stone is decreased in proportion to the relative amount of true armor stone remaining on the jetty slope.
- Jetty crest elevation reduction decreases the jetty freeboard, increases the potential for wave damage on the lee of the jetty due to wave overtopping, and decreases the reliability of the jetty segment.
- As the area of the jetty cross-section is reduced, the resilience of the jetty segment decreases, affecting the jetty reliability and increasing the likelihood for segment function failure (breaching).

The upper cross-section of each jetty segment is affected by wave-related loading (dynamic failure modes) when wave action exceeds the capacity of the jetty armor units (or exposed interior material) to resist being displaced off the upper cross section. The upper section can also be affected by static stability modes migrating upward from the lower cross-section.

Wave damage can be caused by waves impinging on the area of the jetty facing the waves or by waves overtopping the jetty and attacking the crest or lee side of the jetty. Wave overtopping can be considerable when the jetty freeboard is reduced by either high water levels or by a low crest elevation (low by design or through accumulated damage). Many areas of the North and South Jetties are subjected to heavy wave action on both sides of each jetty. This means that the jetty can be directly attacked and overtopped from both sides of the jetty (Figure A2- 26). If armor units or core stone are displaced by wave action, they can be toppled off of the cross section or redistributed in a chaotic and unstable manner. In either case, the damaged jetty section is considered to have experienced reduction of cross-section area and loss of stability.

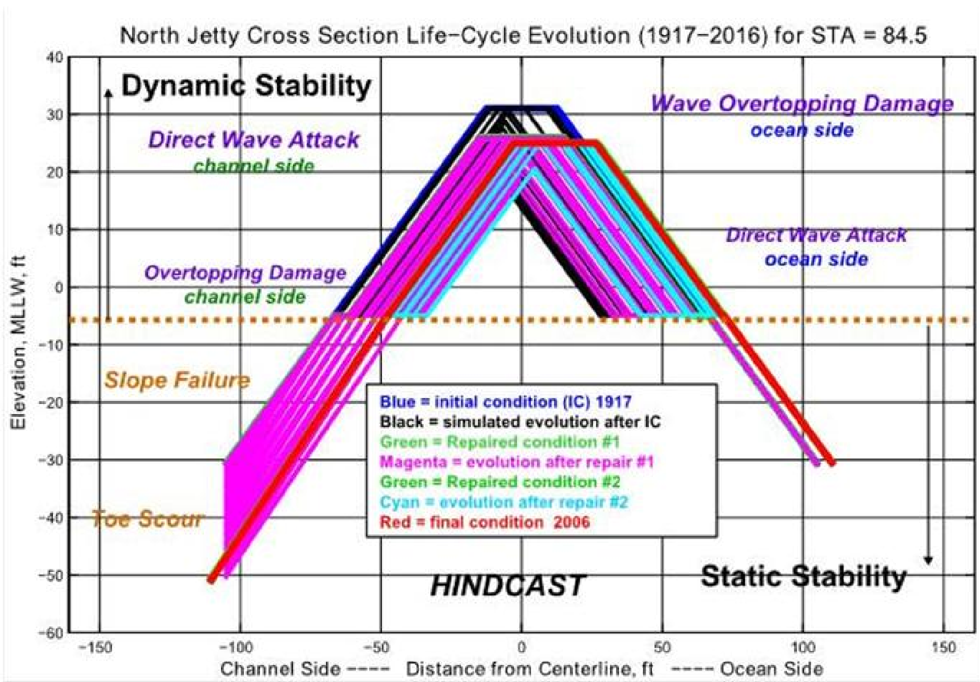


Figure A2- 26. Evolution of Jetty Cross-Section within SRB Model

Evolution of jetty cross-section at station 84+50 based on one realization for hindcast simulation for the MCR North Jetty. The cross-section at this location of the jetty was repaired 2 times during 1917-2006.

Within the SRB model, damage sustained by each jetty segment is accumulated through time. The jetty cross-section is repaired to the full standard template area after the jetty cross-section has been reduced below a prescribed maintenance threshold. If a given jetty segment sustains a very high rate of damage, the segment can fail (breach) before normally planned repairs can be executed. A sizable percentage of the displaced stone armor units and core stone can be "re-used" within the jetty repair template. Figure A2- 15 shows the change in cross-section area for one segment along the North Jetty (at sta. 84+50), during 1917-2006 and is based on one realization for a hindcast simulation. The jetty cross-section degrades and is rebuilt based on the resiliency of the jetty cross-section and its exposure to the forcing environment. The results shown in Figure A2- 15 are performed for each 100-ft segment along the entire jetty.

h. Jetty Damage Functions – Wave Action

Extensive physical model testing was conducted by USACE-ERDC to develop damage functions for the MCR jetties [Ward et al., 2007]. Refer to Appendix A1 for a detailed description of the ERDC physical model setup, testing procedure, jetty cross-section plan development, and testing results. Jetty cross-section configurations evaluated included the existing damaged jetty, restored standard jetty template (interim repair), and 2-8 rehab plans per jetty. Model tests were performed for both stone armor and concrete armor units. The "pool" of best candidate rehab cross-section configurations was narrowed to three plans for the North Jetty, four plans for the South Jetty, and one plan for Jetty A.

The damage functions express wave damage (reduction in cross-section area) vs. incident wave height at the jetty. Figure A2- 27 through Figure A2- 31 describe wave damage functions developed for specific jetty cross-section configurations, for both the North and South Jetties. North Jetty damage functions were used to simulate Jetty A cross-section response. The wave height ordinate values expressed in the damage functions are equivalent to the significant wave height averaged during the peak 2 hours of prototype storm duration. Peak wave height for Pacific Northwest maritime storms, affecting coastal zone, varies from 1 to 4 hours in duration. Physical model tests were conducted incrementally for progressively increasing wave height. A given wave condition was run for 2-hour prototype duration with subsequent incremental cross-section damage being measured.

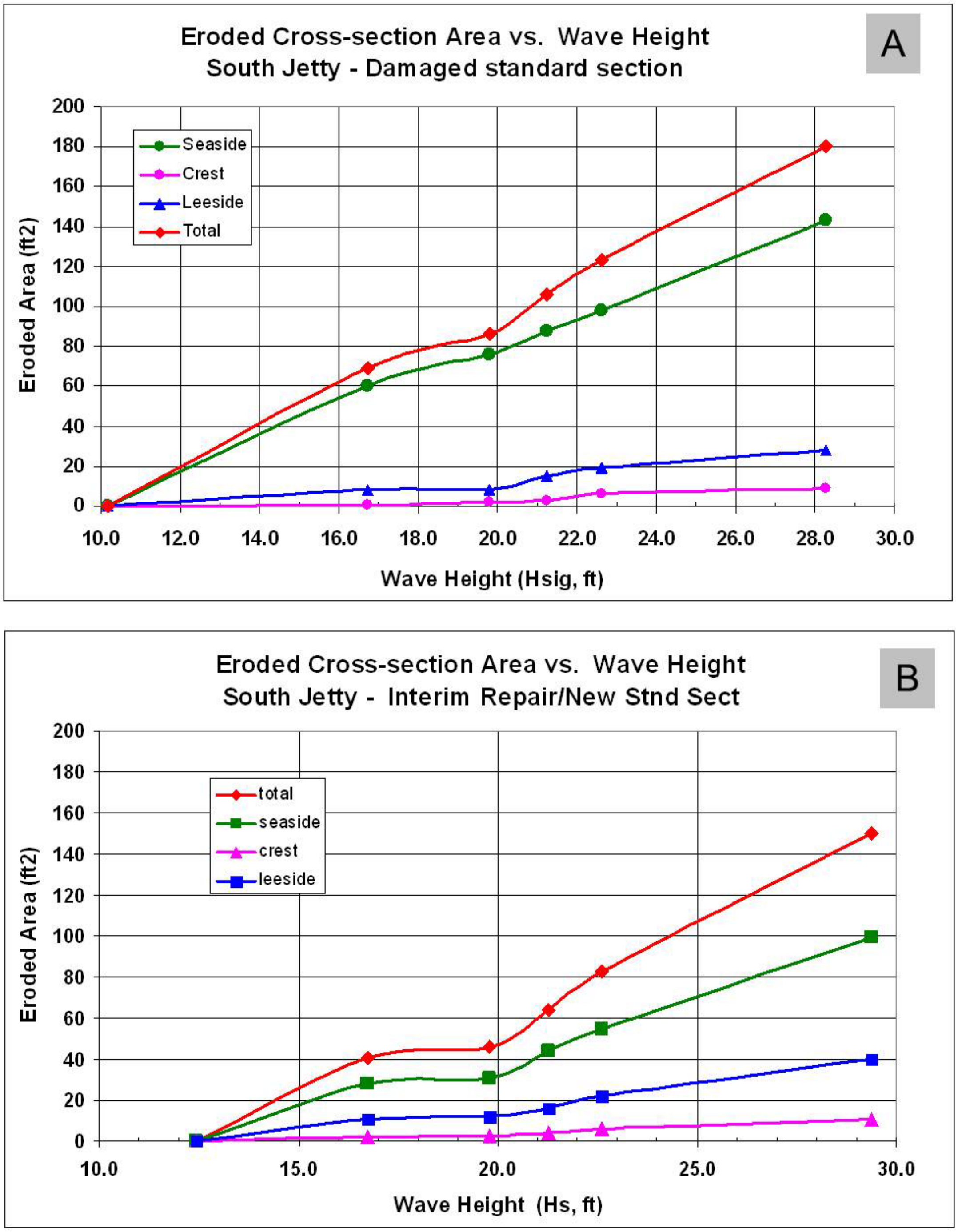
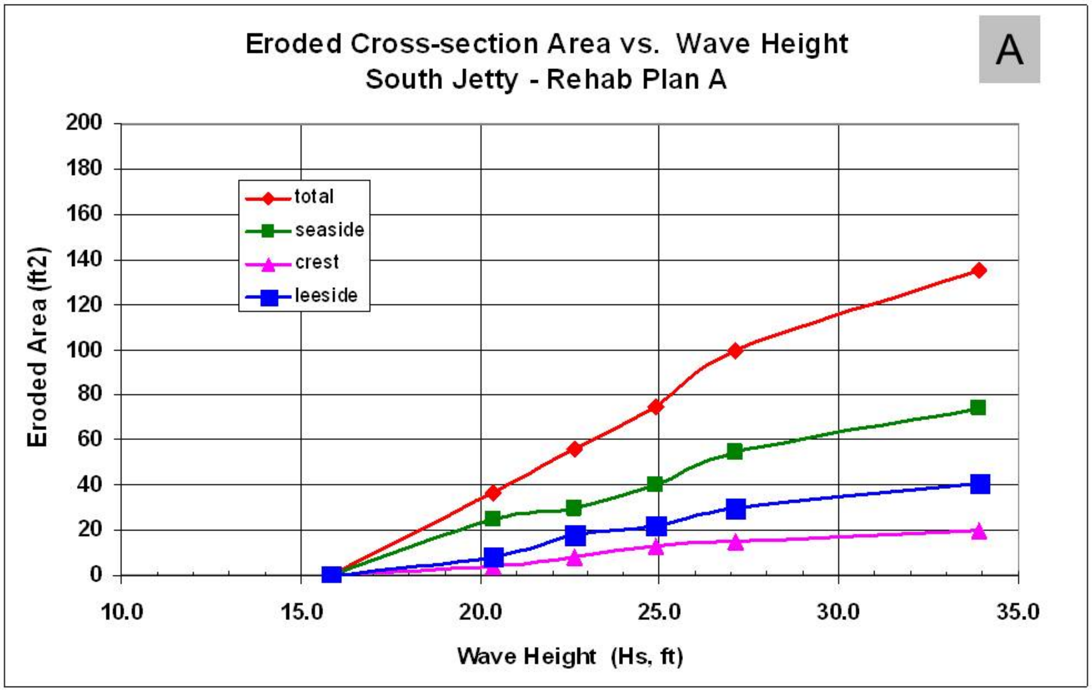


Figure A2- 27. Damage Functions for MCR South Jetty Damaged and Standard Template

Damage functions for MCR south jetty. A) Applies to jetty segments where a standard cross-section has been used and has become damaged. B) Applies to jetty segments based on a standard template that has not been damaged. Damage functions developed at ERDC physical model study [Melby and Ward 2006]. Above damage functions apply to historical jetty cross-sections.



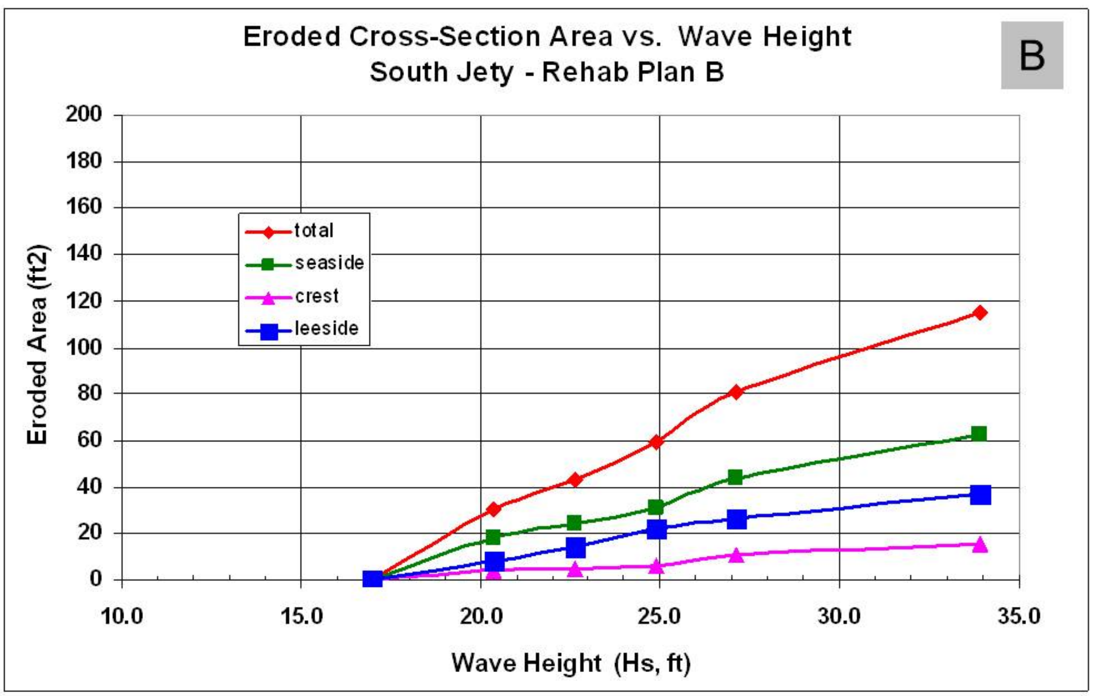


Figure A2- 28. Damage Functions for South Jetty Rehab Plans A and B

Damage functions for MCR South Jetty. A) Applies to South Jetty rehab Plan A. B) Applies to South Jetty rehab Plan B. See Appendix A1 for a description rehab plan cross-sections and design attributes. Damage functions developed at ERDC physical model study [Melby and Ward 2006]. Above damage functions apply to inshore jetty locations (Sta 230).

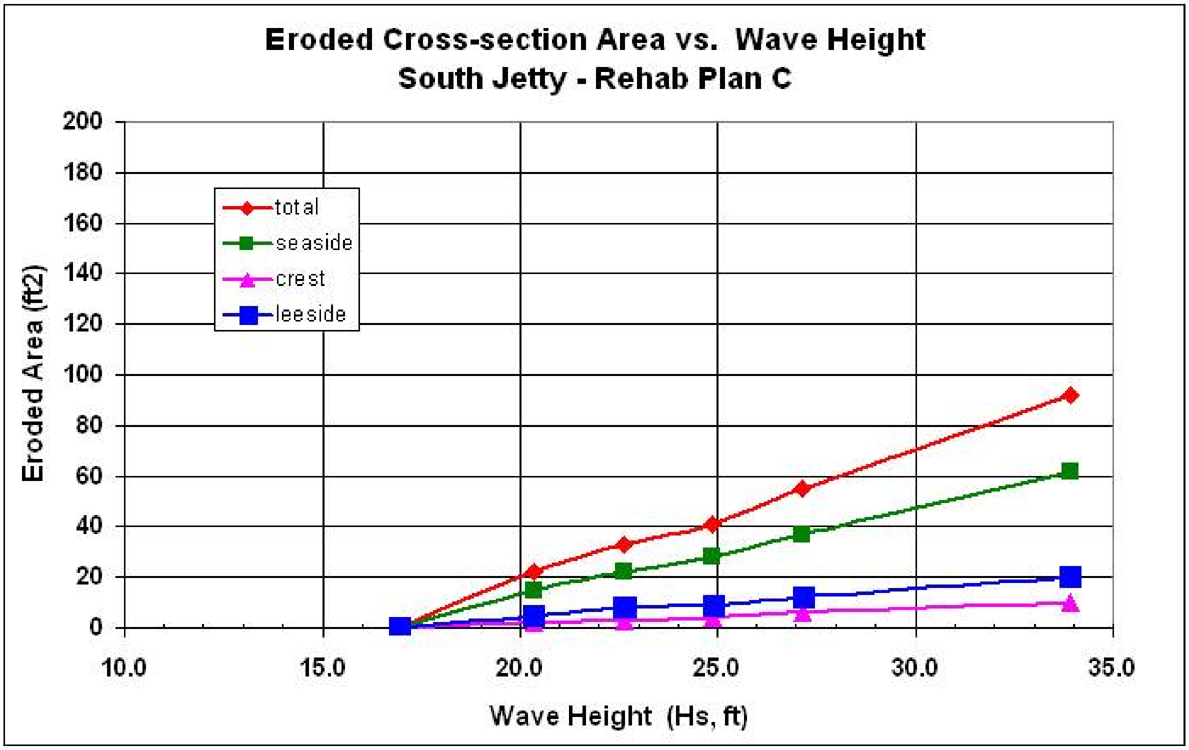
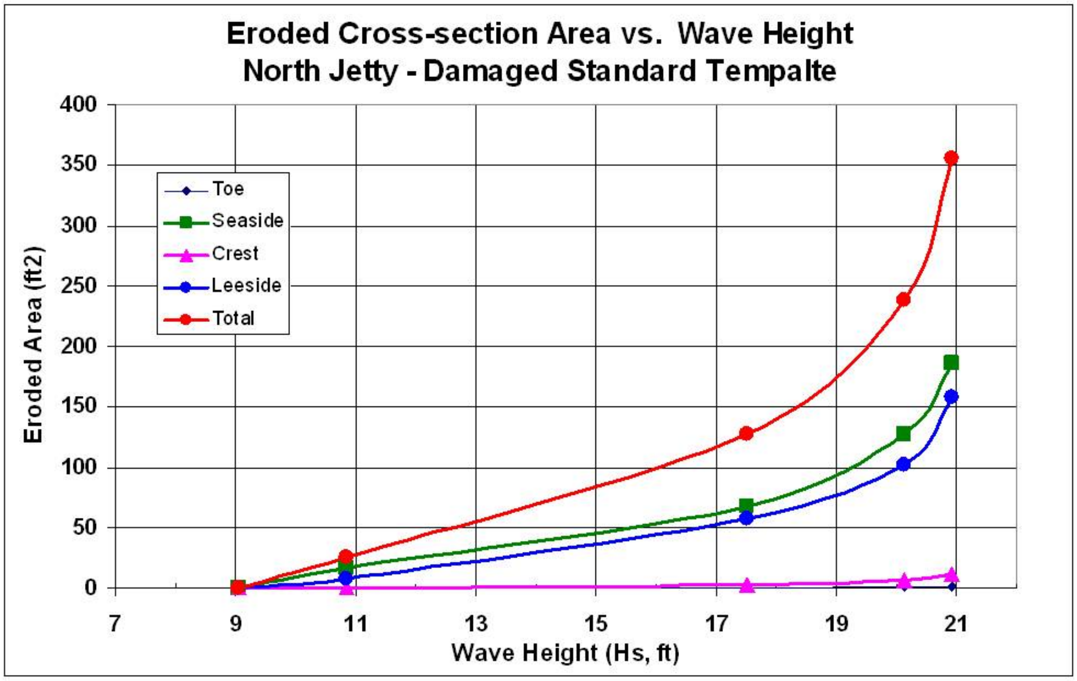


Figure A2- 29. Damage Functions for South Jetty Rehab Plan C

Damage function for MCR South Jetty rehab Plan C. See Appendix A1 for a description rehab plan cross-sections and design attributes. Damage functions developed at ERDC physical model study [Melby and Ward 2006]. Above damage functions apply to inshore jetty locations (Sta 230).



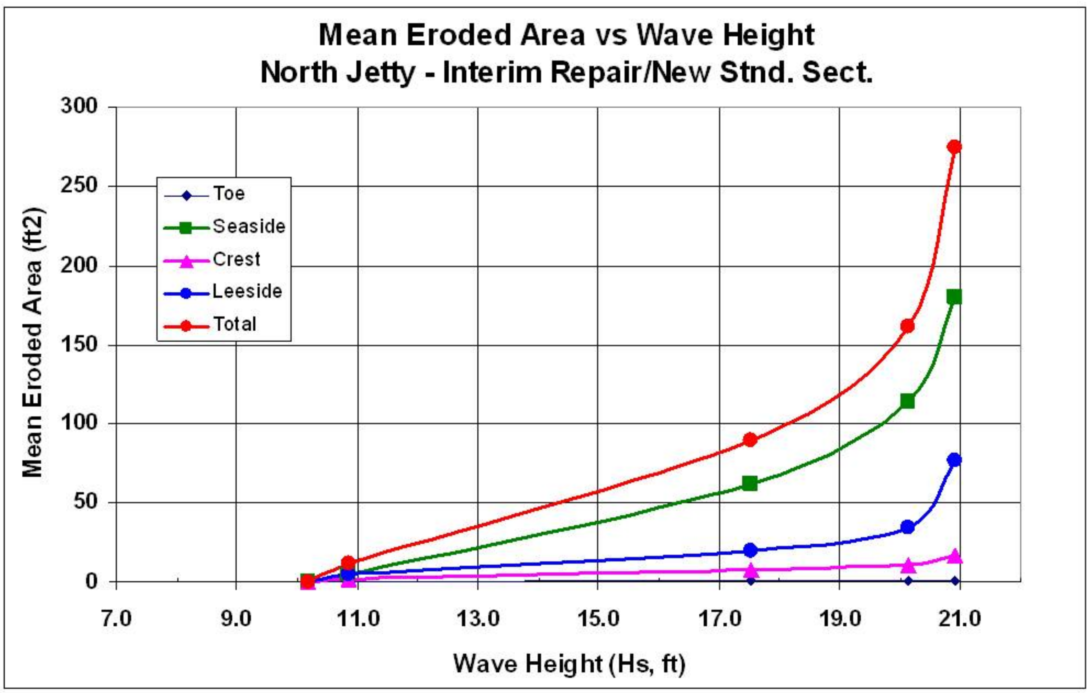
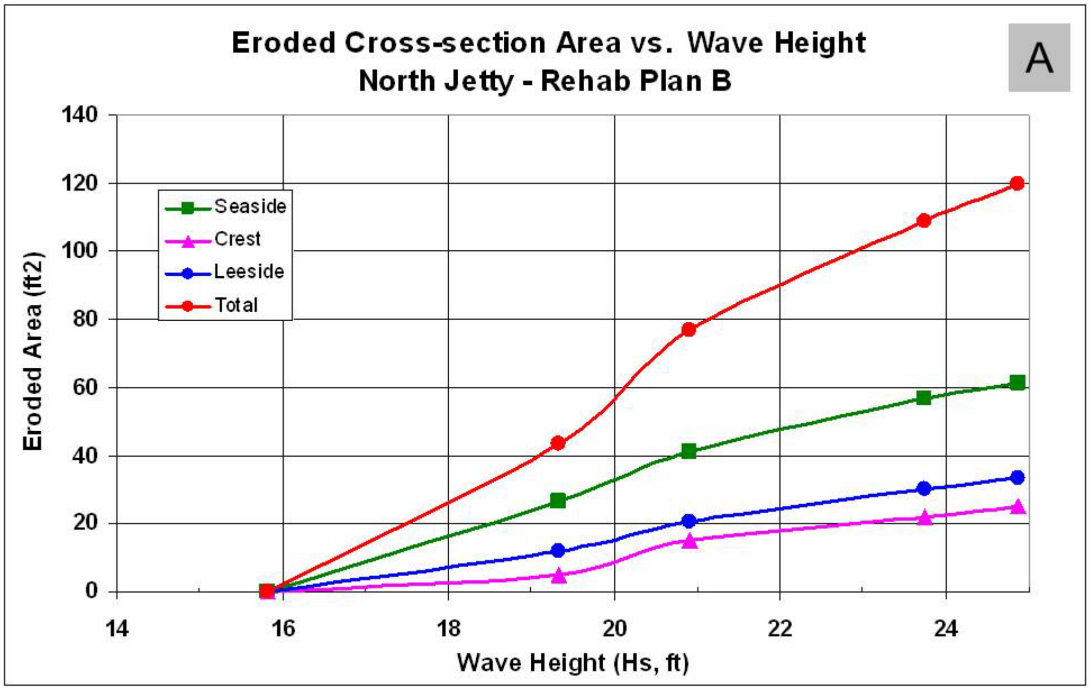


Figure A2- 30. Damage Functions for North Jetty and Jetty A Damaged and Standard Template

Damage functions for MCR North Jetty and Jetty A. A) Applies to jetty segments where a standard cross-section has been used and has become damaged. B) Applies to jetty segments based on a standard template that has not been damaged. Damage functions developed at ERDC physical model study [Melby and Ward 2006]. Above damage functions apply to historical jetty cross-sections.



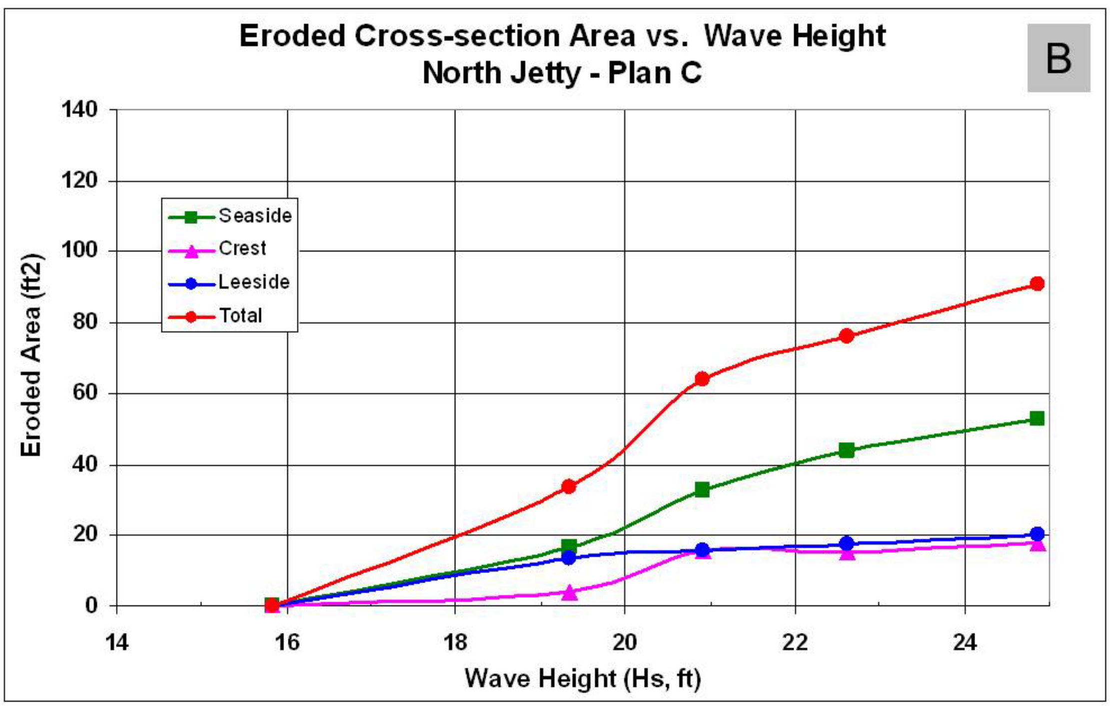


Figure A2- 31. Damage Functions for North Jetty Rehab Plans B and C

Damage functions for MCR North Jetty. A) Applies to North Jetty rehab Plan B. B) Applies to North Jetty rehab Plan C. Plan A was not used for this analysis. See Appendix A1 for a description rehab plan cross-sections and design attributes. Damage functions developed at ERDC physical model study [Melby and Ward 2006]. Above damage functions apply to inshore jetty locations (Sta 230).

Specific jetty cross-section configurations were used to emulate existing damaged jetty sections, repaired "standard repair template" sections, and rehabilitation alternatives. The threshold value for the onset of wave damage, as described by specific damage function, was adjusted depending upon the level of progressive deterioration for the jetty cross-section of interest. The wave damage threshold was also adjusted to account for the robustness of various jetty maintenance scenarios.

The threshold values for jetty head cross-sections were adjusted to account for increased or decreased resilience for a given jetty head configuration. Figure A2- 24 shows how the maintenance threshold for enacting repairs can vary based on the type of maintenance strategy assigned to a given jetty. The scheduled repair strategy is more proactive than the base condition by allowing jetty repairs to occur earlier in the degradation phase to reduce the chance of segment failure (before repairs can be initiated). Scheduled repairs also employ a more resilience (better built cross-section) than the base condition, so the degradation rate for scheduled repairs is usually less than for the base condition. Threshold adjustment (for value of wave height initiating jetty damage) was implemented based on stability equations indicating when: A) a given armor unit size (W_{50}); B) stability number (Kd or equivalent); and C) cross-section configuration would be damaged by wave action. The process of life-cycle hind-casting provided the opportunity to calibrate the SRB model for each jetty. The calibration process focuses on resolving the threshold values for applicable wave damage functions. The calibrated models (for each jetty) were then used to conduct life-cycle forecasting.

i. Wave Action, Cross-Section Area Change, and Repair Tonnage

For each year within a life-cycle simulation, there can be 1 to 11 storms that can affect the individual segments along a given MCR jetty. If the incident wave height for a given storm event exceeds a specified damage threshold value, the jetty segment cross-section is damaged according to applicable damage functions. Wave damage is expressed in terms of cross-section loss. Each side of the jetty is evaluated for a given storm, and wave damage is rendered onto each side of a segment's upper cross-section based on whether the waves are incident to or overtopping the jetty. Annual wave damage imparted onto a given jetty segment results in variable cross-section reduction, per year. The cumulative effect of wave damage reduces the upper cross-section of the jetty over time (for each segment). When the area of the upper cross-section is reduced to a specified maintenance level, the upper cross-section is repaired to restore the cross-section to a specific design template area. The amount of armor stone (repair tonnage) needed to restore the damaged jetty segment is based on the difference between the design template area and the cross-section just prior to repairs. Repair tonnage for a given jetty segment is calculated assuming that the void ratio for placed armor is 0.7:

Repair Tonnage per 100-ft Jetty Segment (for the upper cross-section) =
= 0.7 x gamma x 100 x (Initial Template Area – Area Immediately Prior to Repair) / 2000

As an example, based on a typical North Jetty segment repair, the repair tonnage would be
= 0.7 x 167 lb/ft^3 x 100 ft/segment x (2250 ft^2/segment – 800 ft^2/segment) / 2000 lb/ton
= 8,475 tons

The damage trends and repair scenarios emulated in the SRB model are intended to follow closely with prototype conditions. As the upper cross-section becomes significantly damaged (>1/2 of the crest width is missing on a given side of the jetty), the wave height threshold for initiating damage is reduced and rate of damage sustained by the "damaged" section increases. At this point, the armor layer has been highly disturbed (Kd has decreased) with much of the armor layer being displaced off of the upper cross-section. If sufficient armor stone has been displaced off the jetty cross-section such that core stone is subjected to direct wave action, then the effective size of the "armor" stone is decreased in proportion to the relative amount of true armor stone remaining on the jetty slope.

Recall that a jetty's structural performance is characterized by the capacity of the cross section to resist imposed environmental loading. If the loading exceeds capacity, then the segment incurs damage at specific areas of the cross-section, as governed by applicable failure modes (described by damage functions for upper and lower cross-sections). The functional performance of a jetty is defined by its ability to perform the intended function, within context of sustained structural damage. A given cross-section may be able sustain significant degradation (exhibit poor structural response) yet still provide adequate functional performance, providing that the cross-section has resiliency. At the limit at which the cross-section becomes too small to prevent wave action from breaking through the jetty, the jetty becomes breached, it fails and jetty function is lost at the segment. Segments are considered to be semi-independent because each segment incurs damage independently, yet as one segment fails (looses function), the failed segment can cause neighboring segments to also fail if the neighboring segments have incurred upper section damage beyond a specified threshold (40% of initial section area).

j. SRB Model Simulation of Jetty Repairs – Maintenance Threshold

As is the case of the prototype condition, an active jetty segment located within the body of the jetty is normally repaired before a breach is allowed to occur. Breaching of a jetty segment may occur when the upper cross section area is reduced to a range of 15%-20% of the standard template area (Table A2- 16). At this point, only a fraction of the jetty will be functioning to resist wave action and surface currents. The highly damaged jetty cross-section would be composed of smaller core stone having crest elevation less than 5 ft MLLW. All armor stone is likely to be displaced off the upper cross-section (from jetty crest to -5 ft MLLW). If there is armor stone remaining on the upper section, it will be disjointed and posses little stability. The threshold range for jetty cross-section breaching is based on field experience at other jetty entrances to coastal inlets (Coos Bay, Tillamook Bay, and MCR). The longer the segment remains un-repaired once its cross-section area falls below 20%, the higher the likelihood that the segment will breach. If the cross-section area is reduced to less than 15% of the standard template, the jetty segment is forced to breach within the SRB model.

Table A2- 16. Standard Cross-section Template used to Assess When Jetty Repair or Breaching Occurs for MCR Jetties (recent past and future conditions)

Jetty	Template Area* ft², above WAV_EL = -5 ft	WAV_EL, ft MLLW	Crest Elevation, ft MLLW	Crest Width, ft	Side slope (rise,v : run,h) Channel / Ocean
North Jetty	2250	max(-5 , TE+2)	25	30	1:1.5 / 1:1.5
South Jetty	2475	max(-5 , TE+2)	25	30	1:2 / 1:1.5
Jetty A	1687	max(-5 , TE+2)	20	30	1:1.5 / 1:1.5

**= Template area shown is based on WAV_EL at -5 ft MLLW*
TE = Jetty Toe Elevation

The objective of a responsive maintenance strategy is to monitor structure degradation. When the jetty cross-section degrades to a prescribed threshold, planning for repair is initiated. Funding is procured and jetty repairs are implemented before the jetty is breached. This process requires a certain amount of lead time, which is affected by the prescribed maintenance strategy.

When a jetty segment becomes damaged to the point of requiring repair, the amount of stone needed to repair the jetty segment (replace the rock missing from the cross-section) is reduced to account for partial re-use of the displaced remnant relic stone. The amount of relic stone re-use within a damaged segment can vary from 25%-50% of the displaced cross-section, depending on the water depth at the jetty toe, exposure to extreme wave action, number of previous repairs, and degree of repair deferral. Appropriate values for relic stone re-use within the SRB model are defined through model calibration (hindcasting).

k. Maintenance Strategy and Threshold for Implementing Jetty Repairs

Various jetty repair strategies (options) have been implemented within the SRB model to activate repair of damaged segments within the jetty before they fail and reduce the risk of a jetty breach. The repair scenarios are based on various damage threshold and timing considerations. Maintenance strategies, in order of lowest to highest intervention, include fix-as-fails, interim repairs, and programmed repairs. The ability to evaluate various jetty maintenance strategies allows one to rationally adopt a prescribed approach for managing life-cycle risk for vulnerable infrastructure. Recall that within the SRB model, each segment is repaired as the upper cross-section area becomes less than the imposed maintenance threshold. Depending upon the selected maintenance strategy, repair threshold can range between 15%-72% of upper cross-section area (based on the standard jetty cross section template). The actual threshold used to trigger repairs within a specified maintenance strategy is affected by a degree of random variation. Table A2- 17 summarizes jetty repair threshold values for various maintenance strategies; repair thresholds are cast in terms of the breaching threshold (BT). Threshold values are expressed as a fraction of the standard template (upper jetty cross section); 0.05 = 5% of the standard template. Table A2- 16 lists standard template cross-section for each MCR jetty. Scheduled (or programmed) jetty maintenance initiates repairs 4 years after the upper cross-section area is reduced to a value less than the UPPER threshold. If the jetty is breached (upper section falls below 15%-20% of standard template area), expedited/expressed repairs undertaken to repair the breached segment can be two times more costly than if repairs were conducted under normal conditions.

Table A2- 17. Thresholds used to Activate Jetty Repair or Breach Events for Various Jetty Maintenance Scenarios. Part-A lists thresholds in terms of random variable and BT.

Scenarios are listed in order of potential for breach occurrence; fix-as-fails has a higher likelihood for breaching than scheduled. Percentage (%) is the fraction of standard jetty template area remaining within the upper cross-section. Table A2- 16 lists the standard template area for each jetty.

Jetty Maintenance Scenario- A	Jetty Segment REPAIR			Jetty Segment Hardship	
	UPPER Threshold to Enact Repair	Repair Planning Period	LOWER Threshold to Enact Repair	EXPEDITED Repair Threshold	BREACH THRESHOLD (BT)
Fix-as-Fails	BT + 10%	N/A	BT + 5%	BT + 5%	15% + rand(5%)
Scheduled -V	Variable*	4 yrs	N/A	BT+ 5%	15% + rand(5%)
Historical Repairs	40% – BT +rand(BT)	N/A	BT + 5%	BT+ 5%	15% + rand(5%)
Scheduled - F	67% ± rand(5%)	4 yrs	N/A	BT+ 5%	15% + rand(5%)

Jetty Maintenance Scenario - B	Jetty Segment REPAIR			Jetty Segment Hardship	
	UPPER Threshold to Enact Repair	Repair Planning Period	LOWER Threshold to Enact Repair	EXPEDITED Repair Threshold	BREACH THRESHOLD (BT)
Just-in-Time	25 - 30%	N/A	20 - 25%	20 - 25%	15 - 20%
Scheduled –V	Variable (25 – 65%)	4 yrs	N/A	20 - 25%	15 - 20%
Historical Repairs	25 - 40%	N/A	20 – 25%	20 - 25%	15 - 20%
Scheduled – F	62 - 72%	4 yrs	N/A	20 - 25%	15 - 20%

Scheduled-F = programmed repairs using a **Fixed** UPPER threshold value for initiating the repair planning period.
Scheduled-V = programmed repairs using a **Variable** UPPER threshold value for initiating the repair planning period.
Variable value for UPPER threshold is independently set for each segment (for a given design cross section) by running the SRB model in fix-as-fails to calculate the 85^{th} percentile value of repair or breach initiation.

If the frequency of repairs for a given jetty segment becomes too high (repairs are made within 15 years of previous repair event), the jetty segment is repaired using a repair template having more robust characteristics. In this case, the enhanced template includes larger armor stone which is placed more carefully to achieve improved stability (W50 and Kd are increased by 50%), and the repair unit cost ($/ton) increases by 30% for the affected jetty segment.

1. Fix-as-Fails Jetty Maintenance

To defer jetty maintenance for a long as possible, the jetty is maintained close to the margin of functional loss. The fix-as-fails option attempts to minimize maintenance costs by deferring them into the future for as long as possible. When the jetty repairs are implemented under a fix-as-fails condition, they are not as resilient (reliable) as other, more proactive maintenance scenarios due to a shortened time period to plan and execute the construction. The design armor stone size is smaller and placement standards are less stringent than higher-order maintenance or rehab plans. The threshold for fix-as-fails maintenance was set at a level approximately 10% below the upper threshold for interim repair maintenance strategy. Under a fix-as-fails maintenance strategy, repairs for a given segment can be initiated when the upper cross-section area falls below 30% of the standard template. If repairs are initiated for a cross-section that has been reduced to less than 25%, then the repairs are considered to be expedited to prevent an imminent jetty breach. Expedited repairs carry an elevated cost. Keep in mind that a jetty segment can be breached if the cross-section falls below 15%-20% of the standard template area. The fix-as-fails maintenance option carries an elevated risk for incurring added costs, for having to expedite repairs (to prevent functional loss of a jetty), or responding to a breached jetty. Consequently, there is an elevated likelihood that jetty repairs may be more expensive (cost/ton of repair stone placed) when they do occur, and that the jetty may lose function before repairs are initiated. The present- and future-base condition maintenance strategy for the MCR South Jetty and Jetty A conforms most closely with the fix-as-fails strategy.

2. Interim (Historical and Base Case) Repair Jetty Maintenance

Historical maintenance efforts for MCR jetties are best described by an interim repair strategy. In this scenario, a given jetty is maintained at what is deemed to be a reasonable, yet variable level of degradation to defer jetty maintenance and reduce the risk of realizing jetty function loss. Repair activation under interim repair strategy is based on a monitoring program, resulting in a jetty that is maintained at a higher level than the fix-as-fails strategy. In this case, jetty degradation is sporadically monitored such that repairs may be implemented whenever the jetty cross-section area falls in the range of 20%-40% of the standard template area. The interim repair strategy allows for a wide margin of uncertainty for undertaking repairs. As is the case of fix-as-fails, thresholds (and costs) for implementing expedited repairs or incurring a jetty breach also apply to the interim repair strategy. Because there were periods when the jetties were not well maintained during the previous life-cycle, the interim repair strategy was used to perform hindcast simulations for the MCR jetties. If interim repairs are consistently deferred such that repairs are implemented just in time to prevent a jetty breach, then the repair strategy could be considered as a fix-as-fails condition. Implementation of an interim repair strategy activates jetty repairs, which are more resilient (reliable) than the fix-as-fails option; interim repairs use larger stone and the stone is placed to improve stability. Interim repair cost ($/ton) can be slightly higher than fix-as-fails. The present- and future-base condition maintenance strategy for the MCR North Jetty conforms most closely with the interim repair strategy.

3. Scheduled Repair Jetty Maintenance

The jetty is maintained at a prescribe level of degradation, to manage the risk of jetty breaching and other functional impacts. The scheduled repair strategy emulates an enforced protocol of structure monitoring, repair forecasting, and funds programming to ensure that a structure is maintained to a prescribed condition. The scheduled repair strategy implements structure repairs before the rate degradation accelerates past an acceptable level. Repairs for a given jetty segment are implemented 4 years after the segment has been damaged beyond a specific threshold. The 4-year period emulates a typical method for programming funds needed for navigation structure maintenance. Implementation of a scheduled repair strategy activates jetty repairs which are more resilient (reliable) than either the interim repair or fix-as-fails options; scheduled repairs use larger stone and the stone is placed to improve stability. Scheduled repair cost ($/ton) is higher than interim repairs. There are two options for the scheduled repair scenario:

1. A fixed(F) option prescribes a constant threshold for each segment; each segment is maintained with respect to a constant cross-section threshold. The constant value threshold is set at a fairly low level of degradation, so it is highly likely that repairs will be enacted before the jetty becomes threatened by a breach. Under a fixed scheduled repair option, the jetty is maintained to a consistently higher standard than the interim repair condition, to emulate a risk-adverse posture with respect to jetty breaching.

2. A variable(V) option applies a unique maintenance threshold for each jetty segment; one which is less conservative than the fixed option. To set the segment-specific maintenance threshold, the SRB model is first run in fix-as-fails mode (for a given structure design) to define the 85^{th} percentile value of repair or breach initiation. These values are saved to a database to be used when invoking the schedule repair-variable option. Under a variable scheduled repair option, maintenance of the jetty is optimized to prevent degradation beyond a point which incurs excessive risk of jetty breach yet minimizes the likelihood of over-maintaining the jetty. This is the option adopted to emulate the scheduled repair option in the MCR rehabilitation evaluation report.

I. Challenges for Long-Term Jetty Maintenance

The life-cycle outcome for infrastructure is a function of balancing the resilience of the structure's initial construction with a long-term repair strategy. The paradigm is to manage the trade-off between initial investment vs. maintenance costs. When renewing a structure's life-cycle, the same consideration applies to rehabilitation vs. repairs. Once a specific maintenance strategy is justified and implemented, it must be embraced through the entire life-cycle of the structure. Figure A2- 24 shows how jetty cross-section deterioration rates can vary based on maintenance strategy.

When choosing a specific strategy for maintaining the future life-cycle of a jetty, consideration must be given to the entire time frame under consideration, 50 to 60 years in this case. If a fix-as-fails viewpoint is embraced for jetty maintenance to reduce or eliminate near-term expenditures, then the need for future repairs (as early as 20 years out in time) may escalate to a very high level. Unless future cost outlays are allocated to address the deferred repair costs, the reliability of the jetty will fall below the justified target level.

A scheduled repair maintenance strategy may be enacted to reduce the scope or eliminate the need for jetty rehabilitation. Implementing this type of aggressive long-term maintenance could be more cost effective than expending a large initial re-investment. If the scheduled repair strategy is suspended 10 years into the future life-cycle, then the assumption to proactively maintain the jetty instead of rehabilitating it becomes void. In this case, the initial economic justification to repair rather than rehabilitate is not valid. USACE guidance for life-cycle analysis (ER 1110-2-859) acknowledges the risk of assuming that the requisite funding stream for a given maintenance strategy will remain uninterrupted: "Funding constraints may result in the deferral of critical project repairs, resulting in reduced project reliability." Funding constraints may also result in a lack of funding for construction of other alternatives as well, again resulting in reduced project reliability.

m. Jetty Rehabilitation and Engineering Features

If future maintenance requirements are expected to become unfavorable for a given structure, the option of rehabilitating the structure may offer the opportunity to reduce life-cycle costs and increase reliability. Elements of jetty rehabilitation include jetty cross-section/armor layer enhancement and the addition of engineering features. Engineering features include specific structural elements to stabilize the jetty head, reduce jetty-toe scour, and mitigate jetty root degradation. Several designs for cross-section enhancement have been developed to optimize jetty rehabilitation along each jetty at MCR (see Appendix A1 for design details). The jetty cross-section alternative types that were considered for rehabilitation and implemented as various options within the SRB model are summarized below:

- North Jetty Rehab Cross-Section Alternatives: Minimum, Moderate, and Large
- South Jetty Rehab Cross-Section Alternatives: Minimum, Small, Moderate, and Large
- Jetty A Rehab Cross-Section Alternatives: Low-Profile and Full-Profile

The SRB model includes options to accommodate variations in cross-section configuration for implementing jetty rehabilitation for both a single cross-section (constant along a given jetty) and composite cross-section (spatially variable) alternatives. The SRB model was used to optimize the scheduling of jetty rehabilitation by matching the timing of rehab implementation along various reaches of each jetty to when the jetty is expected to require repair.

Three types of engineering features can be emulated within the SRB model to reduce the effect for a specific process affecting a jetty. Aspects of engineering features are summarized below with design details presented in Appendix A1.

1. A jetty head "cap" consists of a robust 200-ft long bull-nose head geometry featuring very large armor units placed on a wide crest and compound slope cross-section. A jetty head cap has very high reliability and damage threshold. The jetty head engineering feature (head capping) can also be activated within the SRB model in

terms of extending the jetty head beyond the present location, if needed. The benefit for adding a jetty cap is to prevent (or significantly reduce) loss of the jetty head, which reduces shoaling into the MCR inlet. Stabilizing the jetty head can also prevent wave action from increasing along the jetty or within the inlet. Extending the jetty head beyond the present location can further reduce shoaling within the MCR inlet.

2. Jetty spur groins are small, low-profile appendage structures that can reduce the rip-current that locally affects scour along the jetty toe (foundation). Spur groins can be implemented within the SRB model at specific jetty locations and at specific times during the jetty life-cycle.
3. A graded back-fill (lagoon-fill) option can be activated within the SRB model to emulate stabilization of the landside North Jetty root which is presently being de-stabilized by storm wave and tidal surge action propagating through the jetty. If the lagoon fill feature is enabled, then degradation along the North Jetty root due to surge action is eliminated.

Other smaller-scale engineering features are not included within the SRB model. These include measures to protect the backshore along each jetty by augmenting the foredune along the oceanside of the North and South Jetties (North Jetty berm and South Jetty dune augmentation, respectively).

n. Combined Maintenance Strategy for Jetty Rehabilitation

It may be advantageous to employ a given repair strategy at the start of a structure's life-cycle and then change to another type of repair strategy later in the life-cycle. Such could be the case for jetty rehabilitation. Before a given segment is rehabbed, it is assigned an interim repair strategy and, after jetty rehab, the segment is assigned a scheduled repair strategy. In this scenario, the jetty is maintained at a reasonable level of degradation before a planned rehab condition to reduce the likelihood of a jetty breach while rehab construction is being planned or ongoing. After the jetty rehab is completed, the jetty is maintained at a slightly higher level to minimize the risk of functional loss for the newly restored cross-section. The above scenario is employed within the SRB model for evaluating rehabilitation alternatives for the MCR jetties.

o. Standard Upper Cross-Section Template

Recall that each jetty segment is repaired independently of each other. The repaired segment's upper section is restored to the geometry imposed by a "standard" repair template with attendant armor/core stone attributes. A standard repair template (upper area of a cross-section) is specified in terms of standardized parameters for jetty side slope, crest elevation, crest width, and the elevation at which wave damage diminishes (WAV_EL). Life-cycle results based on a segment-by-segment repair scenario can produce highly variable estimates for time-varying cost from one year to the next and one life-cycle realization to the next. Monte Carlo simulation is used to estimate expected values of life-cycle metrics within context of a highly variable outcome. Table A2- 16 summarizes the present repair template values for the three MCR jetties. For hindcast conditions, the standard template for the upper cross-section is based on the design section respective to the time of jetty performance. Refer to Appendix A1 for definition of the design and repair template configurations used for each jetty during the previous life-cycle.

p. Unit Repair Length

A unit repair length (reach) was developed for each jetty based on the previous life-cycle to portray the average reach length for a given repair campaign. Unit repair length is a metric reported by the SRB model and can be used to assess jetty life-cycle performance in terms of jetty maintenance requirements. The unit repair reach for the MCR jetties are specified below in terms of a mean value and standard deviation:

- North Jetty standard repair length = 3,100 ft ± 1,100
- South Jetty standard repair length = 5,000 ft ± 2,400 ft
- Jetty A standard repair length = 1,900 ft ± 1,500 ft

q. Jetty Segment Failure Consequences

The longer a damaged jetty segment goes without repair, the higher the rate of cross-section degradation due to wave action, and the more likely that the jetty segment could breach before repairs are made. In rare instances, a jetty segment may be damaged at such a high rate as to fail (loose function) before timely repair can be implemented. A given jetty segment has the *potential* to lose function when the upper cross-section area has been reduced to less than 20% of the standard upper cross-section. Within the SRB model, a jetty segment is assumed to fail when the upper cross-section is reduced to less than 15% of the standard upper cross-section. If the jetty segment fails, the segment has functional reliability = 0. If a jetty segment adjacent to a breached segment has less than 40% of its cross-section remaining, the adjacent segment can be induced to breach. This process is intended to account for the destabilizing effect that a breached jetty has on adjacent areas of the jetty. Within the SRB model, the maximum length for a given breach event location is 3 segments. Table A2- 17 summarizes threshold values used within the SRB model for enacting jetty repair and for initiating segment failure, expressed as a percentage of a standard upper cross-section template.

1. Jetty Head Recession

The default condition within the SRB model is to allow the jetty to recede landward as degradation affects the jetty head. This means that if a jetty segment fails at the seaward terminus of the jetty, the subareal jetty head will recede landward. The SRB model will simulate jetty head repairs if the appropriate model parameter has been set to rebuild the receding head. In most Pacific Northwest prototype cases, jetty heads are allowed to recede landward without repair due to the difficulty and high cost associated with jetty head repair. Resilient jetty head repair alternatives are generally not considered to be within the “normal” maintenance budget. In some cases, jetty head recession will cause accelerated recession of the shore profile along the jetty root and adjoining shoreline areas exposing the jetty to increased wave action and increasing the requirement for maintenance dredging. This process is replicated in the SRB. Although the option is available within the SRB model to force the jetty head to be maintained at its initial condition, it was not used to assess MCR future jetty life-cycle performance, as it was deemed impracticable for the MCR jetties. In hindcast mode, the frequency of jetty repairs is specified for each segment and, in some cases, the jetty head was repaired multiple times. The SRB model will rebuild the jetty head if historical conditions dictate.

r. Monte Carlo Approach

Employing the Monte Carlo method within the SRB model enhances interpretation of the inter-annual cost stream by stabilizing the variation due to the many random factors employed, and stabilizes expected value estimates for annualized cost. Monte Carlo enhancement to the SRB life-cycle simulations involves running multiple life-cycle iterations and generating statistical estimates of the life-cycle ensemble. The SRB model uses Monte Carlo method to increase the confidence of life-cycle estimates and allow for the evaluation of variance.

6. DEFINITION OF VARIABLES USED IN SRB SIMULATION

a. Environmental Loading

The MCR jetties are subjected to the vigorous loading associated with storm waves, tidal action, and morphological change. Each jetty is uniquely affected by the forcing environment at MCR due to structure orientation, location, and the sequence of project development. As the inlet continues to evolve, the loading affecting each jetty has been, and will continue to be, variable in time and space. The two primary environmental loading factors affecting jetty stability are incident wave action and jetty toe scour. Contributing factors include long-term morphological change and the variation of water level. The following sections describe how environmental loading was implemented within the SRB model to emulate both the actual conditions historically experienced and the expected range in future conditions at the MCR inlet.

Wave action, produced by winter storms, motivates much of the damage sustained by each jetty. Within the SRB life-cycle model, water levels and incident wave heights produced by winter storm events drive the damage functions that are used to evaluate cross-section evolution for each segment along a jetty. Figure A2- 32 shows the distribution of data points along each jetty at the MCR which are used to impose the annual wave loading environment to each jetty segment. Figure A2- 33 (and the following paragraphs) describes how the near shore wave environment is assigned to each of the points shown in Figure A2- 32.

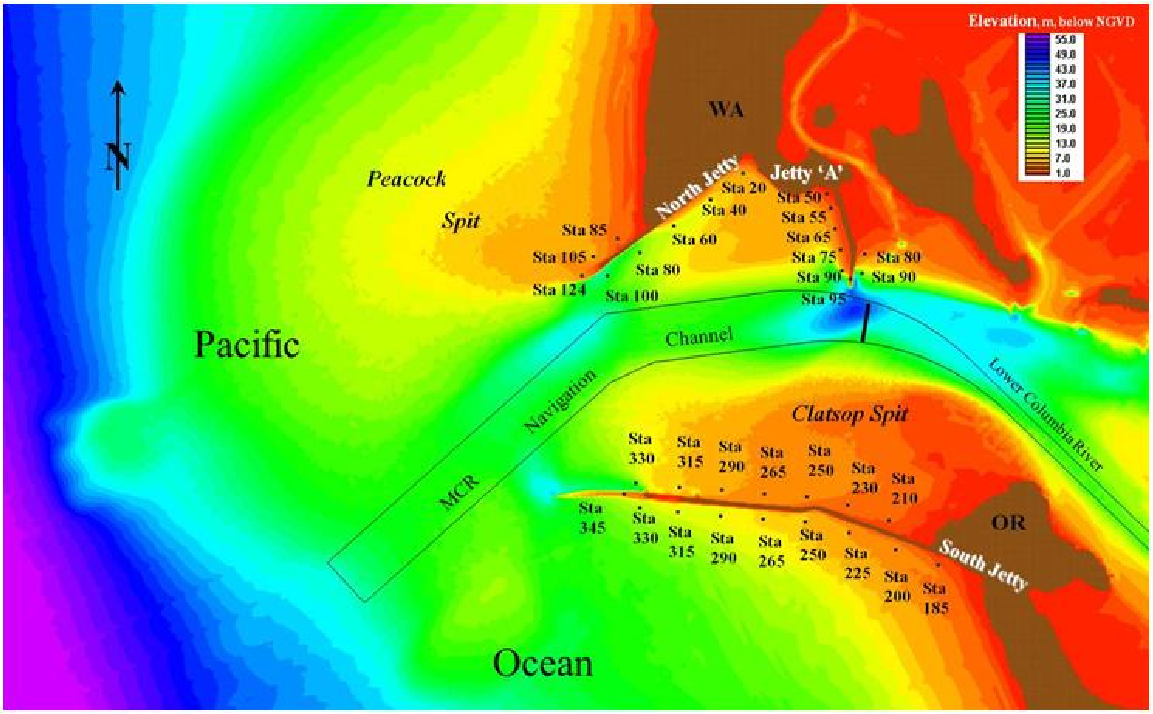


Figure A2- 32. Close-Up View of MCR Bathymetry as Described in STWAVE Model

Area shown is 10 km (north-south) x 15 km (east-west). Distance between North and South Jetties is 3 km. Survey data is a composite from 2003-2007. Note the variability in water depth along each jetty; waves at inshore jetty locations become depth-limited. Refer to Appendix A1 for additional details. Labels along each jetty refer to jetty station location at which STWAVE output was obtained for using in the SRB model.

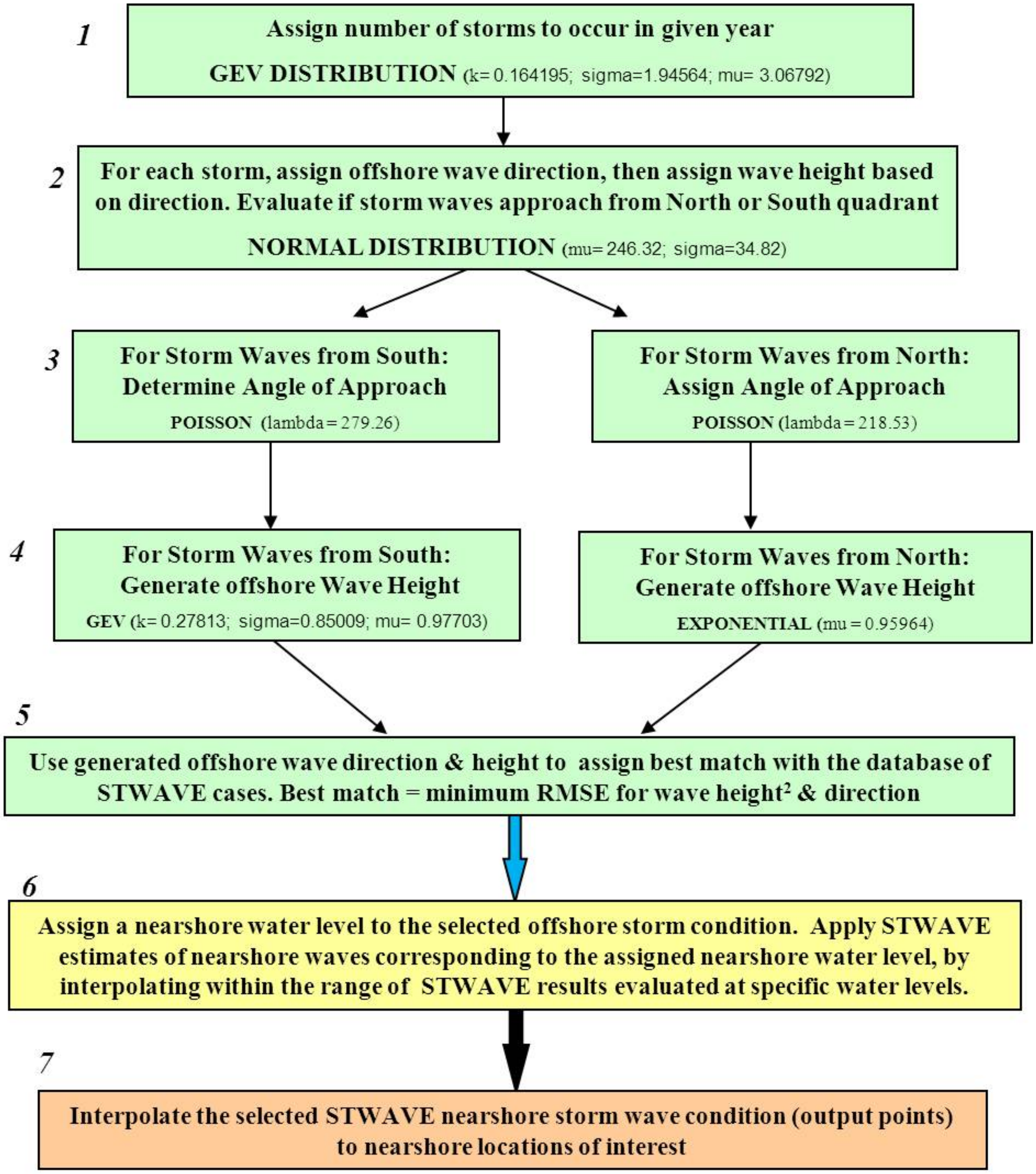


Figure A2- 33. Flowchart for Assigning Nearshore Wave Conditions

Assign Number of Storms per Year (step 1): A peak over threshold analysis (POT, for Hsig >= 7 m) was performed using wave data measured offshore of MCR during 1987-1998. A total of 89 storms were identified. Figure A2- 34 through Figure A2- 37 show results in terms of a histogram and define the median and maximum number of storm events per year is 4 and 11, respectively. A generalized extreme value (GEV) distribution was determined to provide the best approximation for the POT histogram. Within the SRB model, a random number is generated using the GEV distribution to estimate the N-storms that can occur during any given year. Figure A2- 38 shows that although the GEV distribution is bounded at n-storms = 11, less than 3% of the randomly generated events exceed the upper bound.

<u>Generate Candidate Offshore Wave Direction and Height (steps 2-4):</u> From the POT analysis for Hsig >= 7 m, a total of 59 peak wave heights had associated mean wave directions on record. Results are shown in Figure A2- 35 in terms of a histogram for mean offshore wave direction. By closer inspection of the mean wave directions from the 59 storm events, the histogram appears to be bimodal, with data separation between 245º and 255º. Using the separation point of 250º, a random number is generated within the SRB model using a NORMAL distribution to determine if the storm event wave direction is from the north (250º - 320º) or south (180º - 250º). No storm events with Hsig $\geq$ 22 ft have been observed to have approach direction greater than 320º or less than 180º. For storm waves approaching the MCR from the north, the mean wave direction is estimated with a POISSON distribution and the wave height is estimated with an EXPONENTIAL distribution (Figure A2- 36 and Figure A2- 37, Right). For a storm approaching from the south, the mean wave direction is estimated with a POISSON distribution and the wave height is estimated with a GEV distribution (Figure A2- 36 and Figure A2- 37, Left). Step 4 is completed (for each candidate storm event) after an offshore wave height and associated direction has been assigned.

Of the 59 peak wave events having statistics for associated mean wave direction, 52 events were found to have reliable directional spectral data as measured at NDBC buoys 46029 and 46089 during 1998-2008. Each of the 52 offshore wave events was transformed to the near shore region of MCR, for a given storm water level, using the numerical wave model STWAVE [Smith et al., 2001]. The STWAVE model used the directional spectra observed for each of the 52 storm events as offshore boundary conditions. The transference of offshore wave conditions to the MCR jetties is problematic without using observed directional wave spectra as an offshore boundary condition (BC). The offshore wave environment in the Pacific Northwest is too complex to be described by parameterized spectra. Directional offshore wave data (spectra) for the MCR is available from 1998 onward. This is why the ensemble of 52 offshore wave events is pooled from 1998-2008. This ensemble included the three largest observed wave events on record for the MCR offshore region (1987-2008). The STWAVE modeling was performed a priori and externally from the SRB model to develop a database of storm wave conditions along each jetty (Figure A2- 32) for various water levels. Recurrence intervals for the 52 events span a range of: 5 times per year to once in 25 years (Figure A1- 71 and A1- 73). Table A2-24d (left hand side of table) lists summary statistics for each of the 52 offshore storm wave events simulated using STWAVE. Refer to Appendix A1 for added details.

<u>Assign Offshore Wave Direction and Height (step 5):</u> After the values for offshore wave height and direction values have been generated in step 4, a best-match STWAVE storm wave solution is selected. The best-match event is selected by minimizing RMSE between: A) The values of height^2 and mean wave direction for the generated offshore wave event (step 4) <u>vs.</u> B) The values of height^2 and mean wave direction conforming to the ensemble of 52 events simulated using STWAVE.

Note that the above procedure applies a database of storm wave conditions along each jetty, applicable to the *present morphological condition* of the MCR inlet. Because gravity (wind generated) waves are modified by water depth and the water depth varies along each jetty, the storm wave environment along each jetty is highly variable. During minor storm events, waves along the inshore area of the jetties can be depth-limited. For a given water level, the waves are the same height regardless of the height of offshore storm waves. During severe near shore wave conditions, waves along many areas of each jetty become depth-limited, regardless of the height of waves offshore. In areas where the storm waves are depth-limited, the storm water level plays a larger role in defining near shore wave height than does offshore storm intensity. For these near shore areas, a 1-year offshore wave height occurring on a 10-year near shore water level will produce a larger wave height at a given jetty than a 25 year offshore wave height super occurring on a 1-year near shore water level.

<u>Assign a Storm-induced Water level and Select the STWAVE Solution (step 6):</u> Figure A2-39 through Figure A2- 42 describe the best-fit distributions that were used to stochastically simulate individual components for near shore water level. The observed data is shown in figure A1-78. Each water level component (for MCR) was simulated using a GEV distribution and was bounded by the extreme values of the observed data. The PDFs capture 100% of the total possible variation for each water level component. The PDFs are clipped at the upper and lower bounds, affecting less than 1% of the simulated result. Figure A2- 42 shows the result of combining each of the simulated water level components (PDF realizations) to estimate a total water level per storm event. The SRB model applies appropriate water level component PDFs to generate a randomized total near shore water level associated with a realized storm event. The effect of sea level rise is added to the storm-induced water level to produce a total event water level. The event-based water level generated in step 6 is used to interpolate from within the range of STWAVE solutions, based on the three water levels associated with a given candidate storm.

<u>Interpolate the Selected STWAVE Nearshore Wave Field onto All Jetty Segments (step 7):</u> The SRB model spatially interpolates the above derived STWAVE wave solution along the solution points shown in Figure A2- 32 to develop a continuous description of the wave field along each jetty for each storm wave event. The storm wave environment along the jetty is further modified based upon the present morphological stage within the jetty life-cycle being simulated. This series of steps produces the combined wave and water level environment along the jetty for a given storm event. The realized wave event is used to estimate jetty damage by accessing the appropriate damage function.

The above process is repeated for each storm event within a given year. Wave induced damage is calculated for each storm event realized within each year of the SRB simulation, using wave-damage functions developed by ERDC [Ward and Melby 2007]. Reliability is calculated using the mean value and standard deviation for the annual storm wave and mean value and standard deviation for water level environment realized each year. The above stochastic approach accounts for variation of: A) annual storm climate-numbers of storms per year; B) individual storm wave parameters-height, direction, period; C) the superposition of water level components-tide, storm surge, and infra-gravity transients; and D) the evolving morphological stage of the inlet. Values of wave and water level were applied along each jetty segment for each storm within each year of a given SRB simulation.

Emulation of past and future bathymetry conditions (and related wave environment) for the MCR inlet is handled indirectly through the application of morphological factors, as described in *Foundation Effects*.

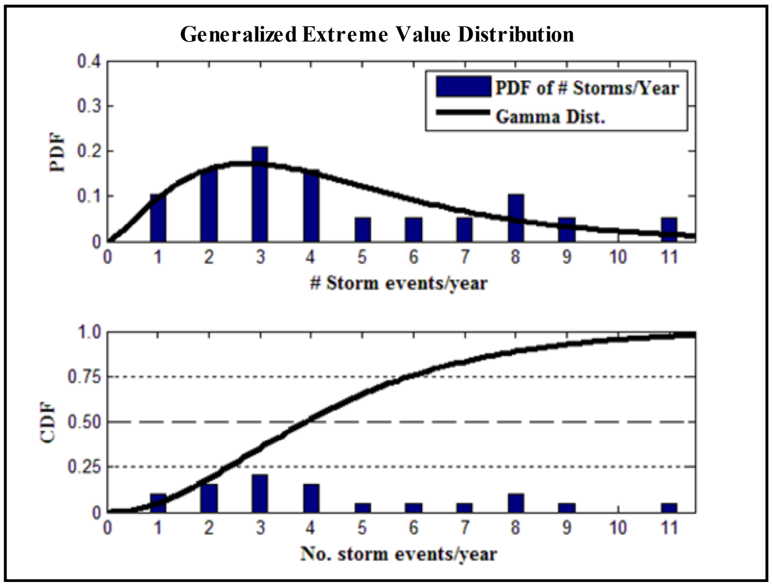


Figure A2- 34. Generation of Random Wave Parameters: Generalized Extreme Value Distribution

Within the SRB model, a random number is generated using a GEV distribution to estimate the number of storms that can occur during any given year.

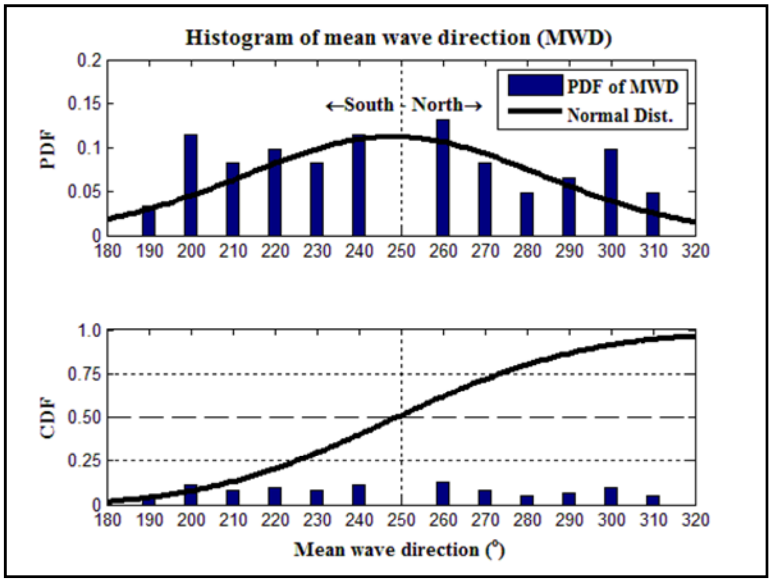
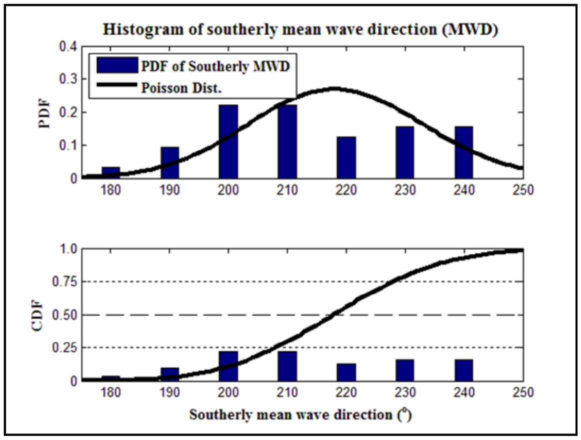


Figure A2- 35: Generation of Random Wave Parameters: Histogram of Mean Wave Direction

Within the SRB model, a random number is generated using a NORMAL distribution to determine if the storm event (offshore) wave direction is north or south of 250 degrees azimuth. If wave direction is south of 250 deg, storm wave direction and height is further resolved in Figure A2- 36 and Figure A2- 37 *at bottom LEFT. If wave direction is north of 250 deg, storm wave direction and height is further resolved in* Figure A2- 36 *and* Figure A2- 37 *at bottom RIGHT.*



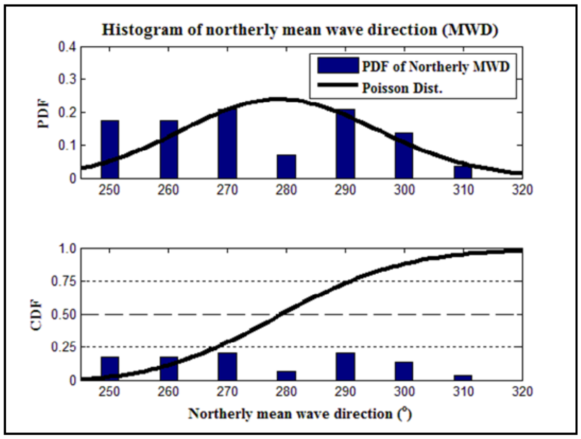


Figure A2- 36. Generation of Random Wave Parameters: Histogram of Southerly/Northerly Mean Wave Direction

For a storm approaching from the SOUTH the mean wave direction is estimated with a POISSON distribution (LEFT).For a storm approaching from the NORTH, the mean wave direction is estimated with a POISSON (RIGHT).

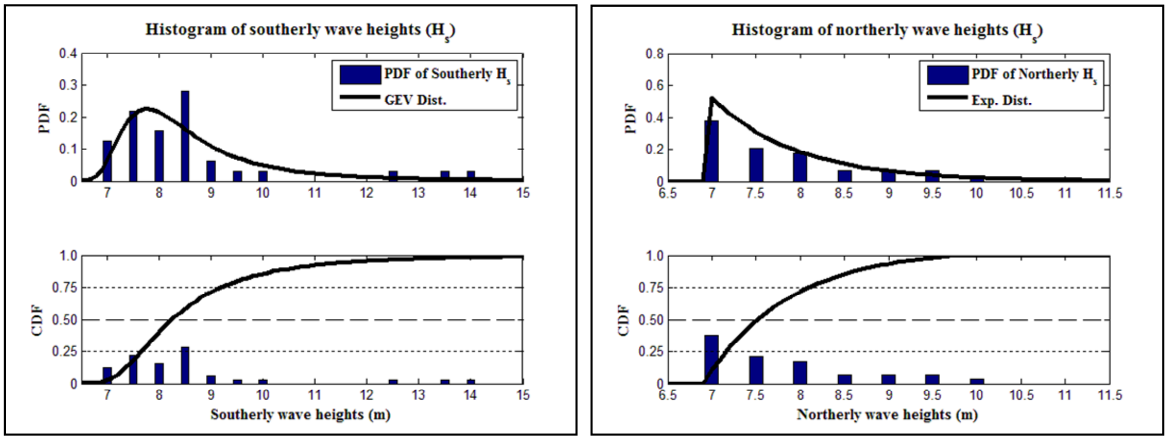


Figure A2- 37. Generation of Random Wave Parameters: Histogram of Southerly/Northerly Wave Heights

For a storm approaching from the SOUTH the wave height is estimated with a GEV distribution (LEFT).For a storm approaching from the NORTH, the wave height is estimated with an EXPONENTIAL distribution (RIGHT).

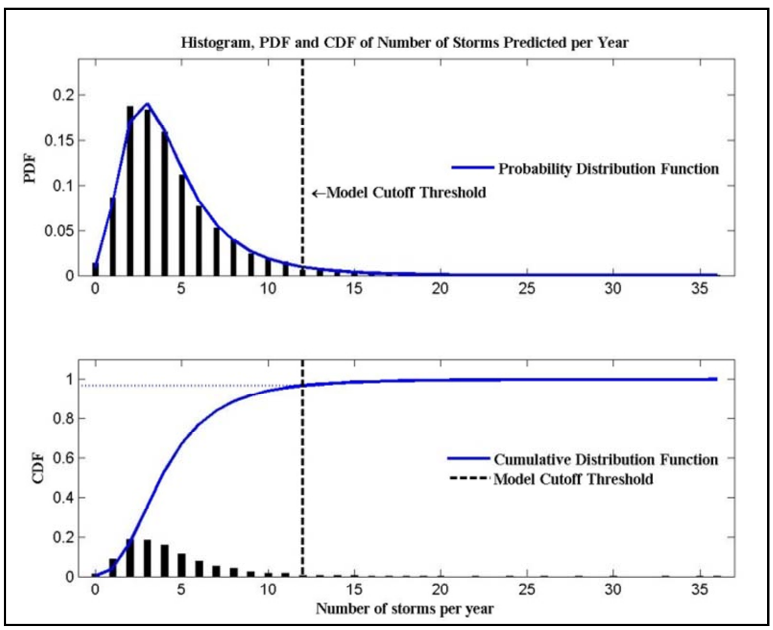


Figure A2- 38. Generation of Random Water Level Parameters: Histogram, PDF and CDF of Number of Storms Predicted per Year

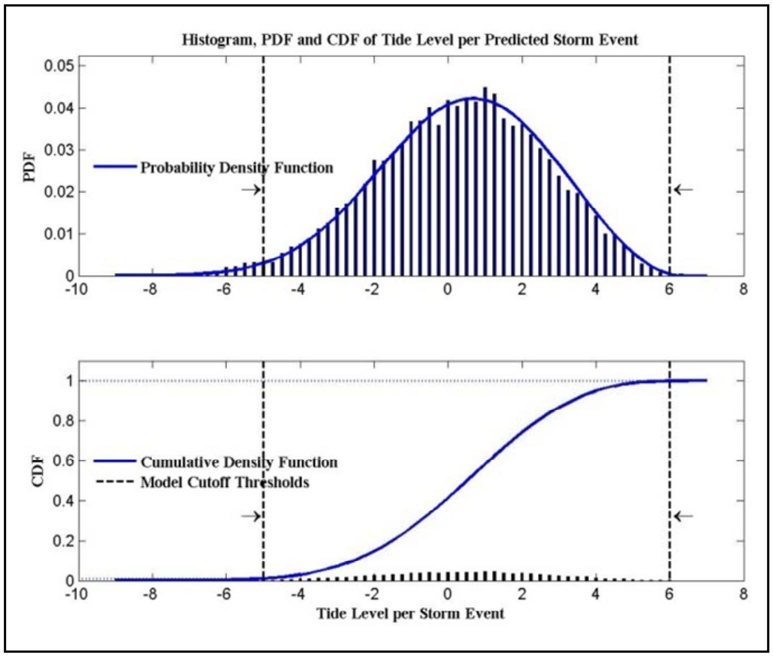


Figure A2- 39. Generation of Random Water Level Parameters: Tide Level per Storm Event

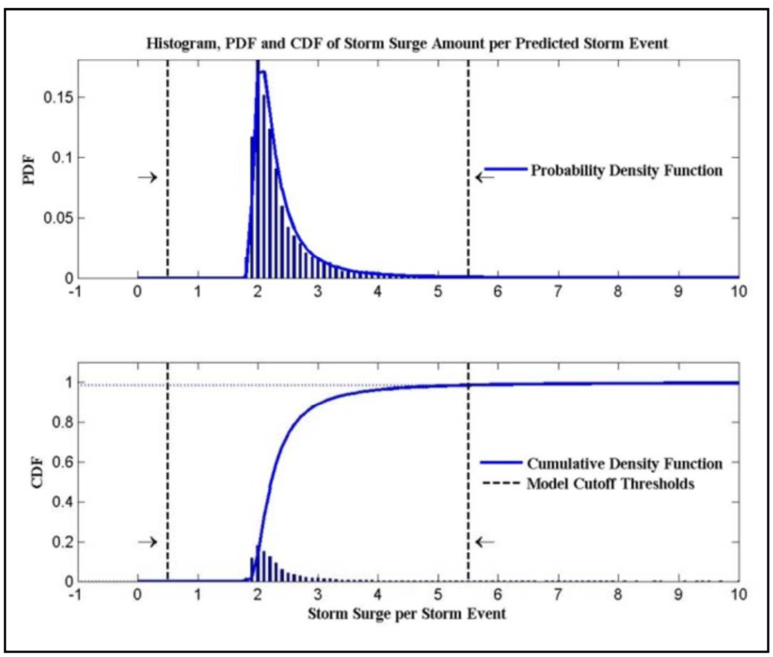


Figure A2- 40. Generation of Random Water Level Parameters: Storm Surge per Storm Event

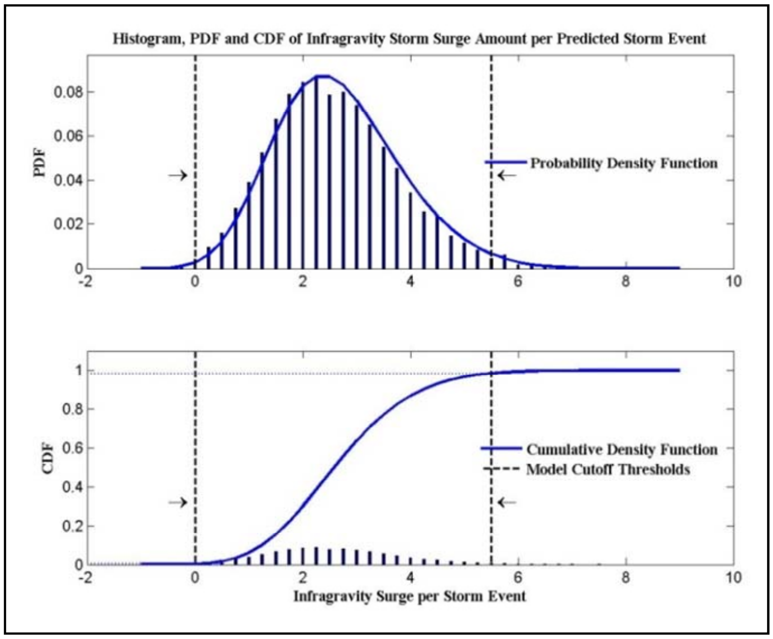


Figure A2- 41. Generation of Random Water Level Parameters: Infragravity Surge per Storm Event

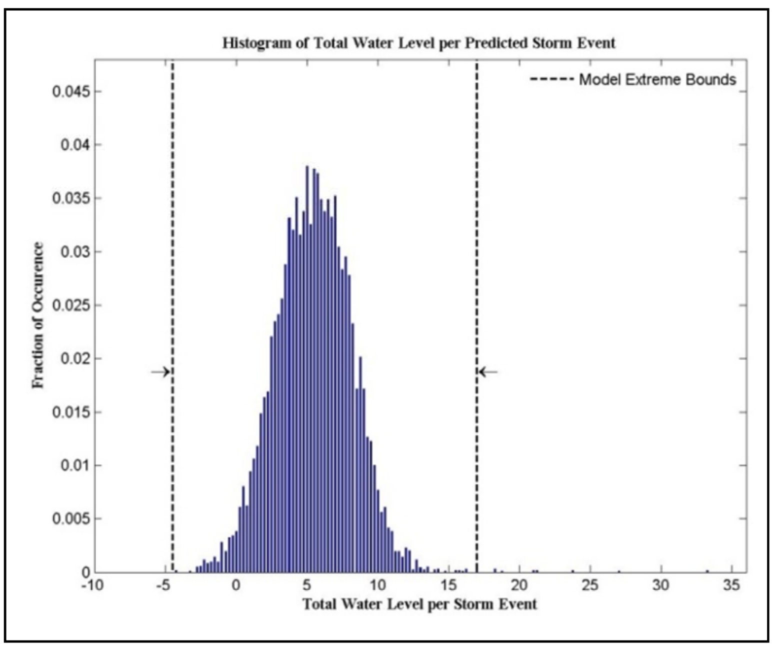


Figure A2- 42. Generation of Random Water Level Parameters: Total Water Level per Storm Event

1. Offshore Wave Climate

The offshore storm wave climate affecting the MCR was established a priori outside of the SRB model by synthesizing the observed range of winter storm wave conditions during

1987-2008. Synthesized parameters include offshore wave height, wave period, wave direction, and number of storms per year. The SRB model proceeds sequentially year by year through a given life-cycle simulation. For each year in the simulation, an offshore storm climate is generated through a series of probability density functions (PDFs) to define the number of offshore storms, associated wave characteristics, and nearshore water level associated with each storm. There can be 1 to 11 storm events affecting the MCR inlet per year, having offshore significant wave height (Hsig) ≥ 22 ft. The maximum offshore Hsig observed during 1987-2008 was 46.3 ft. An extremal analysis of the wave data observed during 1987-2008 produced the following return intervals for offshore Hsig (Appendix A1):

- 1-year storm event = 29 ft (observed)
- 4-year storm event = 36 ft (observed)
- 25-year storm event = 46 ft.(observed)
- 50-year storm event = 51 ft (projected based on extremal analysis)
- 100-year storm event = 55 ft (projected based on extremal analysis)

Based on the observations made to date, the largest offshore waves (> 4-year event) approach the MCR from the south-southwest. This is consistent with the configuration and transit path of cyclonic storm systems approaching the Pacific Northwest Coast. Figure A2- 33 outlines a procedure used within the SRB model to simulate the offshore storm wave environment annually affecting MCR (steps 1-5). The procedure is based solely on observed wave event data, and does not include data extrapolated from the extremal analysis. The largest observed event is equivalent to the 25-year offshore wave. Figure A2- 34 through Figure A2- 37 describe the best-fit distributions that were used to stochastically simulate offshore wave parameters based on observed wave events. Consequently, the storm events emulated within the SRB life-cycle model can produce offshore Hsig ranging from 22 ft to 46 ft. Steps 6-7 (Figure A2- 33) summarize how the generated offshore storm wave condition is interrogated to select a nearshore wave condition for each MCR jetty.

2. Water Levels

To account for the effect that water level can have on nearshore wave height, STWAVE simulations were performed for each of the 52 offshore wave events using three different nearshore storm water levels: a low value conforming to a sub-annual occurrence (1.3 ft MLLW); a median value conforming to the annual 1-year event (8.5 ft MLLW); and extreme high water level conforming to a 20-year event (15.8 ft MLLW). MLLW is approximately equal to -3.5 ft NGVD. The nearshore storm-induced water level was developed from a superposition of variably-correlated random components featuring: A) astronomical tide; B) quasi-static storm surge; and C) infra-gravity transient due to storm wave grouping. Refer to Appendix A1 for detailed description of the MCR water level environment.

3. Sea Level Rise

The effect of sea level rise was included for assessments of *future* jetty performance at the MCR. Future sea level rise estimated within the SRB model is outlined in EC-165-2-211

[USACE 2009]. The EC prescribes a method for defining three future projection curves which are used to bound the estimate for sea level rise over time. The sea level projections (curves) are site-specific and are derived based on the historical sea level trend blended with the huestatic effect. EC curve #1 defines the lowest expected bound for sea level rise, EC curve #2 defines a prudent expected trend, and EC curve #3 defines the highest expected bound. The sea level projections that were used within the SRB model were based on the NOS station at Astoria, Oregon. Within the SRB model, each jetty life-cycle realization (extending 50 years beyond the base year 2011) was assigned a randomly generated sea level rise trend, which is bounded by EC curve #1 (-0.2 ft) and EC curve #3 (1.8 ft). Figure A1-79 shows a subset of 9 randomly generated sea level trends superimposed on the three EC curves. A total nearshore water level is estimated for each storm (k) by adding the estimated sea level rise (for a given year, i) to the nearshore storm-induce water level, described above. Sea level rise effects were not included within the historical assessment of jetty performance (hindcast).

4. Nearshore Wave Climate and Water Levels

As noted above, 52 offshore storm wave events were transformed to the jetties a priori to estimate the nearshore wave field for a range in water levels. Each candidate offshore storm was evaluated (using STWAVE) for three water levels, producing a data-base of 156 nearshore storm wave conditions.

5. Return Period for Extreme Nearshore Waves

The largest event within the data base of 52 storms is equivalent to the 25-year offshore wave. To investigate how an extreme offshore wave events (greater than the 25-year) would equate along the MCR jetties, two offshore wave events (50-year and 100-year) were simulated using the STWAVE model for the moderate and extreme water level. The BC (directional wave spectra) for these extreme events was estimated by increasing the spectral energy of the observed 25-year wave event to achieve the associated extremal analysis wave heights (figure A1-73). The results of transforming the 50-year and 100-year wave events to the jetties, using STWAVE, indicate that the nearshore wave height at the jetties increases less than 0.1 meters as compared to the 25-year observed offshore storm condition. The reason for the above result is that the largest offshore waves approach the Pacific Northwest Coast obliquely from the south-southwest, expending much energy through refraction as the waves shoal and refract into the nearshore. By the time these waves reach the MCR jetties, the wave height is reduced much more (on a relative basis) than smaller offshore waves that approach the coast from a more direct angle (southwest to northwest).

In consideration of the above, the estimated return period for events affecting the MCR jetties is based on storm events less than the 4-year return period, combined with water level events spanning sub-annual to a 20-year occurrence. These lesser offshore events produce waves that approach the coast from southwest – northwest (which are not reduced as much by shoaling and refraction as waves from extreme events) and can affect nearshore infrastructure to a greater degree. Based on the above considerations, the return interval for the largest nearshore events affecting the jetties (as emulated by the 52 offhshore wave conditions and 3 water levels) is estimated to range from the sub-annual event (5 times per year) to a 40-year event. The 40-year nearshore wave event is based on a 2-year offshore event occurring on a 20-year water level. Regardless of the severity of an offshore wave event, the largest waves that the jetties will "see" are nearshore equivalent to the 2-year offshore wave event. The morphology of the MCR inlet protects the jetties from the severity of extreme offshore wave events and nearshore water level modulates the effect of offshore waves.

b. Foundation Effects

1. Morphological Change

The actual wave environment affecting a given jetty can be modified over time based upon the water depth at the structure, as controlled by the evolution of the shoal (morphology) on which the structure was built. If waves are depth-limited along a given jetty location and the water depth along the structure increases over time (shoal recession), then the wave environment at the structure will also increase over time. If the shoal on which a jetty was founded accreted such that water depth along the jetty was to decrease, then the wave environment would decrease over time. The effect that morphological change has on wave conditions at MCR has been estimated for past and future jetty life-cycle simulations, with respect to the present condition (Table A2- 13 through Table A2- 15).

Bathymetry data describing the MCR inlet conditions for periods of time in the distant past (more than 30 years ago) were incomplete in areal coverage. The absence of a complete historical bathymetry data set of the MCR inlet precluded accurate wave modeling for the MCR inlet in the historical setting. There is no data set yet observed to describe the future condition of the MCR inlet. Attempting to accurately reproduce the entire bathymetric condition at the MCR inlet for past or future conditions, to a resolution necessary for detailed wave modeling, was deemed impossible. The morphological factors given in Table A2- 13 through Table A2- 15are used to modify the wave environment along each jetty for the life-cycle time period of interest with respect to the present condition. These factors were estimated based on assessing the evolving morphological stage of the inlet using historical bathymetry data (for hindcast simulations) and extrapolation of recent observed bathymetry change (for future life-cycle simulations). In summary, morphological factors were used to adjust the present bathymetry-wave condition of the MCR inlet to enable estimation of past or future wave conditions along each jetty. The morphological factors were used of as a surrogate method to emulate past and future MCR wave conditions in the absence of detailed bathymetry data.

2. Jetty Toe Scour

The waves and currents can interact along the transition between jetty side slope and the seabed to form an organized rip-current system. These local rip currents run along the interface of the jetty and seabed and can erode and transport sediment away from the jetty's foundation. The resultant scour that forms along the jetty's base and adjacent shoreline can be more pronounced and localized than the large-scale processes which drive morphological change affecting tidal shoals. At some jetty locations, the jetty toe (interface between jetty and seabed) has been eroded by more than 40-ft vertical, resulting in the progressive collapse of the jetty cross-section. Scour of the jetty toe is typically limited to the seaward half of the jetty and sometimes the jetty root. However, jetty toe scour can affect the jetty anywhere if the channel thalweg migrates toward the jetty or secondary circulation (caused by an eddy or wave action) sets up an enhanced rip current along the jetty. These scour effects have occurred along the MCR jetties at various times and locations during the present life-cycle.

As the inlet continues to evolve, the location and nature of jetty toe scour will change along each jetty. Historical rates of jetty toe scour have been calculated by comparing the elevation of the structure toe along the jetty alignment (immediately prior to construction) to various periods after jetty construction. Future scour rates were estimated based on extrapolating present scour rates combined with the effect of estimated future morphology change at the inlet. Table A2- 13 Table A2- 15list the historical (observed) and future (estimated) scour rates along each side of the MCR jetties. These values were used within the SRB model. Scour rates for each side of a given jetty were evaluated on a 500-ft reach basis, and these values are adapted to each jetty segment (100 ft) using interpolation within the SRB model. Jetty toe scour for each segment accumulates through time (for each simulation year) within the SRB model. As discussed previously in this appendix, excessive jetty toe scour can lead to destabilization of the jetty foundation; this effect is cumulative and can affect the entire structure side slope.

Implementation of spur-groin engineering features can interact with the rip-current system along a given jetty to reduce the rate of scour affecting the jetty toe. If the option for implementing spur-groins is activated within SRB model for future life-cycle simulations, the estimated rates for jetty toe scour are reduced, as described in Table A2- 12 (Part II-1).

c. Jetty Cross-Section Attributes

Within the SRB model, jetty stability is related to the time-varying resilience of the jetty's cross-section in terms of an upper and lower region for each segment. Multiple attributes are tracked within the SRB model to describe the time-varying geometry of the jetty cross-section. Attributes for a given jetty segment are recorded in terms of the upper and lower region. To assess the time-varying condition of a jetty segment, the present cross-section attributes are compared to the jetty's initial condition or a set of threshold conditions. Initial conditions and associated jetty cross-section thresholds are specified within the SRB model script or by external data (.mat) files. When a given jetty segment is repaired or rehabilitated, the cross-section attributes are reset to the appropriate initial conditions and related threshold values.

1. Lower Cross-Section Attributes

The geometry of the jetty's lower cross-section is affected by slope instability, as motivated by the lowering of the jetty toe through scour, which can occur independently on either side of the jetty. Recall that the response of the lower region of a jetty cross-section can affect the upper region. Active SRB model parameters which describe the time-varying condition of the lower cross-section include:

- Lower Region Structure Side Slope (θ_L) – variable for each side of the jetty.
- Lower Region Crest Width (CW_L) – variable for each side of jetty, with respect to centerline.
- Toe Elevation (TE) – variable for each side of the jetty.
- Lower Region Cross-section Area – a function of θ_L, CW_L, and TE.

The initial condition side slope for the lower cross-section is set at 1.5H:1V. If a given side of the jetty is subjected to scour, the jetty toe is lowered and the side slope is adjusted to meet the geometry constraints. The side slope can be reduced to a limiting slope of 1.3H:1V, at which point the slope is re-adjusted to a stable slope of 1.4:1V. Unless the jetty segment is repaired or rehabilitated, the lower slope will vary between 1.4H:1V to 1.3H:1V as the toe is lowered by scour. The crest width of the lower region serves as the bench on which the upper cross-section rests (see Figure A2- 18 and Figure A2- 26). The crest elevation of the lower region is located at WAV_EL. The area of the lower cross-section is calculated in terms of the lower region crest width, side slope, and toe elevation.

2. Upper Cross-Section Attributes

The upper section of a jetty can be directly damaged by wave action or indirectly damaged by the lower region's response to toe scour and slope instability. As the upper cross-section of a jetty is damaged, the resiliency of the upper cross-section can be reduced in two ways.

Cross-section Geometry Reduction. Less area remaining within the upper section of a jetty means less area remaining to resist a jetty breach (loss of jetty function). As the cross-section becomes more damaged, the damage rate can increase. If the cross-section is damaged to a point such that the crest elevation becomes reduced, the wave overtopping effects can promote added rates of damage on the lee side of the jetty. The following parameters are used to modify the geometry of the upper section of a jetty as it is damaged by wave action or effects induced by lower section instability.

- Upper Region Structure Side Slope (θ_U) – constant value, each side of the jetty.
- Upper Region Crest Width (CW_U) – variable on each side of jetty, with respect to centerline.
- Upper Region Jetty Crest Elevation (CE_U) – variable elevation of the jetty's crest.
- Upper Region Cross-Section Area – a function of θ_U, CW_U, CW_L, and CE_U.

Reduction in Armor Layer Stability. As the upper cross section is damaged, the stability of the jetty's armor layer becomes compromised. The degree of armor layer stability loss is related to the reduction in jetty crest width with respect to the initial (or repaired) condition. Regardless of how the upper jetty cross-section is damaged, *crest width* is the geometric parameter used to actively modify the performance aspects of the cross-section. The total crest width of the jetty is bisected into a channel side and ocean side component. Damage sustained by the upper region of a jetty is expressed in terms of an equivalent crest width reduction, which is a function of the damaged area and structure side slope. The slope of the upper cross-section is set and held at a constant value of 1.5V:1H, as sustained damage causes the jetty crest to translate inward toward the centerline.

The following armor layer characteristics are modified as the crest width (on each side of the jetty) is reduced:

Median armor unit size (W_{50}). As the crest width of the jetty is reduced, less of the armor layer remains to protect the interior of the jetty and the jetty interior becomes exposed to wave action. At this point, much of the armor layer has been displaced off of the upper cross-section such that core stone is subjected to direct wave action. The effective size of the armor stone is decreased in proportion to the relative amount of true armor stone remaining on the jetty slope (core stone becomes more prevalent along the disturbed slope face). When the crest width on a given side of the jetty has been reduced to less than 1-ft wide, the mean armor stone size of the upper jetty slope is reduced to 70% of the initial condition. The standard deviation of armor stone size is adjusted accordingly.

Armor Unit Stability Coefficient (K_d). When armor units are displaced from their set position within the armor layer of a jetty, the armor units lose the aspect of interlocking, which affords an added degree of stability for the armor layer en mass. As the jetty incurs damage, crest width of a jetty is reduced, and the armor unit stability coefficient (or equivalent stability parameter) is reduced to reflect the disruption of the armor layer. If the crest width on a given side of the jetty has been reduced to 10-30% of its initial width, then Kd is re-set to max (0.9* initial value, 2.5). If crest width on a given side of the jetty has been reduced to less than 10% but greater than 1 ft in width, then Kd is re-set to max (0.8* initial value, 2.2). If crest width on a given side of the jetty has been reduced to less than 1 ft in width, then Kd is re-set to max (0.7* initial value, 1.8). The reduction in Kd is based on an equivalency of Kd and values of $H/H_{d=0}$, for 0 to 50% cross-section damage, as expressed by the Hudson equation in the SPM [USACE 1984].

The initial condition for jetty cross-section geometry and armor layer characteristics are set within the SRB model according to the design parameters implemented at the time of jetty construction. In some cases, there can be considerable variation in jetty cross-section attributes along the structure length, and from one side of the jetty to the other. If a given jetty segment is repaired or rehabilitated, the jetty cross-section attributes are reset according to the specific plan implemented (specified within the SRB model). Appendix A1 describes jetty parameters applicable for the initial condition, historical repairs, rehabilitation plans, and future repairs for each MCR jetty.

7. MCR JETTY LIFE-CYCLE HINDCAST – SRB MODEL CALIBRATION

Before performing hindcast simulations for a given structure, it is essential that a structure's as-built condition be established to match the actual post-construction condition of the prototype. Fortunately, the historical record for the MCR jetties is good and data was available to define the initial conditions for jetty toe elevation, jetty cross-section geometry, armor/core stone attributes, and historical scour rates for MCR jetties. Refer to Appendix A1 for historical jetty repair details. Repair history for each jetty is summarized in terms of the location and type of jetty stone placed, and construction methods. The SRB model hindcast jetty maintenance strategy was set at "interim repair" to emulate the maintenance conditions actually undertaken during the historical life-cycle of each jetty.

When executing a hindcast SRB simulation, the initial condition geometry, jetty armor/core stone attributes, and jetty foundation scour rates are defined for the entire jetty, on a segment-by-segment basis. Table A2- 13 through Table A2- 15 summarize observed scour rates along the MCR jetties as employed in the SRB model. The historical repair sequence is defined within the model to assign the number of times segments can be rebuilt, applicable thresholds to initiate wave-induced damage, and stone "re-use" parameters. The storm wave and water level climate is generated for a given life-cycle iteration (89 years for North Jetty, 97 years for South Jetty, and 67 years for Jetty A), and then jetty life-cycle calculations are performed sequentially for each year, for all jetty segments. Monte Carlo simulations are performed by running multiple life-cycle iterations and generated statistical estimates of the life-cycle ensemble. Output produced by the SRB model includes text-based data files (cost data), the entire MATLAB simulation environment, and multiple graphic summaries. The model skill of each jetty hindcast was assessed by comparing the simulated hindcast result to actual metrics based on time-varying repair cost, sequence of repairs, number of repairs made per jetty segment, and crest elevation of jetty at the end of historical performance period. Other informative metrics discussed included time varying reliability, cross-section area, and cost expended per segment.

a. Hindcast Calibration Parameters

Several calibration parameters with the SRB model require adjustment to become fully resolved within the context of a specific jetty, or reaches within a given jetty. Calibration parameters that affect jetty degradation include "wave-damage thresholds" for: A) initial state jetty cross-section; B) damaged initial state cross-section; C) repair cross-section; and D) damaged repair cross-section. The parameter that affects unit repair costs is "armor stone re-use factor," which defines how much of the damaged-displaced armor stone is re-used in the subsequent repair and can be different for each observed repair event. Within the framework of hindcast simulations, the above calibration parameters are held constant after being adjusted through model calibration. For future life-cycle simulations, the above parameters are allowed to randomly vary about the mean value (achieved through calibration).

Calibration of jetty damage thresholds is achieved by converging simulations from the SRB model with the observed life-cycle history in terms of the occurrence and frequency when the jetty was actually repaired though its historical life-cycle. The model was considered to be calibrated when the simulated jetty profile for the end-state condition was equivalent to the observed end-state condition. The observed end-state condition for each jetty was defined by detailed topographic/bathymetric surveys conducted during 2006-2007.

b. North Jetty Simulated Historical Performance, 1917-2006

To avoid redundancy in reporting hindcast results for all three jetties, a detailed description is given here for the North Jetty results and summary descriptions given for the South Jetty and Jetty A. Much of the North Jetty descriptive results can be applied to the other jetties when interpreting the graphical results summarized within this appendix.

Upon completion of the North Jetty in 1917, the entire ocean side of the jetty was exposed to wave action due to the inlet's morphological condition. Soon after completion of the North Jetty, the presence of the jetty radically reformed Peacock Spit producing subareal deposition along the north side of the North Jetty. The SRB model simulated the time-varying condition of Peacock Spit as its rapid accretion first acted to protect the ocean side of the North Jetty from wave and currents and then re-exposed the jetty to the elements during gradual recession of the Spit. The intensity of wave action along exposed areas of the North Jetty in 1917 was estimated to be less than the present condition due to the orientation and geometry of the underwater shoals. Because of this, the initial condition wave environment along the ocean side of the North Jetty was reduced from present average conditions using a morphological factor varying from 0.7 near the landward end of the jetty (station 25), to 0.75 at 4/5 of total jetty length (station 100), to 0.65 at the jetty head (station 124). For similar reasons, the initial condition for wave environment along the channel side of the North Jetty was reduced (from present day value) using a morphological factor ranging from 0.6 at the landward end (station 20), to 0.8 at 3/5 of total jetty length (station 80), to 0.65 at the jetty head. Morphological factors for the North Jetty are shown in Table A2- 13. The morphology factors changed through time, from the initial condition values to 1.0 for the present condition. Wave events realized within the SRB model are modified "at the jetty" using the time-varying morphology factors (Table A2- 13 through Table A2- 15). A key assumption in the SRB model is that the average long-term *offshore* wave (deepwater) climate, at time of jetty construction, was similar to present.

Figure A2- 43 shows the center line profile for "as-built" initial condition, observed condition in 2006, and simulated condition in 2006. There is good agreement between observed and simulated end-state. Note the extent of jetty head recession, which is being aggravated by severe toe scour. As Peacock Spit continues to recede landward into the future, the toe scour effect will translate landward. Figure A2- 44 shows the progression of damage to the cross-section at station 97.5and subsequent repairs for the last Monte Carlo iteration, and complements the information shown in Figure A2- 26. Figure A2- 45 through Figure A2- 47 show the timing, number, and location of repairs historically made to the North Jetty. Areas further seaward from station 70 require additional repair due to the increased exposure to wave action and toe scour. There is good agreement between actual repairs made and the simulated condition. Note how the jetty head has receded landward, despite the repairs made. The number of repairs that can be made within the SRB hindcast is prescribed. The model can initiate repairs up to the prescribed number, but it is not required to initiate any repairs unless sustained damage exceeds an imposed threshold. No repairs were made to areas inshore of station 54, which explains why the jetty profile in 2006 was in poor condition. Figure A2- 48 shows the spatial variation of total cross-section area along the jetty for three periods of time (1917, 1922, and 2006) complements the results shown in Figure A2- 43.

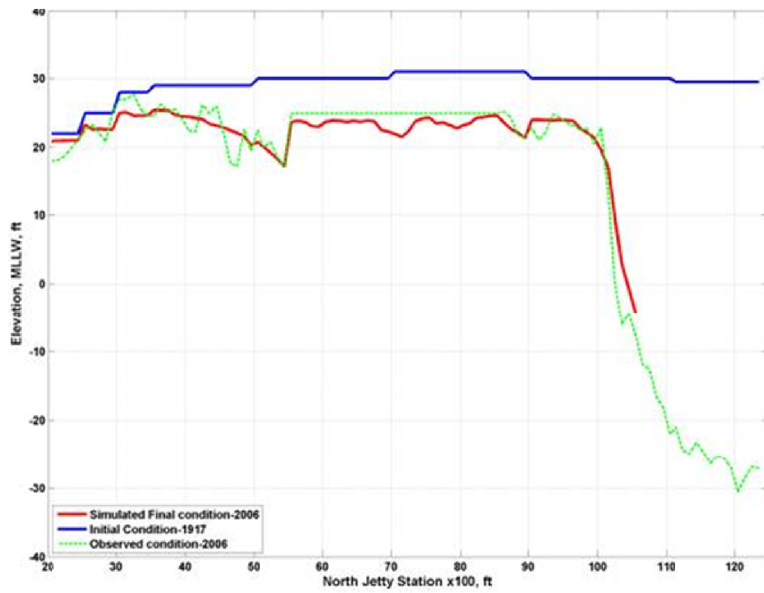


Figure A2- 43. Monte Carlo: North Jetty Crest Profile Evolution: 1917-2006

Centerline profile for MCR North Jetty: extends from landward limit (Sta. 20) to seaward limit (Sta. 124). Comparison of initial condition (1917) to observed and model simulated final condition (2006).

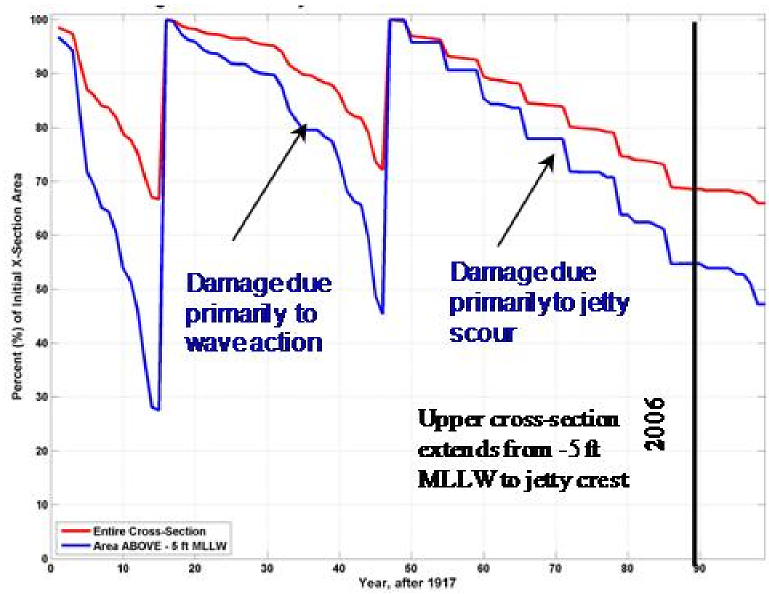


Figure A2- 44. Change in North Jetty Cross-Section Area at STA 97.5: 1917-2016

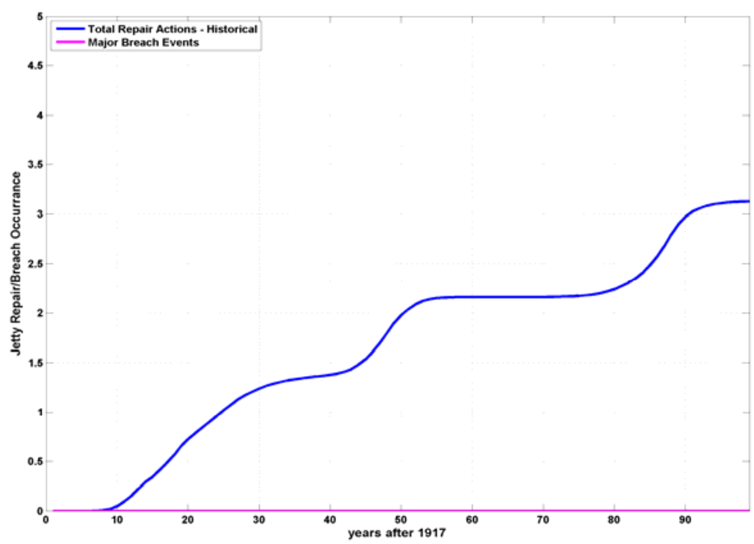


Figure A2- 45. Monte Carlo: North Jetty – Cumulative Occurrence of Repairs and Breaches: 1917-2012

Cumulative jetty repairs for hindcast simulation. The number of jetty segments repaired has been normalized based on the average repair length of 3,100 ft per North Jetty repair campaign.

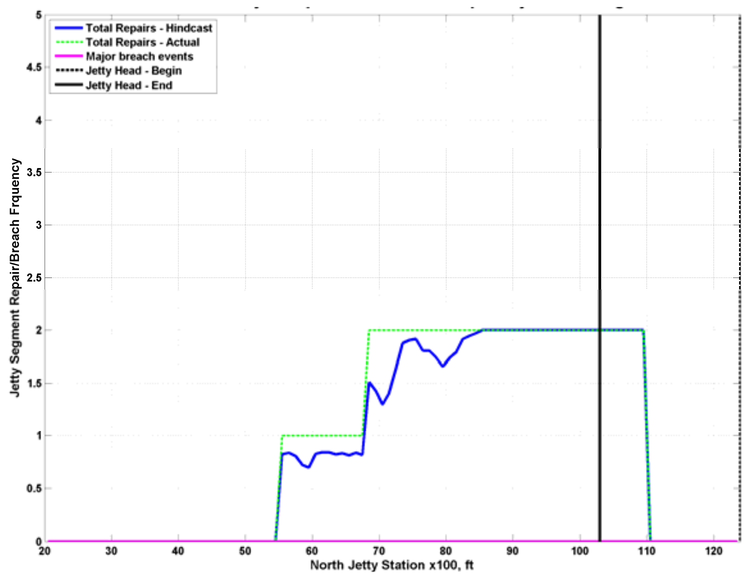


Figure A2- 46. Monte Carlo: North Jetty – Repair & Breach Frequency/100-ft Segment: 1917-2012

Comparison of actual jetty repair history to hindcast condition, based on frequency and location of repairs. The jetty head location is indicated for 1917 and 2006 (simulated condition).

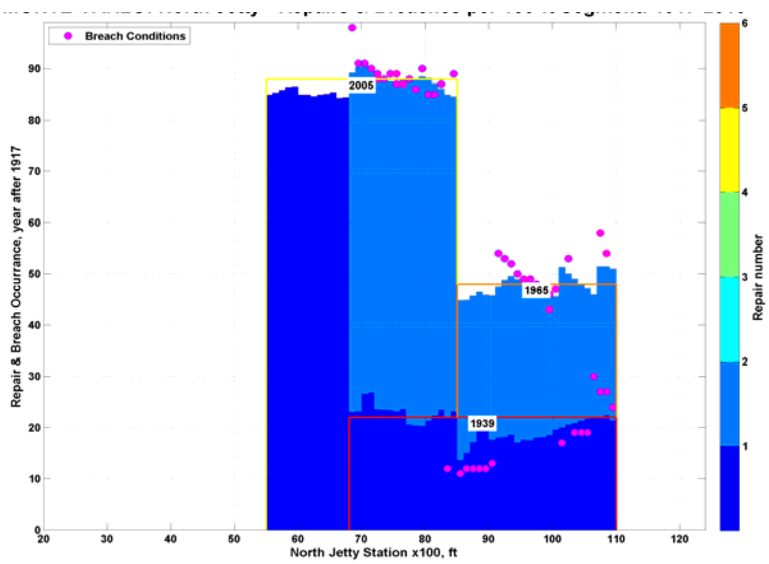


Figure A2- 47. Monte Carlo: North Jetty – Repairs & Breaches per 100-ft Segment: 1917-2016

Hindcast repair occurrence; dark bars are first repair, lighter bars are second repair. Onset of repairs is based on bar endpoint.

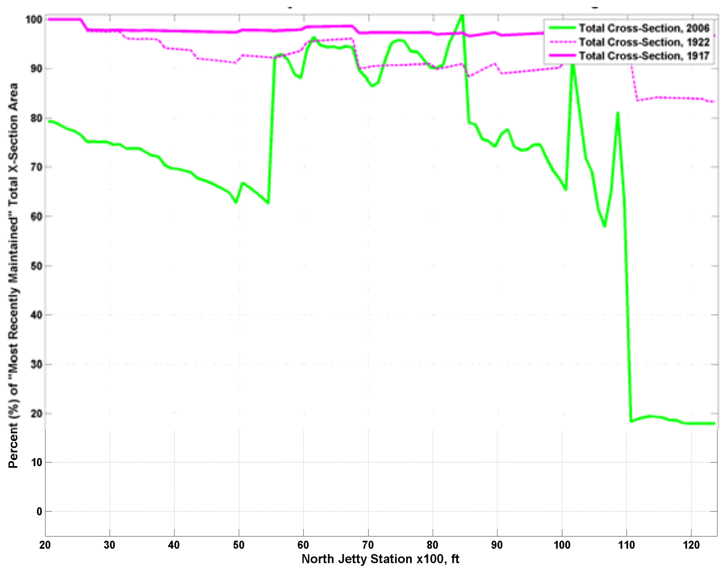


Figure A2- 48. Monte Carlo: North Jetty Total Cross-Section Area Change: 1917-2016

Variation in total cross section area along jetty for 3 different times during the North Jetty hindcast period.

Figure A2- 49 illustrates the time varying reliability for structural and functional jetty performance, pertaining to the upper cross-section of the jetty (above -5 ft MLLW). The values are shown for each year and have been averaged along the entire jetty, out to the seaward limit of the jetty head. Dynamic reliability indicates how well the jetty resists damage due to wave action. A value below 0.5 indicates that the overall jetty has a high probability of experiencing rapid degradation due to wave action (see Table A2- 3). Dynamic reliability is highly variable because the performance modes are very sensitive to wave height and water level. As wave height and water level can vary considerably, so does dynamic reliability. Functional reliability indicates the likelihood that the jetty will continue to perform its intended function to protect the MCR navigation channel from interrupted service initiated by a failed (breached) jetty section. A value above 0.8 indicates that the jetty is functioning adequately; a value below 0.4 indicates that jetty function is at risk of failure (see Table A2- 4). Functional reliability is based on the cross-section area remaining with the upper section and dynamic reliability, and displays less irregularity than dynamic reliability due to the buffering effect of the cross-sectional area. Immediately after initial construction, the North Jetty has full cross-section and moderate resilience to resist the wave conditions affecting the jetty. However, the rate of scour and elevated wave forcing along the outer end of the jetty quickly began to reduce the cross-section in this area, resulting in rapid reduction of reliability during the first 8-10 years of service life.

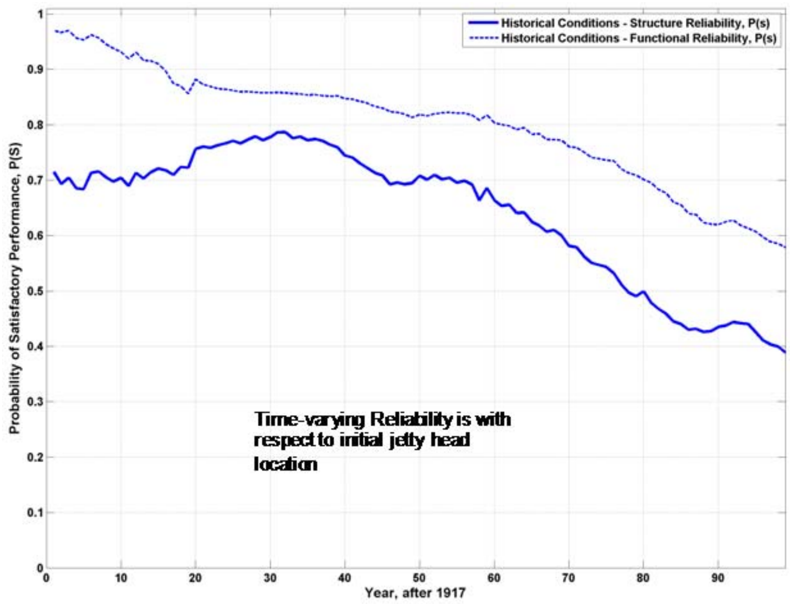


Figure A2- 49. Monte Carlo: Variation in North Jetty Reliability: 1917-2016

The abrupt change in reliability at year 10 (1927), is due to the rapid accumulation of sediment along the north side of the North Jetty acting to protect the jetty from wave action.

Around hindcast year 10 (1927), Peacock Spit began to rapidly accrete past station 100 along the ocean side of the jetty, protecting the ocean side of the jetty from wave action and scour. At the same time, jetty repairs begin to come on-line in the model. The combined effect of restored jetty section and "shoal protection" is shown in Figure A2- 49 as an increase in dynamic and functional reliability. Beginning in year 30 (1947), dynamic reliability began to fall off as Peacock Shoal began to recede and jetty segments become exposed to increase weave and current action. Functional reliability responds more slowly to these changing conditions, as this metric tends to decline after the jetty becomes damaged. In year 50, the North Jetty experiences another campaign of repairs and reliability increases slight. After year 60 (1977), the North Jetty experiences continual reduction in reliability as the previous repairs become degraded and Peacock Spit continues its landward recession exposing more of the un-repaired jetty to added degradation. Localized repairs executed late in the structure life-cycle do little to improve both reliability measures. The North Jetty ends its historic life-cycle in a state of deferred repair, low reliability, and high vulnerability. The future condition appears to be one of continuous repairs, uncertain reliability, and risky project performance.

Figure A2- 50 compares the actual repair cost to the simulated repair cost (shown in $2010). There is overall good agreement between the actual vs. observed costs, but there are some differences in repair timing. The difference between actual and hindcast total life-cycle cost is 1%. The cost stream associated with actual jetty repairs occurs as a stepwise function of time, due to the lagging nature of executing repairs on infrastructure which is inherently costly and difficult to maintain; interim repairs lag repair need by 1-6 years. The SRB model initiates repairs as the damage exceeds the maintenance threshold for each active jetty segment, sometimes resulting in a more continuous repair cost-stream than actual conditions;

jetty repairs are made when they are needed. There can be a minimal lag effect when simulating jetty repair within the SRB model. The absence of this lag effect should be considered when comparing SRB modeled cost-stream data to actual conditions, the timing of simulated repairs may occur sooner than actual staged conditions indicate.

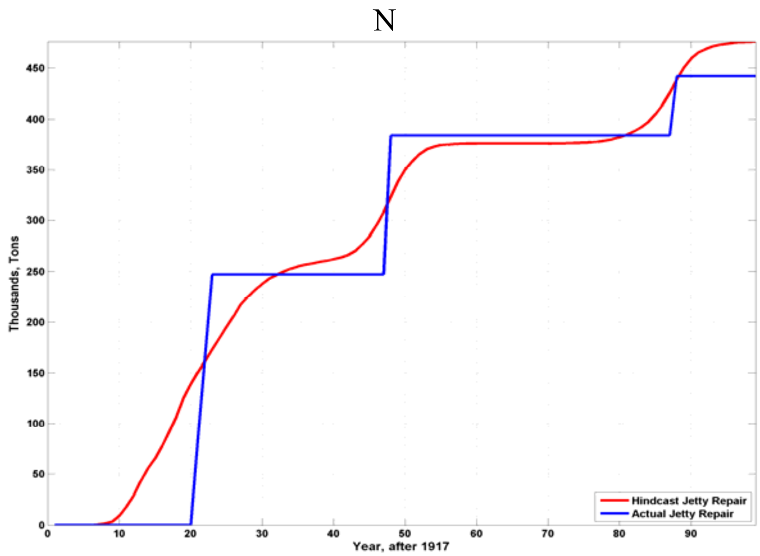


Figure A2- 50. Monte Carlo: North Jetty Life-Cycle Cumulative Repair Tonnage: 1917-2016

c. South Jetty Simulated Historical Performance, 1910-2007

Figure A2- 51 through Figure A2- 57 summarize the SRB model results from simulating the historical 97-year life-cycle of the South Jetty, based on a 1000-iteration Monte Carlo simulation. Figure A2- 51 shows the center line profile for "as-built" initial condition, observed condition in 2007, and simulated condition in 2007. There is good agreement between the observed and simulated end-state. Note the extent of jetty head recession, which is being aggravated by severe toe scour. The concrete cap is located at station STA 330 and shows signs of degradation (see Appendix A1). Figure A2- 52 describes cross-section evolution at jetty STA 300 for the last iteration of the Monte Carlo sequence. During this particular life-cycle iteration, STA 300 was simulated to have been repaired two times (1928 and 1963) after initial construction in 1910.

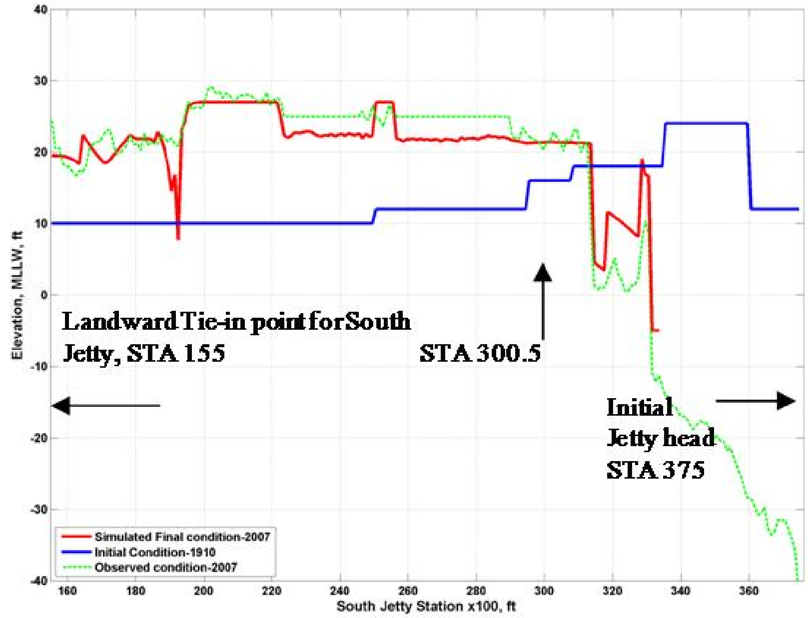


Figure A2- 51. Monte Carlo: South Jetty Crest Profile Evolution: 1910-2007

Centerline profile for MCR South Jetty: extends from landward limit (Sta. 115) to seaward limit (Sta. 375). Comparison of initial condition (1910) to observed and model simulated final condition (2007).

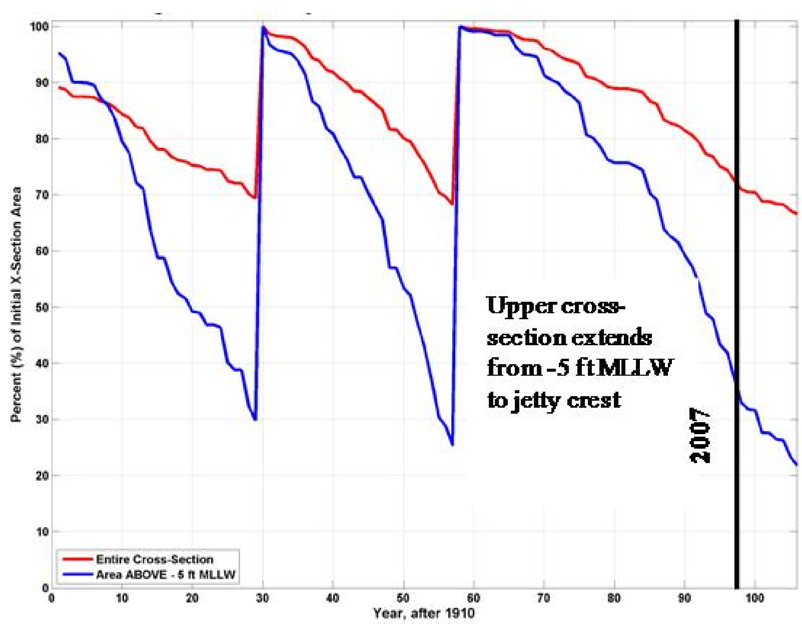


Figure A2- 52. Change in South Jetty Cross-Section Area at SAT 300.6: 1910-2016

Variation of upper cross-section area at Sta 300 during one Monte Carlo realization .The cross section accumulated damage and was then repaired at a the "interim repair" threshold. 2 repairs.

There are some differences in repair timing; as discussed for the North Jetty. Figure A2- 53 through Figure A2- 55 show the timing, number, and location of repairs historically made to the South Jetty. Areas along station 250-260 have relatively fewer repairs than adjacent area due to the sheltering effect of the "knuckle" area. Areas along station 200-250 require additional repair due to exposure to heavy wave action and the fact that past repairs featured less resilient jetty cross-section than areas further offshore. Compare Figure A2- 51 and Figure A2- 54, there is good agreement between actual repairs made and the simulated condition. Note how the jetty head has receded landward, despite the repairs made to the outer end of the jetty. Figure A2- 56 describes the time-varying reliability for the South Jetty during 1910-2007. Large upswings in reliability correspond with large-scale repair campaigns conducted during the 1930s and 1960s; significant areas of the jetty cross-section area was either restored or improved. The armor stone size used for most of these repairs was less than what was needed due to the severe exposure of the South Jetty. This is why the reliability was not significantly improved after each major repair campaign. By comparing Figure A2- 55 and Figure A2- 56, one can see that reliability is correlated with the onset (or absence) or jetty repairs.

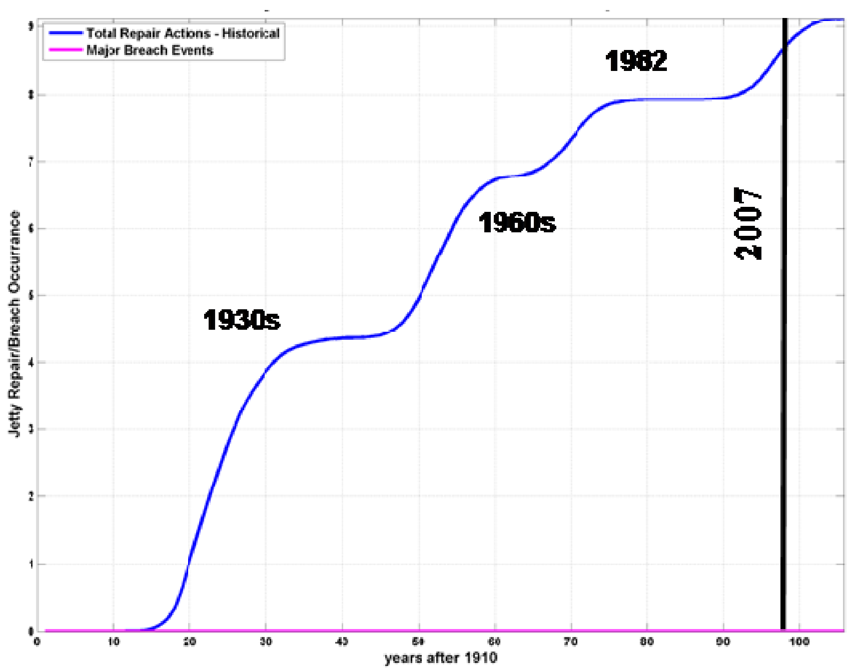


Figure A2- 53. Monte Carlo: South Jetty – Cumulative occurrence of Repairs and Breaches: 1910-2016

Cumulative jetty repairs for hindcast simulation. The number of jetty segments repaired has been normalized based on the average repair length of 5,000 ft per North Jetty repair campaign.

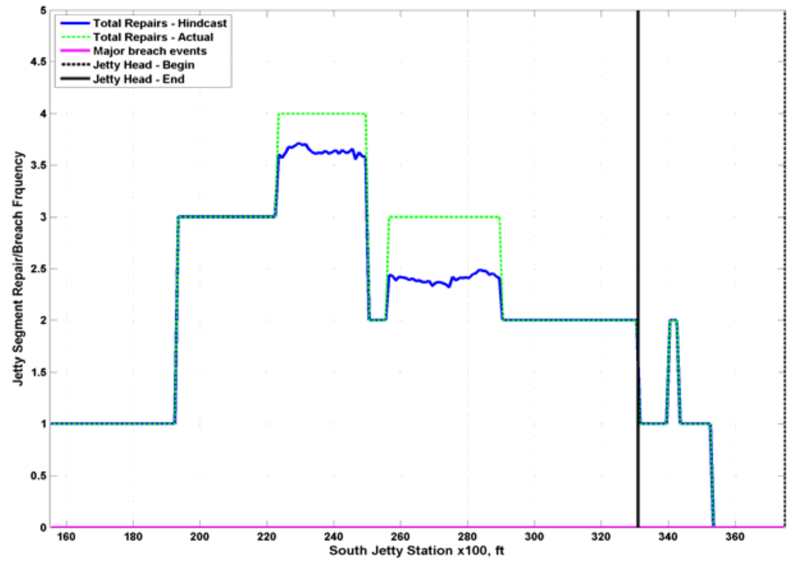


Figure A2- 54. Monte Carlo: South Jetty – Repair & Breach Frequency/ 100-ft Segment: 1910-2016

Comparison of actual jetty repair history to hindcast condition, based on frequency and location of repairs. The jetty head location is indicated for 1910 and 2007 (simulated condition).

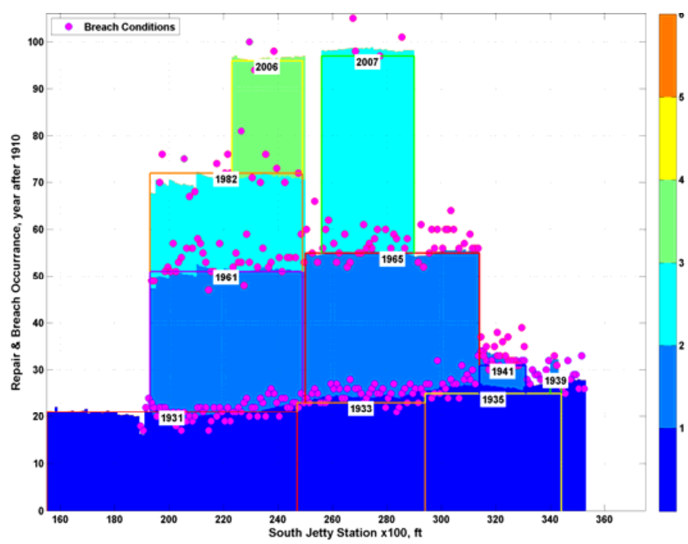


Figure A2- 55. Monte Carlo: South Jetty – Repairs & Breaches per 100-ft Segment: 1910-2016

Hindcast repair occurrence for MCR South Jetty, shown for each 100 ft jetty segment. Dark bars are first repair, lighter bars are second repair. Onset of repairs is based on bar endpoint.

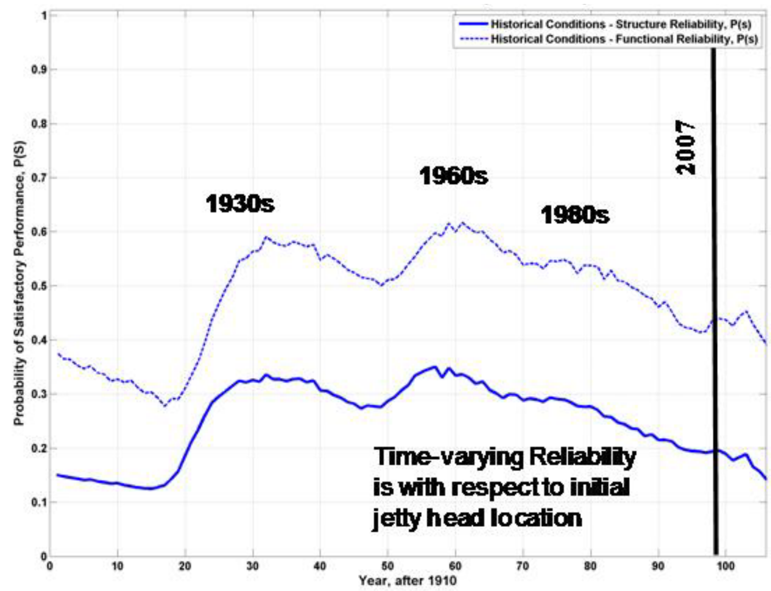


Figure A2- 56. Monte Carlo: Variation in South Jetty Reliability: 1910-2016

Hindcast reliability for the MCR South Jetty for hindcast condition (1910-2007). The upward change in reliability at year 25 (1935) and year 55 (1965) is due to major jetty repair campaigns.

Figure A2- 57 compares the actual repair cost to the simulated repair cost (shown in $2010). There is good agreement between the actual vs. observed costs; the difference between actual and hindcast total life-cycle cost is 1%.

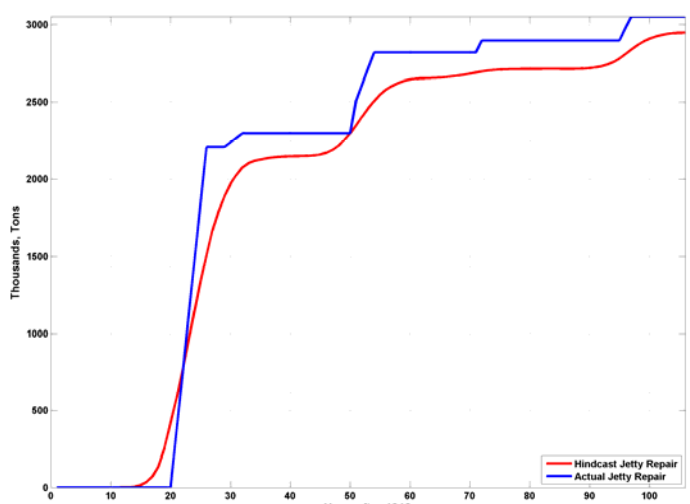


Figure A2- 57. Monte Carlo: South Jetty Life-Cycle Cumulative Repair Tonnage: 1910-2016

d. Jetty A Historical Performance, 1939-2006

Figure A2- 58 through Figure A2- 64 summarize the SRB model results from simulating the historical 67-year life-cycle of the MCR South Jetty, based on a 100-iteration Monte Carlo simulation. Figure A2- 58 shows the center line profile for "as-built" initial condition, observed condition in 2006, and simulated condition in 2006. There is good agreement between observed and simulated end-state. Note the extent of jetty head recession, which has been aggravated by severe toe scour at areas beyond station 95. Figure A2- 59 describes cross-section evolution at station 300 for the last iteration of the Monte Carlo sequence. During this particular life-cycle iteration, station 67 was simulated to have been repaired two times (1958 and 1963) after initial construction in 1939.

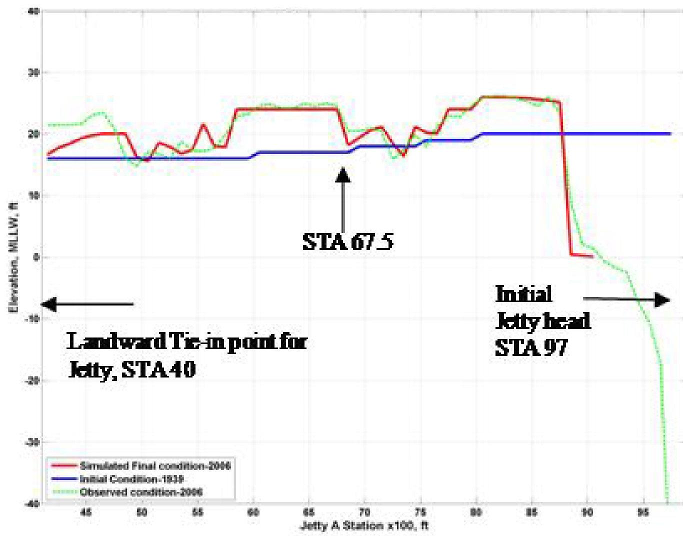


Figure A2- 58. Monty Carlo: Jetty A Crest Profile Evolution: 1939-2006

Centerline profile for MCR Jetty "A": extends from landward limit (Sta. 41) to seaward limit (Sta. 97). Comparison of initial condition (1939) to observed and model simulated final condition (2006).

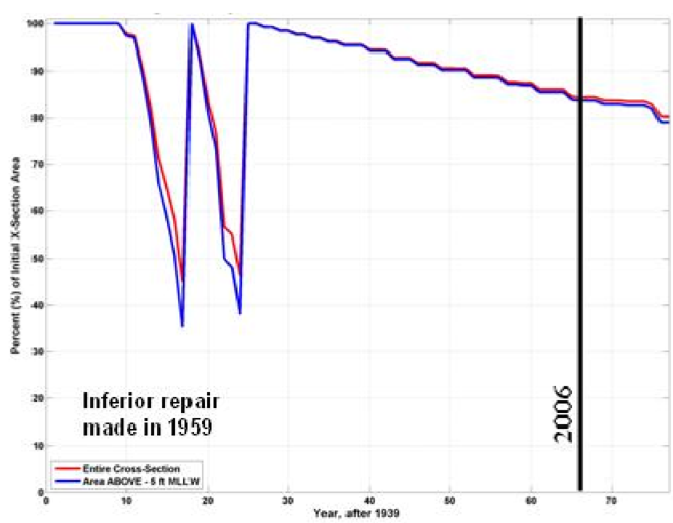


Figure A2- 59. Change in Jetty A Cross-Section Area at STA 67.5: 1936-2016

Variation of upper cross-section area at Sta 67 during one Monte Carlo realization .The cross-section accumulated damage and was then repaired using the "interim repair" threshold. Two repairs.

Overall, there is good agreement between actual repairs made and the simulated condition.

Figure A2- 60 through Figure A2- 62 show the timing, number, and location of repairs historically made to Jetty A. The area from station 41-46 was likely repaired based on the need to establish consistent equipment access to the rest of Jetty A. The tendency of the SRB model was to not repair this area due to low exposure to wave action during the life-cycle. Comparing Figure A2- 58 and Figure A2- 61 shows that the outer end of the jetty took a beating from station 90 outward. Note how the jetty head has receded landward, despite the repairs made to the outer end of the jetty. Figure A2- 63 describes the time-varying reliability for Jetty A during 1939-2006. The reduction in reliability during year 0 (1939) to 19 (1958) occurred despite a sustained program of continual jetty maintenance. The reason for this is based on two factors. First, Jetty A was constructed on a large sand shoal that rapidly retreated from station 89 in 1939 to station 49 by 1960. The recession of ocean side morphology exposed Jetty A to increased wave action. A second factor contributing to reduced reliability during 1939-1958 were the repairs made to the jetty during this period. The stone size obtained and the cross-section template for some of these early repairs was deficient. Jetty A repairs made during 1958 and 1962 were more robust, resulting in improved reliability. This condition persisted until the later repairs became damaged, with the jetty now in a serious condition of deferred maintenance. By comparing Figure A2- 62 and Figure A2- 63, it can be seen that reliability is correlated with the onset (or absence) or jetty repairs and retreating morphology.

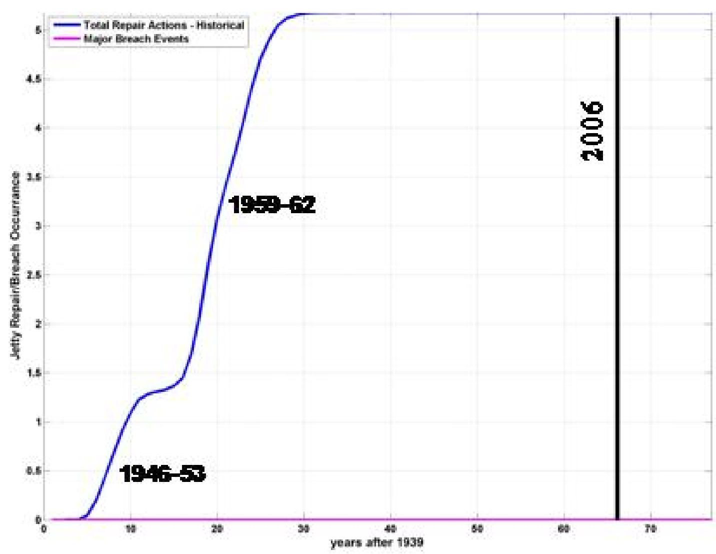


Figure A2- 60. Monte Carlo: Jetty A – Cumulative Occurrence of Repairs & Breaches: 1939-2016

The number of jetty segments repaired has been normalized based on the average repair length of 1,900 ft per Jetty A repair campaign.

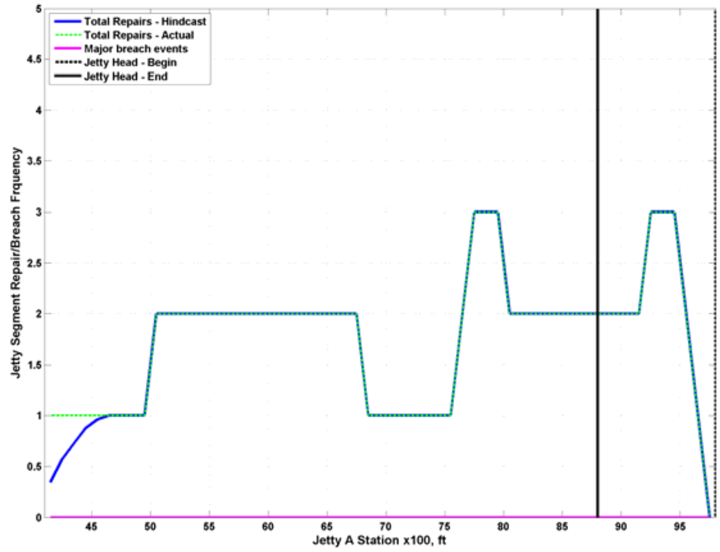


Figure A2- 61. Monte Carlo: Jetty A – Repair & Breach Frequency/100-ft Segment: 1939-2016

Comparison of actual jetty repair history to hindcast condition based on frequency and location of repairs. The jetty head location is indicated for 1939 and 2006 (simulated condition).

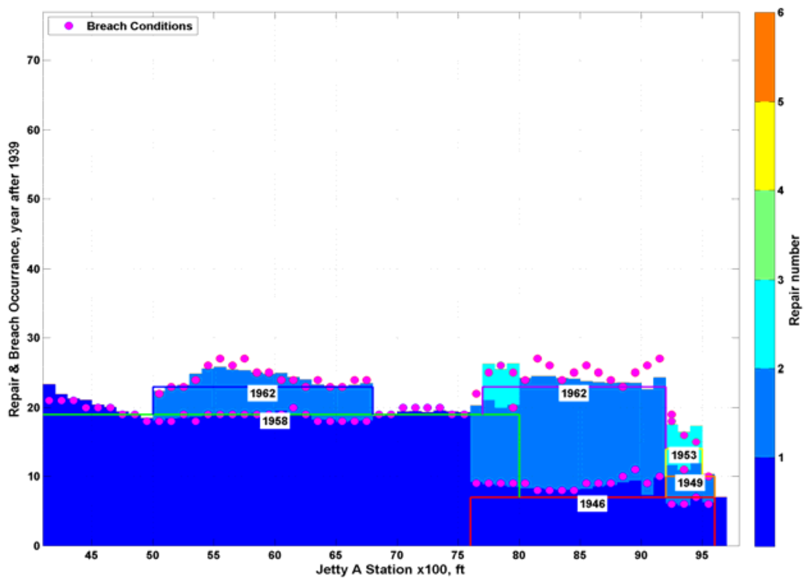


Figure A2- 62. Monte Carlo: Jetty A – Repairs & Breaches per 100-ft Segment: 1939-2016

Dark bars are first repair, lighter bars are second repair. Onset of repairs is based on bar endpoint.

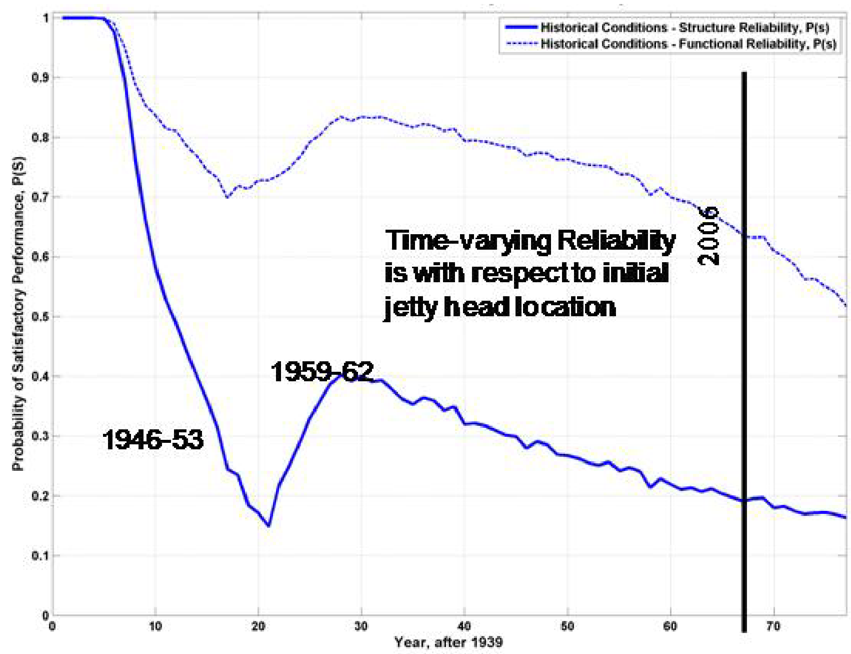


Figure A2- 63. Monte Carlo: Variation in Jetty A Reliability: 1939-2016

Hindcast reliability for the MCR Jetty A for hindcast condition (1939-2007). The upward change in reliability at year 25 (1962) is due the last major repair campaign for Jetty A.

Figure A2- 64 compares the actual repair cost to the simulated repair cost (shown in $2010). There is good agreement between the actual vs. observed costs; the difference between actual and hindcast total life-cycle cost is 4%. There is little difference in repair timing for the hindcast and observed condition.

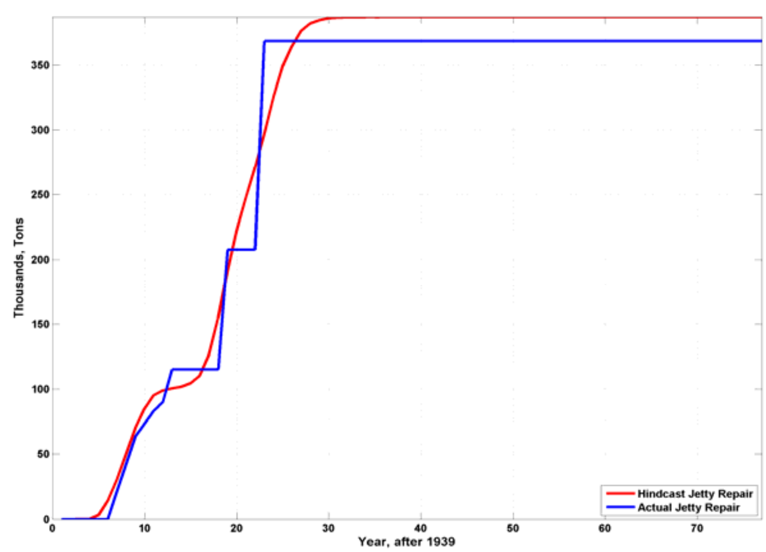


Figure A2- 64. Jetty A Life-Cycle Cumulative Repair Tonnage: 1939-2016

e. Jetty Reliability, Past and Present

Reliability of the MCR jetties has been highly variable through time, as shown in Figure A2- 43Figure A2- 64. Hindcast results for jetty reliability are shown with respect to initial jetty head location (at time of jetty construction). The most significant factors affecting MCR jetty reliability (during the previous life-cycle) have been the morphology evolution at the inlet and past jetty rehabilitation/repair campaigns. Morphology changes have acted to both increase and reduce jetty reliability; this is most notable at the North Jetty when Peacock Spit rapidly accreted during 1917-1939. All three jetties were adversely affected by severe scour that set up along various areas of each jetty. The rehab campaign during the 1930s significantly increased the reliability of the South Jetty and North Jetty, as did the 1960s rehab of the Jetty A. Since the time of previous jetty rehab, the MCR jetties have exhibited progressively lower reliability. The present reliability of North Jetty and Jetty A is significantly lower than at the time of jetty construction. Present reliability for the South Jetty is slightly lower now than at the time of jetty completion (1910). The South Jetty hindcast result is noteworthy because the South Jetty had very low reliability to start with; the 1930s rehabilitation effort had significantly improved the South Jetty reliability from its initial condition in 1910. The present reliability (for 2006/2007) shown in Figure A2- 43 through Figure A2- 64 are fairly LOW because these values are with respect to initial jetty head location (at time of jetty construction).

f. Hindcast Summary

The above hindcast modeling results indicate that the SRB model can accurately portray the historical life-cycle for the three MCR jetties in terms of the following performance metrics: jetty repair location, timing, and frequency; time-varying life-cycle cost; and jetty profile end state. Hindcast reliability clearly illustrates the emergent cyclical behavior of each jetty as it is damaged through time, becomes vulnerable, and is then repaired. As such, the SRB model was considered to be calibrated and verified to perform future life-cycle simulations for evaluation of optimal life-cycle investment strategies for the MCR jetties.

8. FUTURE CONDITION SRB SIMULATIONS

A number of alternatives were evaluated using the SRB Model. The list of alternatives for North Jetty, South Jetty and Jetty A are presented in Table A2- 18 through Table A2- 20; main governing parameters of each alternative are presented in Table A2- 21 through Table A2- 23. A more detailed description for each alternative is given in Appendix A1.

The selected results for each alternative are shown in figures A2-68 through A2-138 (provided at the end of this appendix). Each alternative figure number reference can be found in Table A2- 18 through Table A2- 20.

Table A2- 18. Future Condition Alternatives for MCR North Jetty

Figure No	Alternative Full Name	Alternative Short Name
32	Fix-as-Fail Repair	NJ_fut1_fixasfail_repair
33	Base Condition	NJ_fut1_base
34	Scheduled Repair	NJ_fut1_sched_repair
35	Scheduled Repair w/ Engineering Features	NJ_fut10_sched_repair
36	Scheduled Repair w/ Spur	NJ_fut10_sched_repair_no_headcap
37	Minimum Template Rehab - Immediate	NJ_fut21_immed_rehab_minimum
38	Composite 4 Small Rehab - Immediate	NJ_fut30_immed_rehab_comp4_small
39	Moderate Template Rehab - Immediate	NJ_fut23_immed_rehab_moderate
40	Large Template Rehab - Immediate	NJ_fut24_immed_rehab_large
41	Minimum Template Rehab - Scheduled	NJ_fut21_sched_rehab_minimum
42	Composite 3 Small Rehab - Scheduled	NJ_fut30_sched_rehab_comp3_small
43	Composite 4 Small Modified Rehab - Scheduled	NJ_fut30_sched_rehab_comp4_small_modi
44	Composite 2 Medium Rehab - Scheduled	NJ_fut30_sched_rehab_comp2_medium
45	Composite 1 Large Rehab - Scheduled	NJ_fut30_sched_rehab_comp1_large
46	Moderate Template Rehab - Scheduled	NJ_fut23_sched_rehab_moderate
47	Large Template Rehab - Scheduled	NJ_fut24_sched_rehab_large
48	Base Condition (Hold Head)	NJ_fut1_base_hold
49	Scheduled Repair (Hold Head)	NJ_fut1_sched_repair_hold
50	Scheduled Repair w/ Engineering Features (Hold Head)	NJ_fut10_sched_repair_hold
51	Scheduled Repair w/ Spur (Hold Head)	NJ_fut10_sched_repair_no_headcap_hold
52	Minimum Template Rehab - Immediate (Hold Head)	NJ_fut21_immed_rehab_minimum_hold
53	Composite 4 Small Rehab - Immediate (Hold Head)	NJ_fut30_immed_rehab_comp4_small_hold
54	Moderate Template Rehab - Immediate (Hold Head)	NJ_fut23_immed_rehab_moderate_hold
55	Large Template Rehab - Immediate (Hold Head)	NJ_fut24_immed_rehab_large_hold
56	Minimum Template Rehab - Scheduled (Hold Head)	NJ_fut21_sched_rehab_minimum_hold
57	Composite 3 Small Rehab - Scheduled (Hold Head)	NJ_fut30_sched_rehab_comp3_small_hold
58	Composite 4 Small Modified Rehab - Scheduled (Hold Head)	NJ_fut30_sched_rehab_comp4_small_modi_hold
59	Composite 2 Medium Rehab - Scheduled (Hold Head)	NJ_fut30_sched_rehab_comp2_medium_hold
60	Composite 1 Large Rehab - Scheduled (Hold Head)	NJ_fut30_sched_rehab_comp1_large_hold
61	Moderate Template Rehab - Scheduled (Hold Head)	NJ_fut23_sched_rehab_moderate_hold
62	Large Template Rehab - Scheduled (Hold Head)	NJ_fut24_sched_rehab_large_hold

Table A2- 19. Future Condition Alternatives for MCR South Jetty

Figure No	Alternative Full Name	Alternative Short Name
63	Fix-as-Fail Repair	SJ_fut1_fixasfail_repair
64	Base Condition	SJ_fut1_base
65	Scheduled Repair w/ Engineering Features	SJ_fut10_sched_repair_head_spur
66	Scheduled Repair w/ Head Capping	SJ_fut10_sched_repair_head
67	Scheduled Repair	SJ_fut1_sched_repair
68	Minimum Template Rehab - Immediate	SJ_fut21_immed_rehab_minimum
69	Composite 3 Small Rehab - Immediate	SJ_fut30_immed_rehab_comp3_small
70	Small Template Rehab - Immediate	SJ_fut22_immed_rehab_small
71	Moderate Template Rehab - Immediate	SJ_fut23_immed_rehab_moderate
72	Large Template Rehab - Immediate	SJ_fut24_immed_rehab_large
73	Composite 4 Medium Rehab - Immediate	SJ_fut30_immed_rehab_comp4_medium
74	Composite 1 Large Rehab - Immediate	SJ_fut30_immed_rehab_comp1_large
75	Composite 5 Modified 2 Rehab - Immediate	SJ_fut30_immed_rehab_comp5_modi2
76	Composite 2 Modified 1 Rehab - Immediate	SJ_fut30_immed_rehab_comp2_modi1
77	Minimum Template Rehab - Scheduled	SJ_fut21_sched_rehab_minimum
78	Composite 5 Modified 2 Rehab - Scheduled	SJ_fut30_sched_rehab_comp5_modi2
79	Base Condition (Hold Head)	SJ_fut1_base_hold
80	Scheduled Repair w/ Engineering Features (Hold Head)	SJ_fut10_sched_repair_head_spur_hold
81	Scheduled Repair w/ Head Capping (Hold Head)	SJ_fut10_sched_repair_head_hold
82	Scheduled Repair (Hold Head)	SJ_fut1_sched_repair_hold
83	Minimum Template Rehab - Immediate (Hold Head)	SJ_fut21_immed_rehab_minimum_hold
84	Composite 3 Small Rehab - Immediate (Hold Head)	SJ_fut30_immed_rehab_comp3_small_hold
85	Small Template Rehab - Immediate (Hold Head)	SJ_fut22_immed_rehab_small_hold
86	Moderate Template Rehab - Immediate (Hold Head)	SJ_fut23_immed_rehab_moderate_hold
87	Large Template Rehab - Immediate (Hold Head)	SJ_fut24_immed_rehab_large_hold
88	Composite 4 Medium Rehab - Immediate (Hold Head)	SJ_fut30_immed_rehab_comp4_medium_hold
89	Composite 1 Large Rehab - Immediate (Hold Head)	SJ_fut30_immed_rehab_comp1_large_hold
90	Composite 5 Modified 2 Rehab - Immediate (Hold Head)	SJ_fut30_immed_rehab_comp5_modi2_hold
91	Composite 2 Modified 1 Rehab - Immediate (Hold Head)	SJ_fut30_immed_rehab_comp2_modi1_hold
92	Minimum Template Rehab - Scheduled (Hold Head)	SJ_fut21_sched_rehab_minimum_hold
93	Composite 5 Modified 2 Rehab - Scheduled (Hold Head)	SJ_fut30_sched_rehab_comp5_modi2_hold

Table A2- 20. Future Condition Alternatives for MCR Jetty A

Figure No	Alternative Full Name	Alternative Short Name
94	Fix-as-Fail Repair	JA_fut1_fixasfail_repair
95	Base Condition	JA_fut1_base
96	Scheduled Repair	JA_fut1_sched_repair
97	Small Template Rehab (Plan A) - Immediate	JA_fut22_immed_rehab_small
98	Small Template Rehab (Plan B) - Immediate	JA_fut23_immed_rehab_small
99	Base Condition (Hold Head)	JA_fut1_base_hold
100	Scheduled Repair (Hold Head)	JA_fut1_sched_repair_hold
101	Small Template Rehab (Plan A) - Immediate (Hold Head)	JA_fut22_immed_rehab_small_hold
102	Small Template Rehab (Plan B) - Immediate (Hold Head)	JA_fut23_immed_rehab_small_hold

Table A2- 21. Parameters of Future Condition Alternatives for MCR North Jetty

Folder Name	fut	geometry_ calc_type	Comp_ num	proj_ impl	root_ fill	head_ cap	hold_ head	spur_ place	defer_rep air_begin	defer_re pair_set	write_out_ wav_area	constrain_fo ot_print
NJ_fut1_fixasfail_repair	1	1		0	0	0	0	0	0	0	1	1
NJ_fut1_base	1	1		0	0	0	0	0	1	1	0	1
NJ_fut1_sched_repair	1	1		0	0	0	0	0	3	3	0	1
NJ_fut10_sched_repair	10	1		9	0	1	0	1	3	3	0	1
NJ_fut10_sched_repair_no_headcap	10	1		9	0	0	0	1	3	3	0	1
NJ_fut21_immed_rehab_minimum	21	1		9	0	1	0	1	1	1	0	1
NJ_fut30_immed_rehab_comp4_small	30	1	4	9	0	1	0	1	1	1	0	1
NJ_fut23_immed_rehab_moderate	23	1		9	0	1	0	1	1	1	0	1
NJ_fut24_immed_rehab_large	24	1		9	0	1	0	1	1	1	0	1
NJ_fut21_sched_rehab_minimum	21	1		9	0	1	0	1	1	1	0	1
NJ_fut30_sched_rehab_comp3_small	30	1	3	9	0	1	0	1	1	1	0	1
NJ_fut30_sched_rehab_comp4_small_modi	30	1	4	9	0	1	0	1	1	1	0	1
NJ_fut30_sched_rehab_comp2_medium	30	1	2	9	0	1	0	1	1	1	0	1
NJ_fut30_sched_rehab_comp1_large	30	1	1	9	0	1	0	1	1	1	0	1
NJ_fut23_sched_rehab_moderate	23	1		9	0	1	0	1	1	1	0	1
NJ_fut24_sched_rehab_large	24	1		9	0	1	0	1	1	1	0	1
NJ_fut1_base_hold	1	1		0	0	0	1	0	1	1	0	1
NJ_fut1_sched_repair_hold	1	1		0	0	0	1	0	3	3	0	1
NJ_fut10_sched_repair_hold	10	1		9	0	0	1	1	3	3	0	1
NJ_fut10_sched_repair_no_headcap_hold	10	1		9	0	0	1	1	3	3	0	1
NJ_fut21_immed_rehab_minimum_hold	21	1		9	0	0	1	1	1	1	0	1
NJ_fut30_immed_rehab_comp4_small_hold	30	1	4	9	0	0	1	1	1	1	0	1
NJ_fut23_immed_rehab_moderate_hold	23	1		9	0	0	1	1	1	1	0	1
NJ_fut24_immed_rehab_large_hold	24	1		9	0	0	1	1	1	1	0	1
NJ_fut21_sched_rehab_minimum_hold	21	1		9	0	0	1	1	1	1	0	1
NJ_fut30_sched_rehab_comp3_small_hold	30	1	3	9	0	0	1	1	1	1	0	1
NJ_fut30_sched_rehab_comp4_small_modi_hold	30	1	4	9	0	0	1	1	1	1	0	1
NJ_fut30_sched_rehab_comp2_medium_hold	30	1	2	9	0	0	1	1	1	1	0	1
NJ_fut30_sched_rehab_comp1_large_hold	30	1	1	9	0	0	1	1	1	1	0	1
NJ_fut23_sched_rehab_moderate_hold	23	1		9	0	0	1	1	1	1	0	1
NJ_fut24_sched_rehab_large_hold	24	1		9	0	0	1	1	1	1	0	1

Table A2- 22. Parameters of Future Condition Alternatives for MCR South Jetty

Folder Name	fut	geometry_ calc_type	Comp_ num	proj_ impl	root_ fill	head_ cap	hold_ head	spur_ place	defer_rep air_begin	defer_re pair_set	write_out_ wav_area	constrain_fo ot_print
SJ_fut1_fixasfail_repair	1	1		0	1	0	0	0	0	0	1	1
SJ_fut1_base	1	1		0	1	0	0	0	1	1	0	1
SJ_fut10_sched_repair_head_spur	10	1		11	1	1	0	1	3	3	0	1
SJ_fut10_sched_repair_head	10	1		11	1	1	0	0	3	3	0	1
SJ_fut1_sched_repair	1	1		0	1	0	0	0	3	3	0	1
SJ_fut21_immed_rehab_minimum	21	1		11	1	1	0	1	1	1	0	1
SJ_fut30_immed_rehab_comp3_small	30	1	3	11	1	1	0	1	1	1	0	1
SJ_fut22_immed_rehab_small	22	1		11	1	1	0	1	1	1	0	1
SJ_fut23_immed_rehab_moderate	23	1		11	1	1	0	1	1	1	0	1
SJ_fut24_immed_rehab_large	24	1		11	1	1	0	1	1	1	0	1
SJ_fut30_immed_rehab_comp4_medium	30	1	4	11	1	1	0	1	1	1	0	1
SJ_fut30_immed_rehab_comp1_large	30	1	1	11	1	1	0	1	1	1	0	1
SJ_fut30_immed_rehab_comp5_modi2	30	1	5	11	1	1	0	1	1	1	0	1
SJ_fut30_immed_rehab_comp2_modi1	30	1	2	11	1	1	0	1	1	1	0	1
SJ_fut21_sched_rehab_minimum	21	1		11	1	1	0	1	1	1	0	1
SJ_fut30_sched_rehab_comp5_modi2	30	1	5	11	1	1	0	1	1	1	0	1
SJ_fut1_base_hold	1	1		0	1	0	1	0	1	1	0	1
SJ_fut10_sched_repair_head_spur_hold	10	1		11	1	0	1	1	3	3	0	1
SJ_fut10_sched_repair_head_hold	10	1		11	1	0	1	0	3	3	0	1
SJ_fut1_sched_repair_hold	1	1		0	1	0	1	0	3	3	0	1
SJ_fut21_immed_rehab_minimum_hold	21	1		11	1	0	1	1	1	1	0	1
SJ_fut30_immed_rehab_comp3_small_hold	30	1	3	11	1	0	1	1	1	1	0	1
SJ_fut22_immed_rehab_small_hold	22	1		11	1	0	1	1	1	1	0	1
SJ_fut23_immed_rehab_moderate_hold	23	1		11	1	0	1	1	1	1	0	1
SJ_fut24_immed_rehab_large_hold	24	1		11	1	0	1	1	1	1	0	1
SJ_fut30_immed_rehab_comp4_medium_hold	30	1	4	11	1	0	1	1	1	1	0	1
SJ_fut30_immed_rehab_comp1_large_hold	30	1	1	11	1	0	1	1	1	1	0	1
SJ_fut30_immed_rehab_comp5_modi2_hold	30	1	5	11	1	0	1	1	1	1	0	1
SJ_fut30_immed_rehab_comp2_modi1_hold	30	1	2	11	1	0	1	1	1	1	0	1
SJ_fut21_sched_rehab_minimum_hold	21	1		11	1	0	1	1	1	1	0	1
SJ_fut30_sched_rehab_comp5_modi2_hold	30	1	5	11	1	0	1	1	1	1	0	1

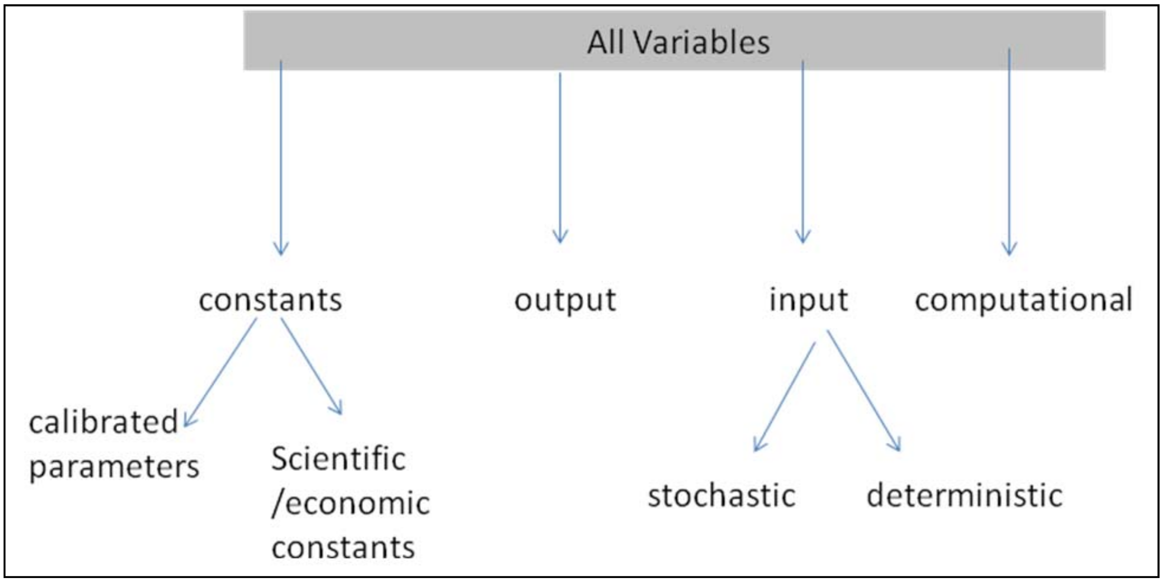
Table A2- 23. Parameters of Future Condition Alternatives for MCR Jetty A

Folder Name	fut	geometry_ calc_type	Comp_ num	proj_ impl	root_ fill	head_ cap	hold_ head	spur_ place	defer_rep air_begin	defer_re pair_set	write_out_ wav_area	constrain_fo ot_print
JA_fut1_fixasfail_repair	1	1		0	1	0	0	0	0	0	1	1
JA_fut1_base	1	1		0	1	0	0	0	1	1	0	1
JA_fut1_sched_repair	1	1		0	1	0	0	0	3	3	0	1
JA_fut22_immed_rehab_small	22	1		9	1	1	0	1	1	1	0	1
JA_fut23_immed_rehab_small	23	1		9	1	1	0	1	1	1	0	1
JA_fut1_base_hold	1	1		0	1	0	1	0	1	1	0	1
JA_fut1_sched_repair_hold	1	1		0	1	0	1	0	3	3	0	1
JA_fut22_immed_rehab_small_hold	22	1		9	1	0	1	1	1	1	0	1
JA_fut23_immed_rehab_small_hold	23	1		9	1	0	1	1	1	1	0	1

9. SRB MODEL SENSITIVITY ANALYSIS AND VARIABLE DEFINITION

a. Variables Used in SRB Model

There are approximately 600 variables used in the SRB model, all of which can be segregated into four categories: constants, output, computational, and input. The below graphic illustrates the four categories for variable definition. Refer to Appendix A3: SRB Model User's Manual for a listing of variables using within the SRB model.



b. Evaluation of Variable Variation

A model sensitivity analysis was conducted to ascertain the effect that random variation of 11 specific model parameters had on the overall predicted life-cycle cost ranges. These specific parameters were deemed to have the most impact on life-cycle performance estimates. The sensitivity analysis was run for each of the three MCR jetties for the base condition (no action alternative). One at a time, the 11 model parameters were allowed to randomly vary, while holding all other parameters at a constant value (mean value). Twenty-five Monte Carlo simulations were run for each varied parameter to obtain a representative range of life-cycle costs for "single parameter" variation.

In addition to allowing each individual parameter to vary one at a time, an additional Monte Carlo simulation was run allowing all parameters to randomly vary simultaneously (unconstrained run). The unconstrained run provided a life-cycle mean cost (global mean) by which to compare the "single parameter" variation results of the sensitivity analysis.

Through this procedure, a range of life-cycle costs, dependent on variation in one parameter, as well as a baseline for comparison (all parameters allowed to vary), were estimated. The results, when plotted, produce an immediate, ranked view of the parameters that have the largest impact on life-cycle cost range. The parameters that were included in this analysis are listed in Table A2- 24.

Table A2- 24. Randomly Varied Parameters, Description and Respective Nomenclature Used in Figure Labels.

Model Parameter Name	Parameter Description	Figure Label
dam_var	Variation on the amount of damage that is applied for a specific wave height in a particular storm event. Adds random variation to the applied damage functions.	**Jetty Wave Damage Variation**
COST_VAR	Variation on the cost labor and materials included in the model (e.g. dredging, breaching, stone costs, etc.). Adds random variation to costs of these items.	**Unit Cost Variation**
lowest_bound	Damage threshold variation for determining when a breach can occur. Adds random variation to the threshold below which breaching is allowed to occur.	**Breach Damage Threshold Variation**
upper_bound	Damage threshold variation for determining when repairs can be made. Adds random variation to the threshold below which repairs can be made.	**Repair Damage Threshold Variation**
B_COST_SEG_INCR	Variation on the dredging cost due to breaching. This is only activated when breaching occurs in the model.	**Breach Related Dredging Costs**
re_use_stone_factor_repair	Variation on the amount of jetty stone that is needed with each successive repair.	**Jetty Stone Repair Factor Variation**
storm_nyear	Variation on the number of storm events per year. Randomly varies the number of storm events predicted to occur annually.	**Annual No. Storm Events**
WAT_LVL	Total Water Level variation (including variation in tide level, storm surge and infragravity surge). Randomly varies the tide level, storm surge and infragravity surge components of the total water level. The sum of the random predictions plus the expected sea level rise for a given year is the total water level during a given storm event.	**Total Storm Water Level**
Wave_H_request	Variation in offshore storm wave height. Adds variation to the deepwater offshore wave height predicted for a given year.	**Offshore Storm Wave Height**
DIR_initial	Variation in primary offshore storm wave direction (Determines from NW or SW direction). Adds variation to the initial direction, which selects waves from the NW or SW, two different storm distributions.	**Offshore Storm Wave Direction [1]**
Wave_DIR_request	Variation in secondary offshore storm wave direction (Variation within NW or SW directions). Adds variation within the initial wave direction.	**Offshore Storm Wave Direction [2]**

Life-cycle costs in the analysis were computed by summing annual costs for each Monte Carlo simulation. Twenty-five (25) life-cycle costs (25 Monte Carlo simulations) were estimated for each varied parameter simulation. The minimum and maximum life-cycle cost for each varied parameter simulation defined the 'life-cycle cost range' of that respective parameter. Then, the life-cycle cost range for each parameter was normalized, ranked and plotted, using the following equation:

$$X_n = \left(\frac{X - \overline{X}_i}{\overline{X}_g} \right)$$

where X_n is the normalized lifecycle costs for variation of a specific parameter; X represents the lifecycle cost minimum and maximum values, in current dollar value; $\overline{X}_i$ is the life-cycle cost mean value computed from each *individual* varied parameter simulation result (mean life-cycle cost of 25 Monte Carlo simulations), and $\overline{X}_g$ is the life-cycle cost *global* mean value computed from the baseline simulation results (mean cost of 25 baseline condition simulations).

When plotted, the results produce a ranked view of the parameters that have the largest to least (top to bottom) effect on estimated life-cycle cost range with respect to the global mean value (Figures A2-29 to A2-31). The cost range associated with each varied parameter in the plots below denotes the amount of variation about the global mean life-cycle cost that can be expected from only the contribution of the specific varied parameter.

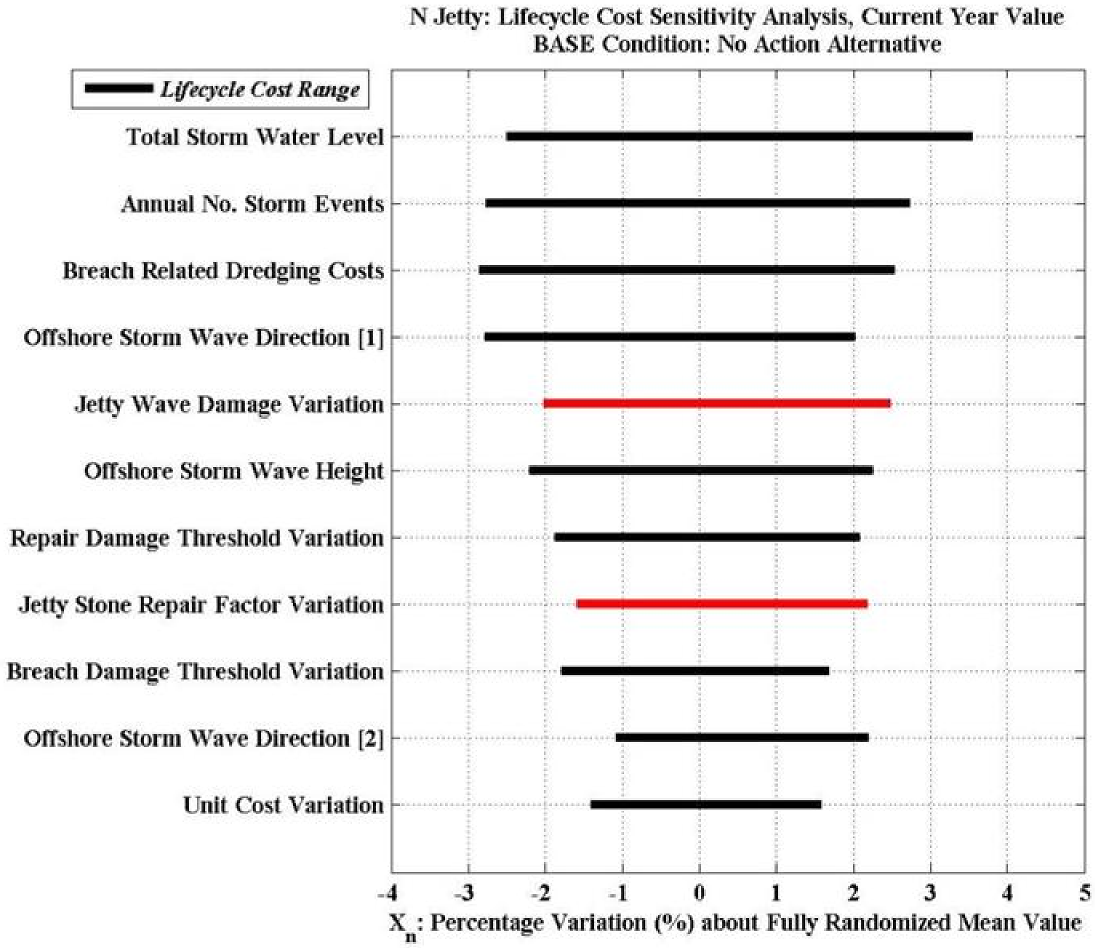


Figure A2- 65. Tornado Plot for North Jetty – Sensitivity Analysis for Key Variables

Red colors denote calibration parameters.

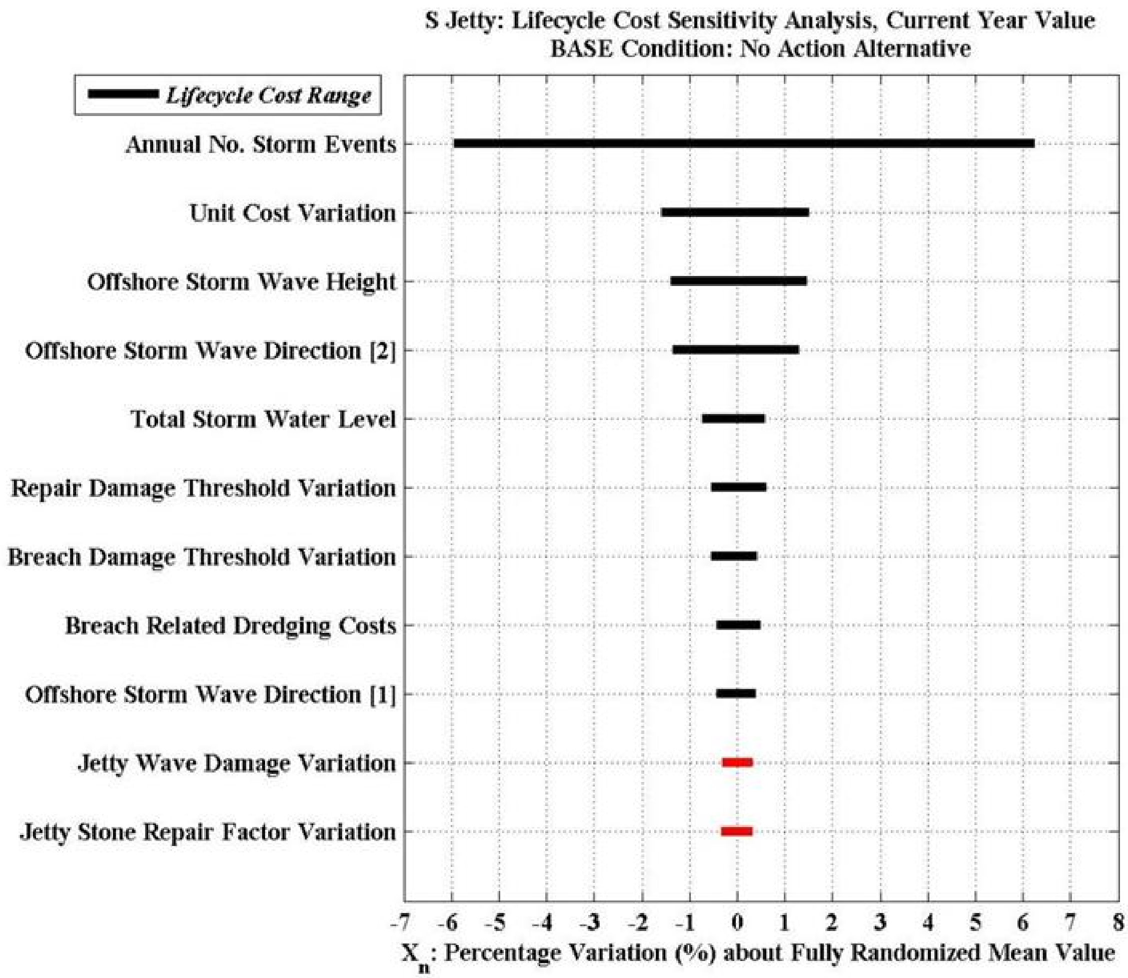


Figure A2- 66. Tornado Plot for South Jetty – Sensitivity Analysis for Key Variables

Red colors denote calibration parameters.

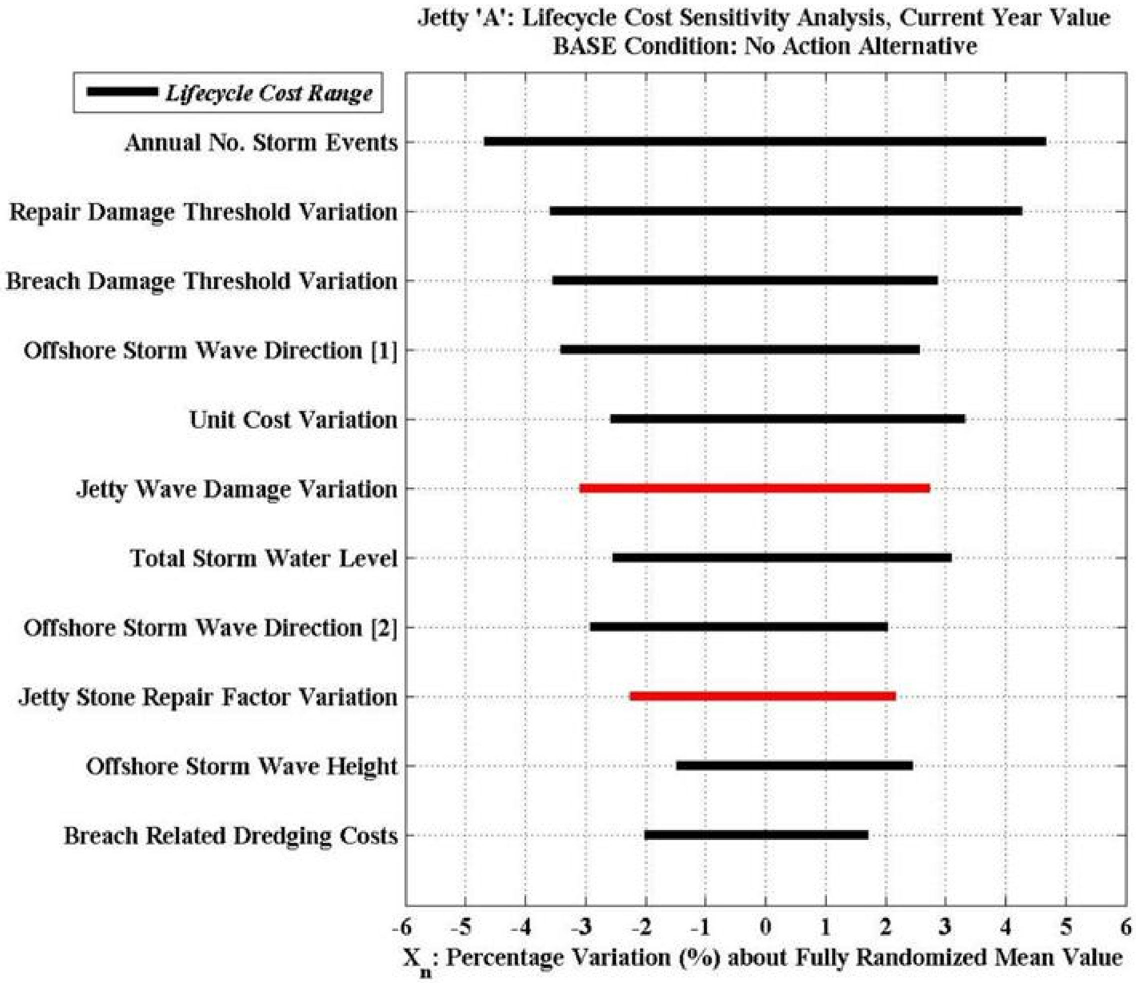


Figure A2- 67. Tornado Plot for Jetty A – Sensitivity Analysis for Key Variables

Red colors denote calibration parameters.

The parameters that were included in this analysis are listed in Table A2- 24. The results produce what is commonly referred to as a 'tornado plot' (a.k.a. tornado chart or tornado diagram) because the shape of the plot when ranked (maximum cost range at top, minimum cost range at bottom) resembles a tornado. An observer can immediately identify the randomized parameters that contribute to the largest variability in lifecycle cost ranges (located at the top of the figure).

c. Influence and Ranking of Key Variables

In Figure A2- 65 through Figure A2- 67, two of the parameters used to calibrate the models are highlighted in red to show the effect that varying the calibrated parameters has on expected life-cycle costs. The calibration parameters appear to have a larger influence over life-cycle costs for Jetty A than for the North or South Jetties.

It is noteworthy to point out that there is a significant difference in tornado plot results between the South Jetty and the other two jetties. The reason for this is that the South

Jetty life-cycle response is a product of the different environmental exposures between the jetties. The South Jetty is the longest of the jetties (i.e., more segments that are subject to damage and repair) and experiences a different storm wave environment (more exposed) than the other two jetties due to its location and orientation. Therefore, it has the potential to experience more damage and repair costs over its expected lifetime.

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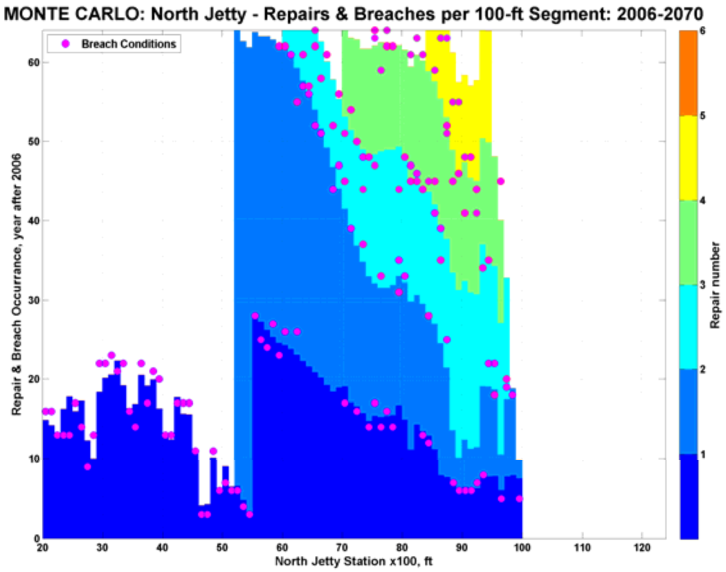

Figure A2-68a. Forecast repair occurrence for MCR North Jetty, shown for each 100 ft jetty segment. Fix-as-Fail Repair.

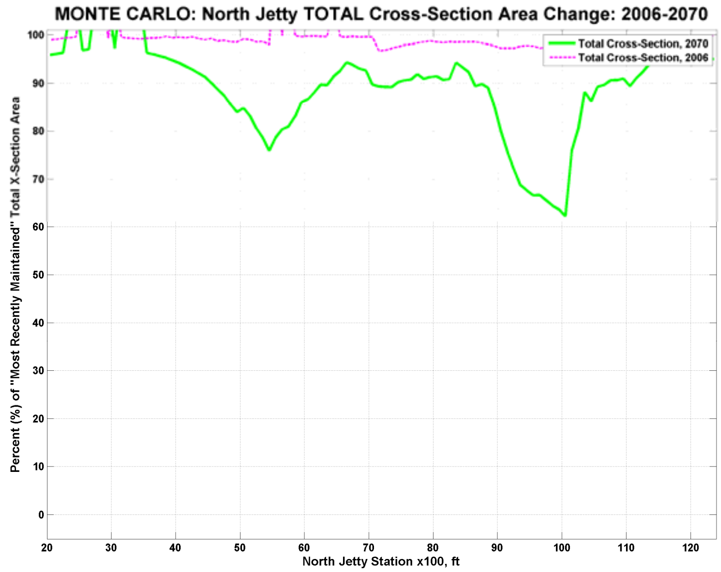

Figure A2-68b. Variation in total cross-section area along MCR North Jetty during forecast period. Fix-as-Fail Repair.

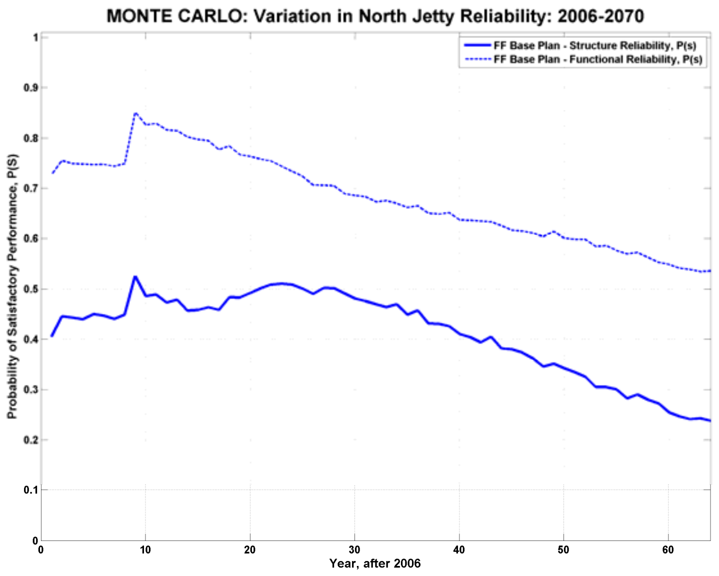

Figure A2-68c. Forecast reliability for MCR North Jetty. Fix-as-Fail Repair.

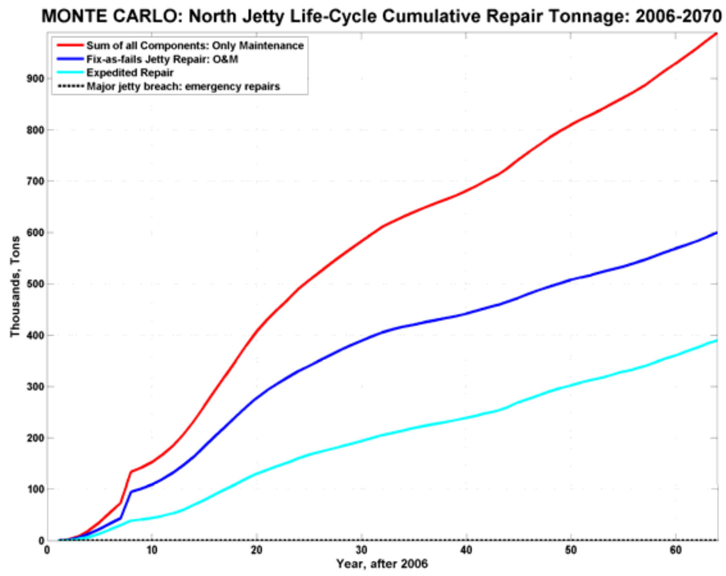

Figure A2-68d. Life-cycle cumulative repair tonnage for MCR North Jetty. Fix-as-Fail Repair.

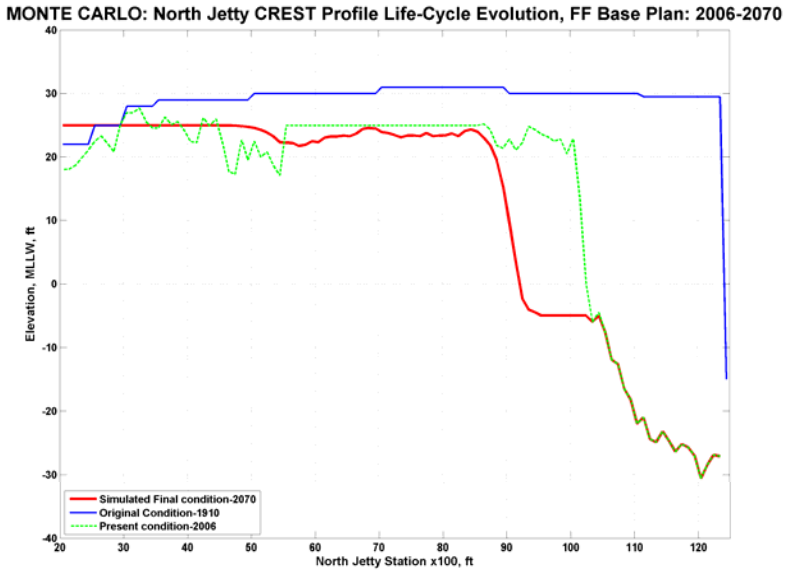

Figure A2-68e. Centerline profile for MCR North Jetty. Fix-as-Fail Repair.

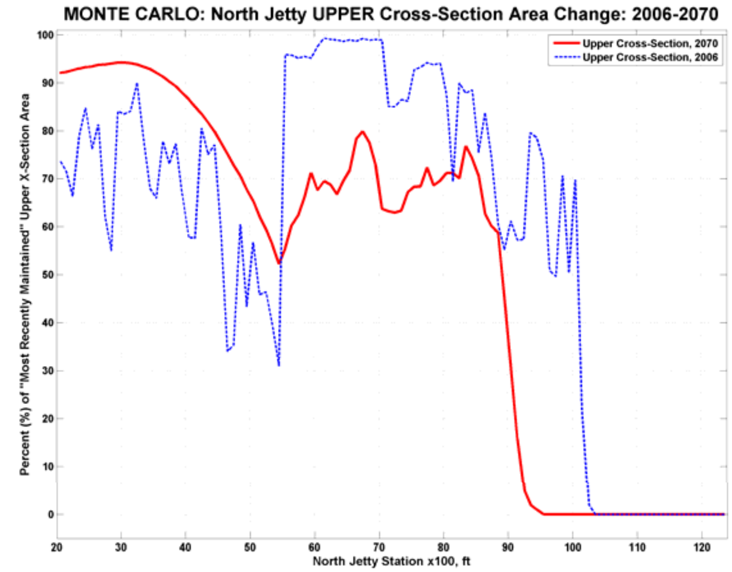

Figure A2-68f. Variation of upper cross-section area for given station of MCR North Jetty. Fix-as-Fail Repair.

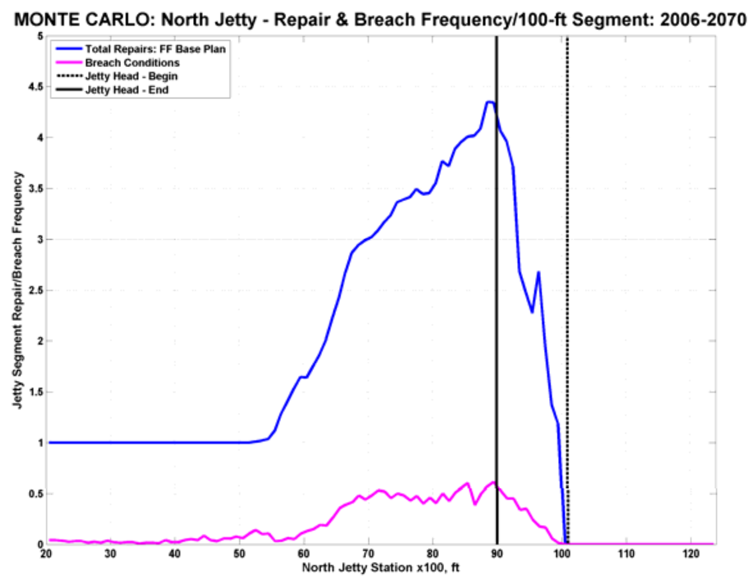

Figure A2-68g. Frequency and location of repairs and breaches for MCR North Jetty. Fix-as-Fail Repair.

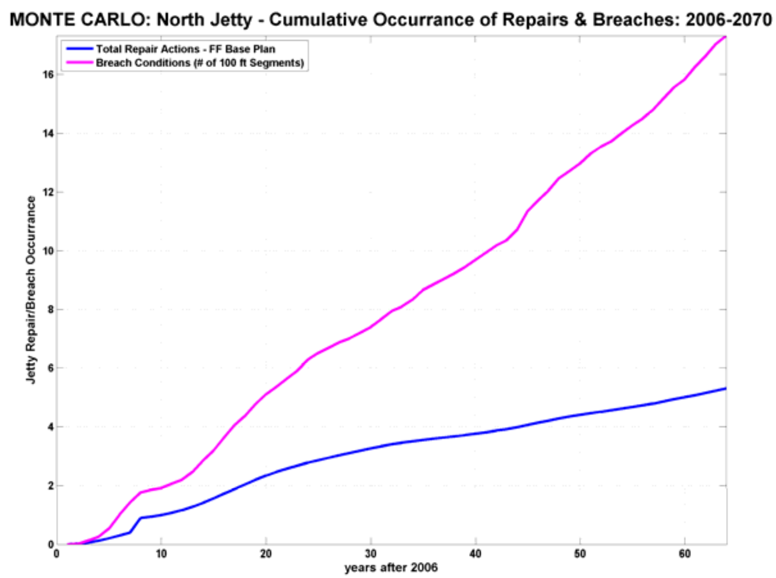

Figure A2-68h. Cumulative occurrence of repairs and breach conditions for MCR North Jetty. Fix-as-Fail Repair.

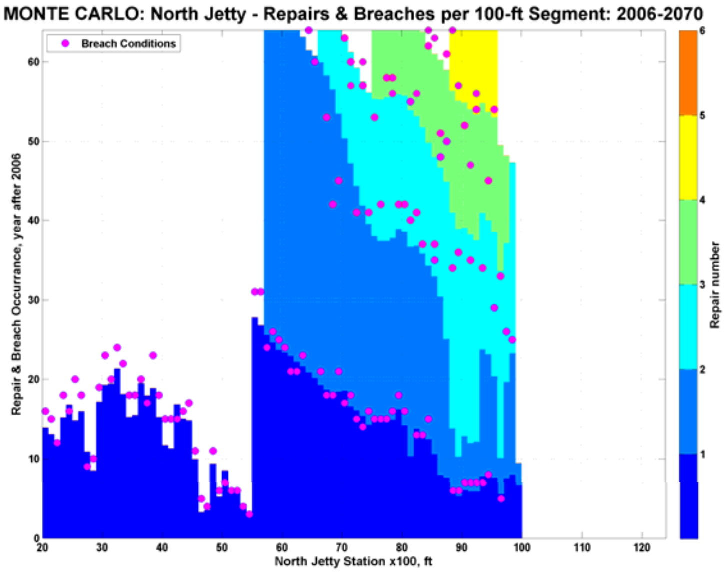

Figure A2-69a. Forecast repair occurrence for MCR North Jetty, shown for each 100 ft jetty segment. Base Condition.

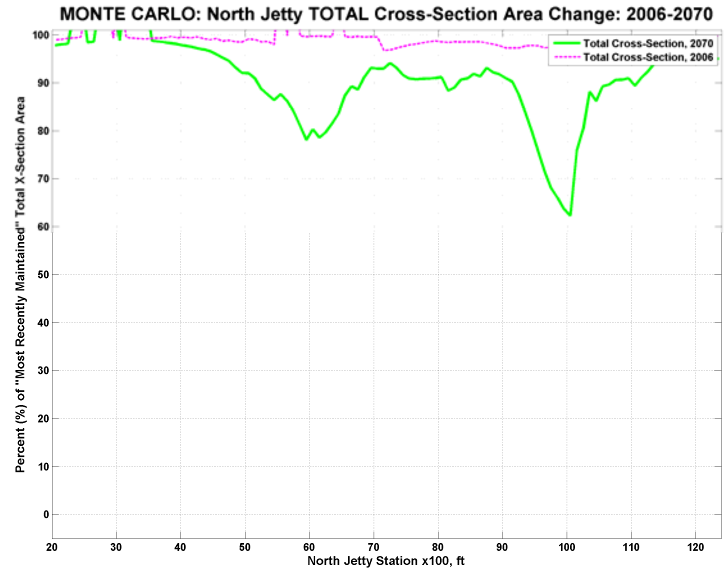

Figure A2-69b. Variation in total cross-section area along MCR North Jetty during forecast period. Base Condition.

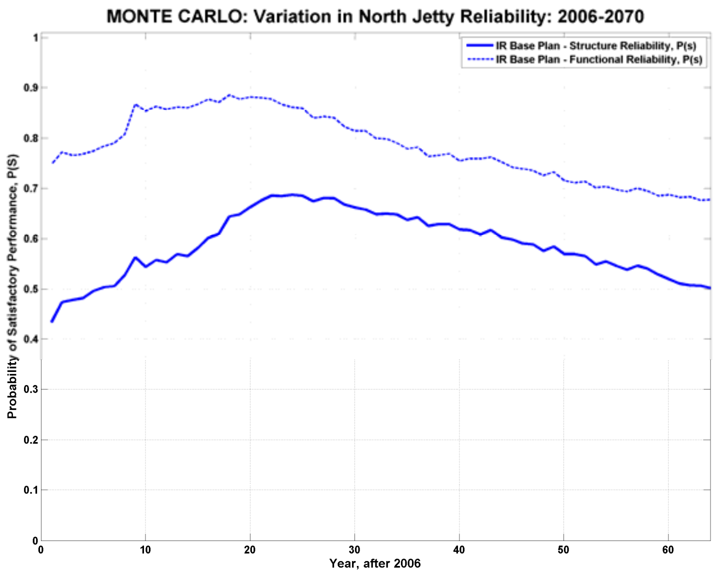

Figure A2-69c. Forecast reliability for MCR North Jetty. Base Condition.

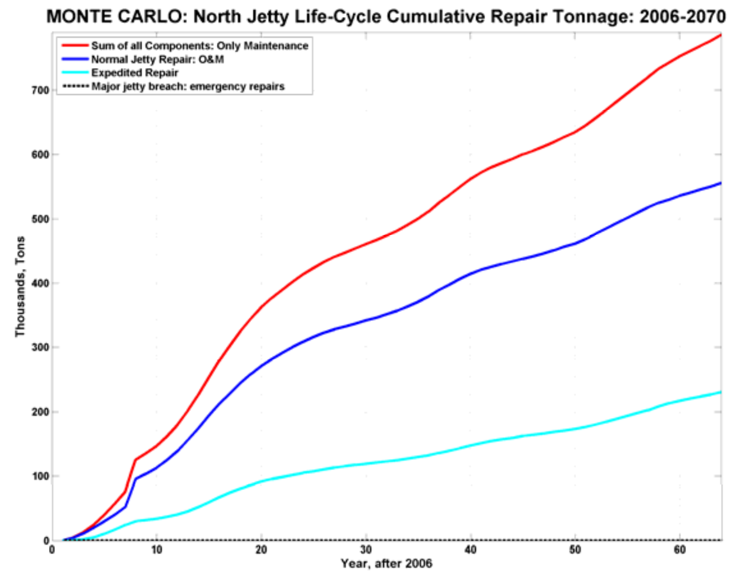

Figure A2-69d. Life-cycle cumulative repair tonnage for MCR North Jetty. Base Condition.

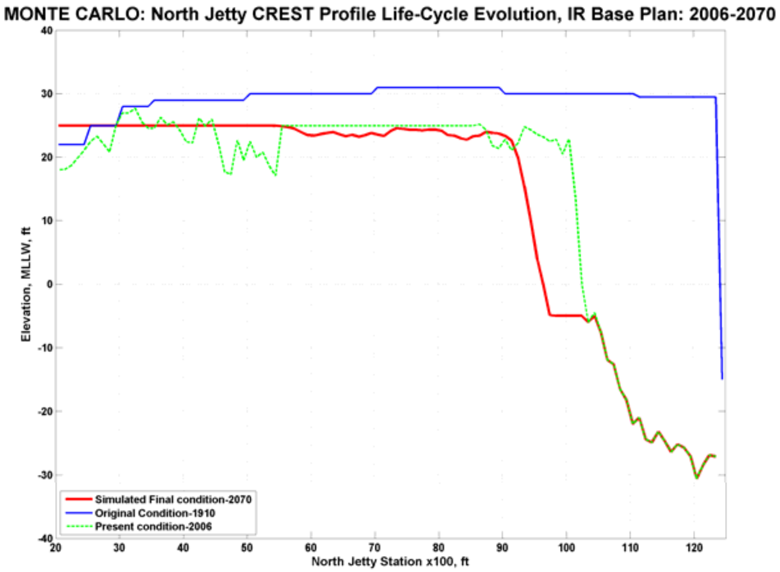

Figure A2-69e. Centerline profile for MCR North Jetty. Base Condition.

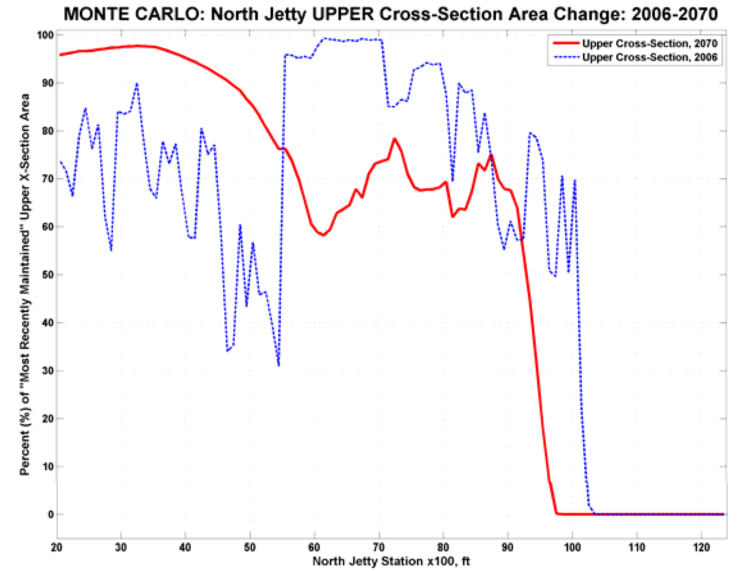

Figure A2-69f. Variation of upper cross-section area for given station of MCR North Jetty. Base Condition.

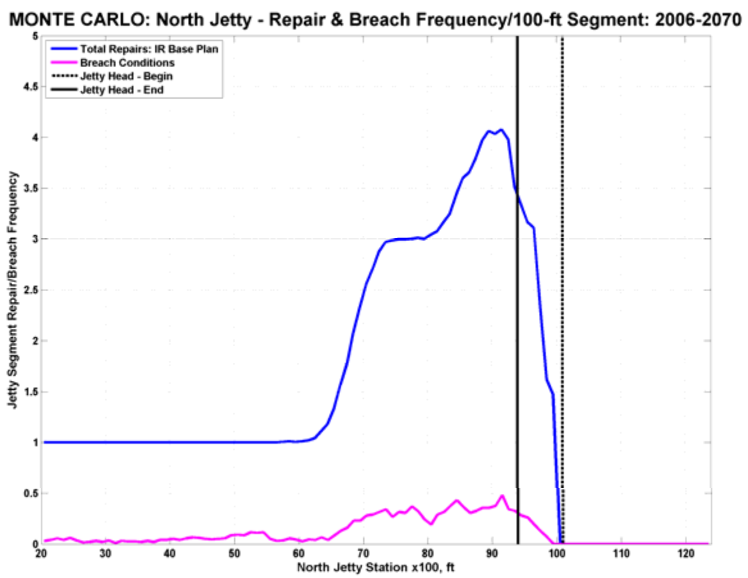

Figure A2-69g. Frequency and location of repairs and breaches for MCR North Jetty. Base Condition.

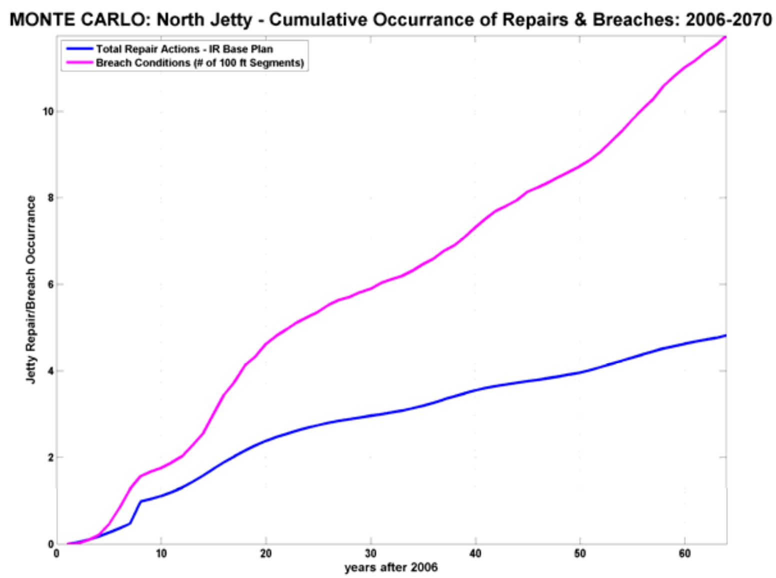

Figure A2-69h. Cumulative occurrence of repairs and breach conditions for MCR North Jetty. Base Condition.

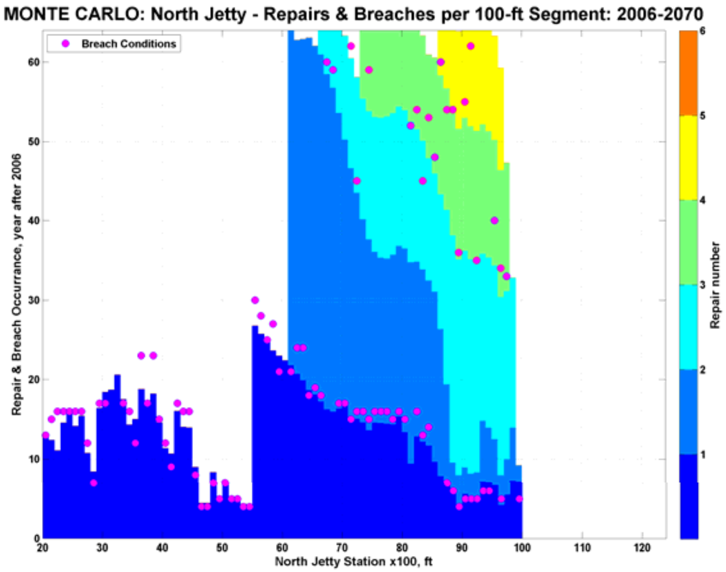

Figure A2-70a. Forecast repair occurrence for MCR North Jetty, shown for each 100 ft jetty segment. Scheduled Repair.

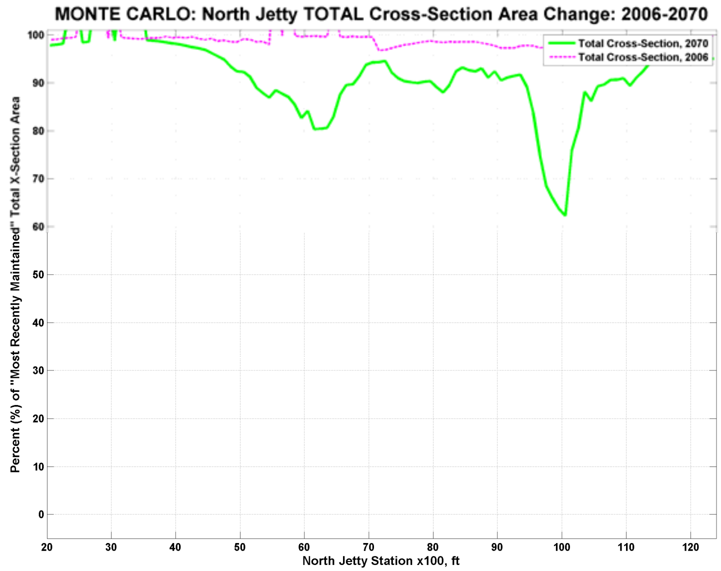

Figure A2-70b. Variation in total cross-section area along MCR North Jetty during forecast period. Scheduled Repair.

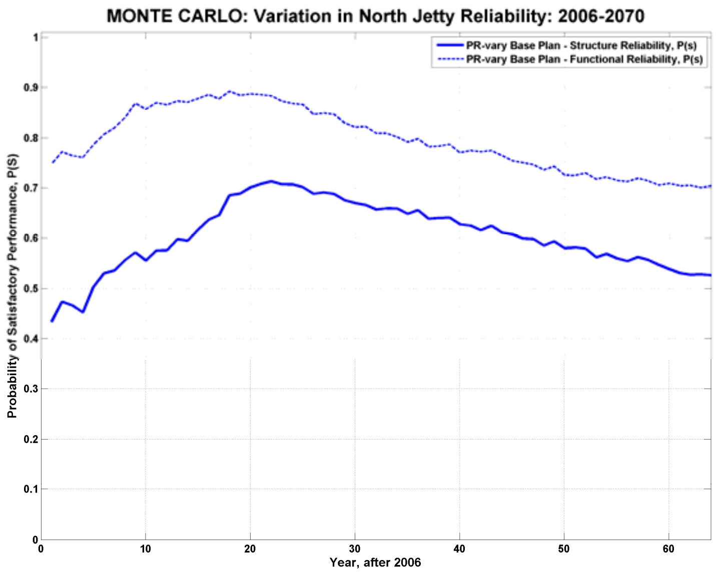

Figure A2-70c. Forecast reliability for MCR North Jetty. Scheduled Repair.

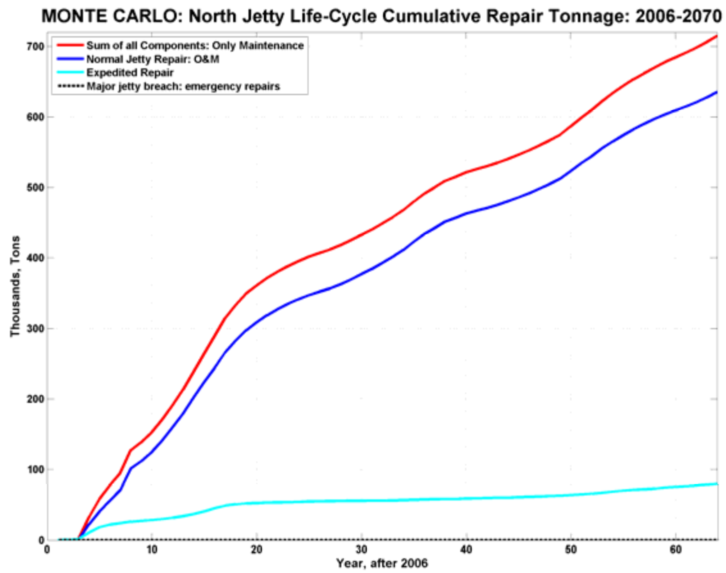

Figure A2-70d. Life-cycle cumulative repair tonnage for MCR North Jetty. Scheduled Repair.

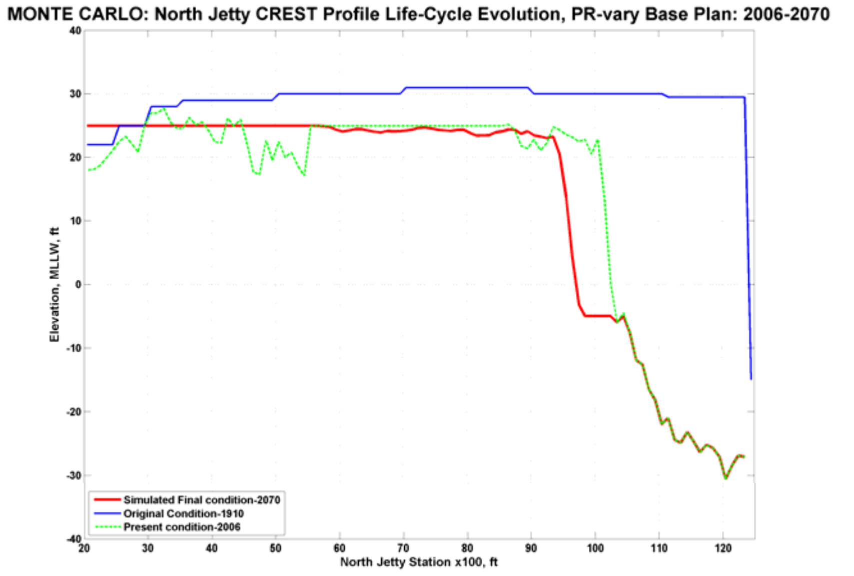

Figure A2-70e. Centerline profile for MCR North Jetty. Scheduled Repair.

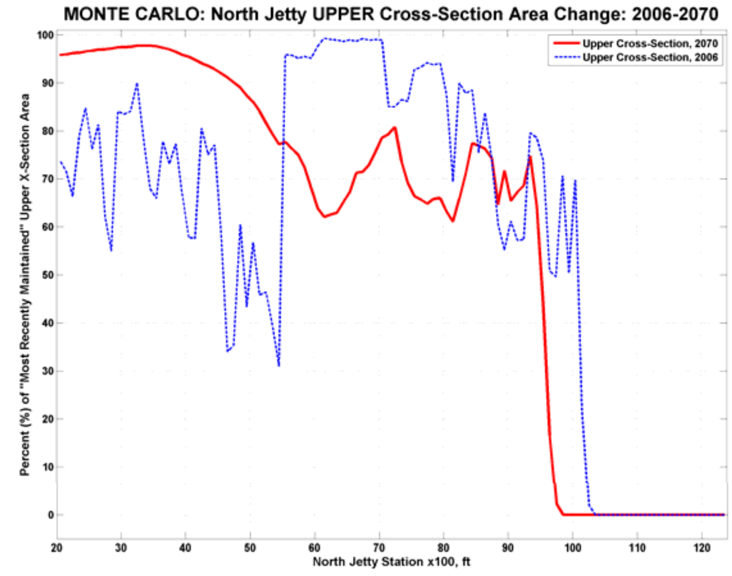

Figure A2-70f. Variation of upper cross-section area for given station of MCR North Jetty. Scheduled Repair.

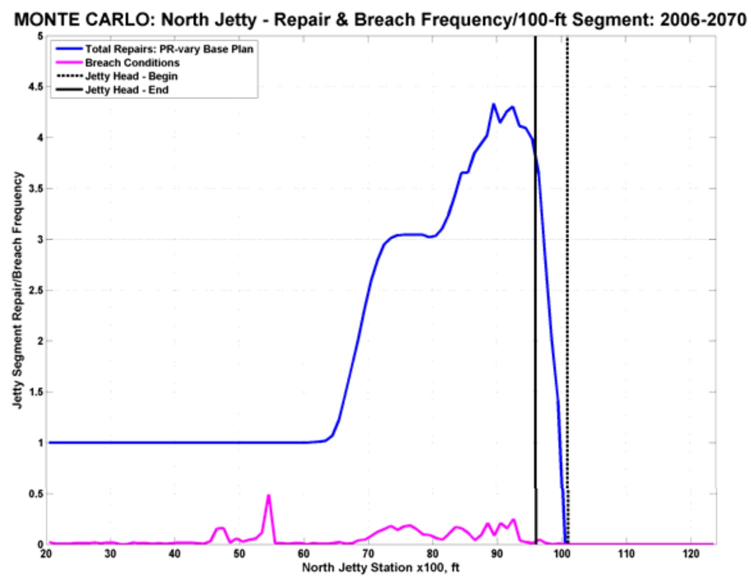

Figure A2-70g. Frequency and location of repairs and breaches for MCR North Jetty. Scheduled Repair.

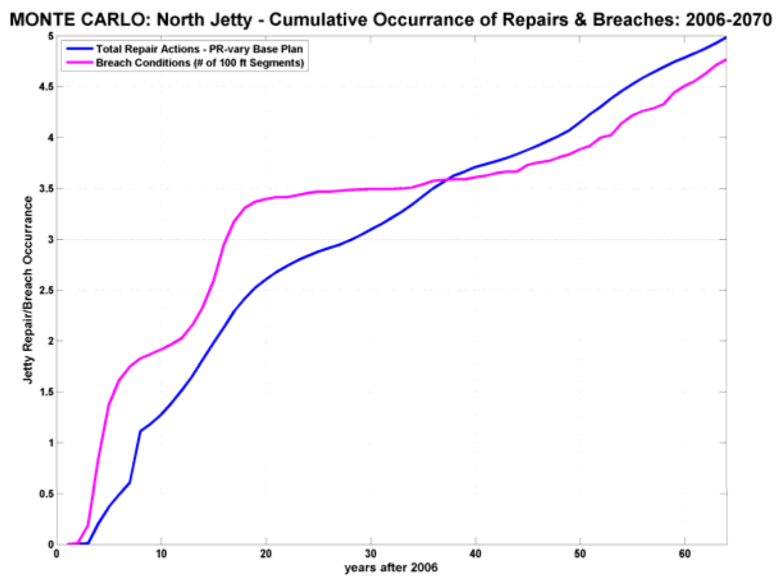

Figure A2-70h. Cumulative occurrence of repairs and breach conditions for MCR North Jetty. Scheduled Repair.

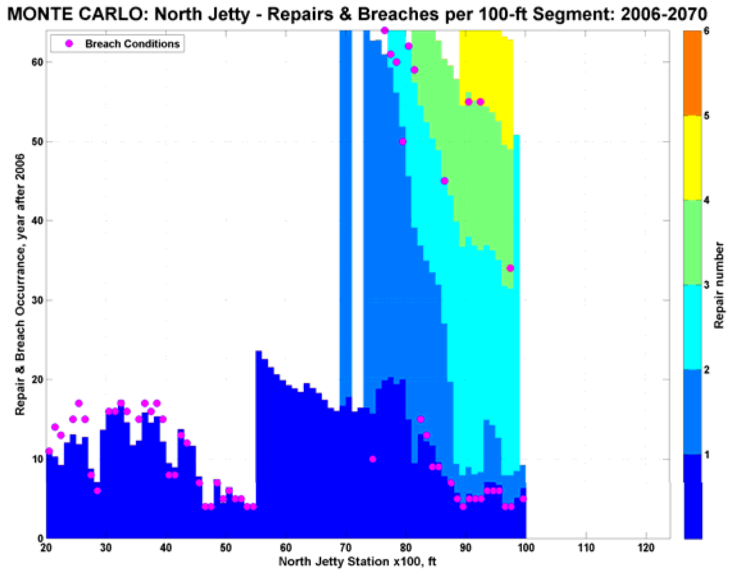

Figure A2-71a. Forecast repair occurrence for MCR North Jetty, shown for each 100 ft jetty segment. Scheduled Repair w/ Engineering Features.

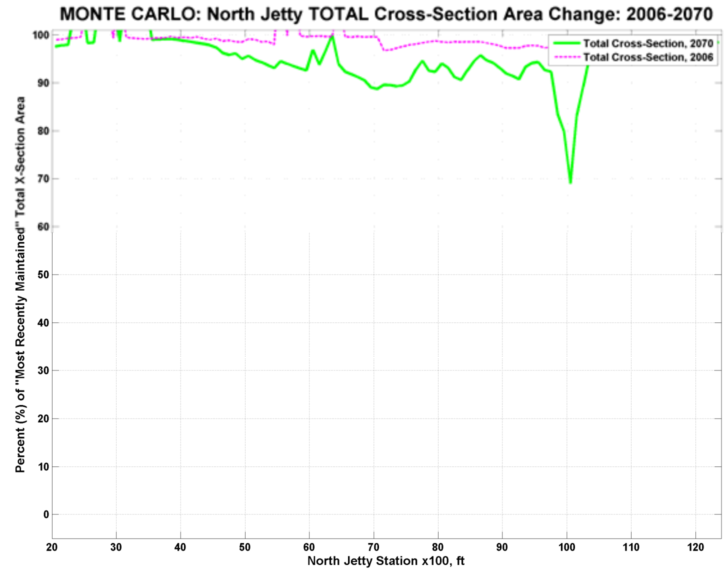

Figure A2-71b. Variation in total cross-section area along MCR North Jetty during forecast period. Scheduled Repair w/ Engineering Features.

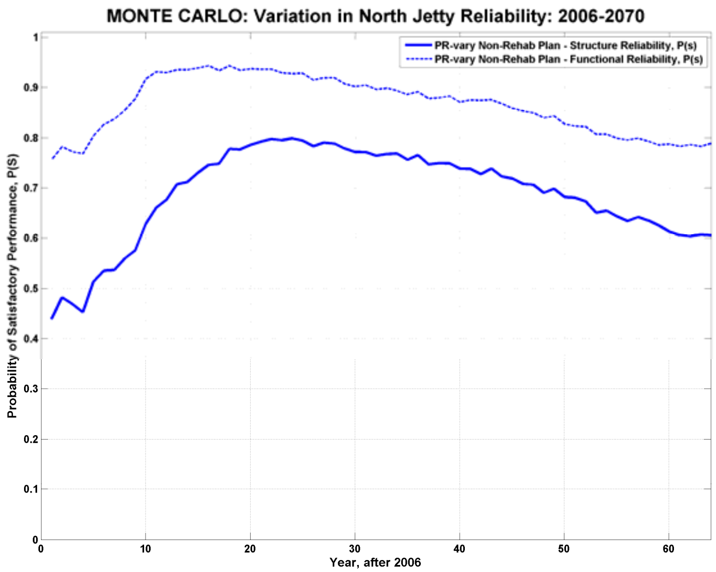

Figure A2-71c. Forecast reliability for MCR North Jetty. Scheduled Repair w/ Engineering Features.

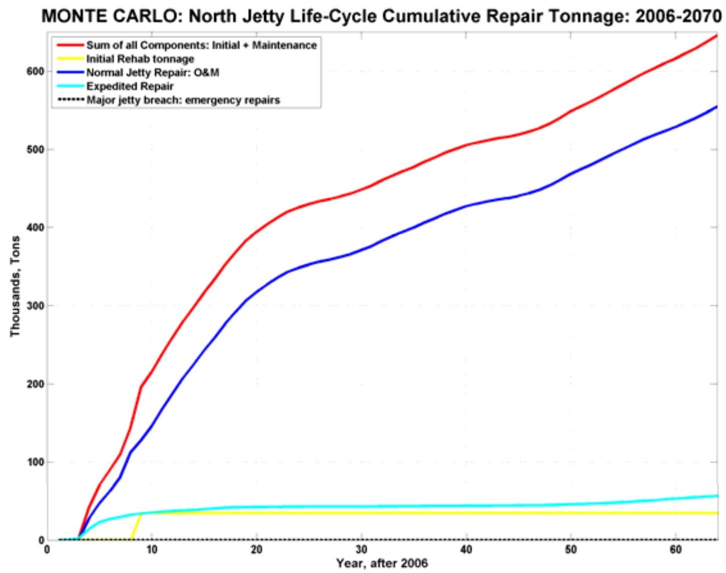

Figure A2-71d. Life-cycle cumulative repair tonnage for MCR North Jetty. Scheduled Repair w/ Engineering Features.

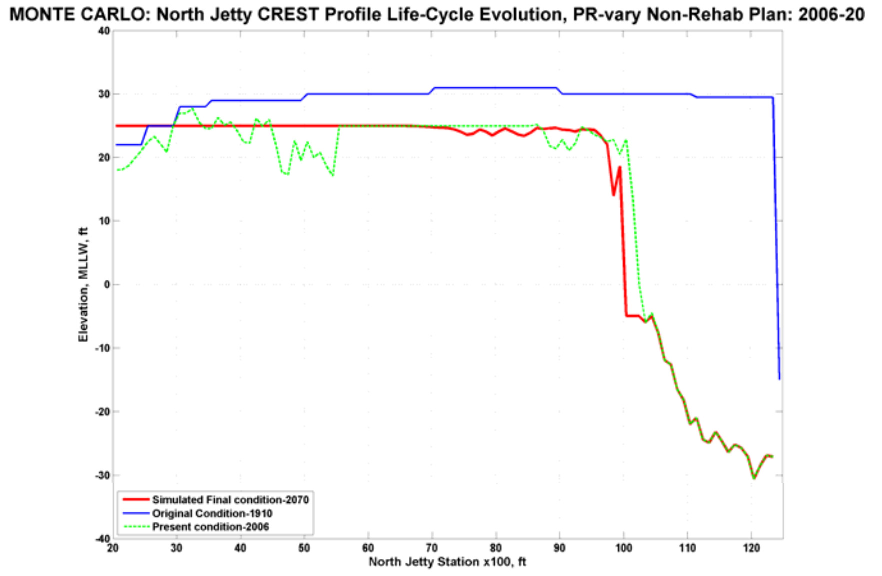

Figure A2-71e. Centerline profile for MCR North Jetty. Scheduled Repair w/ Engineering Features.

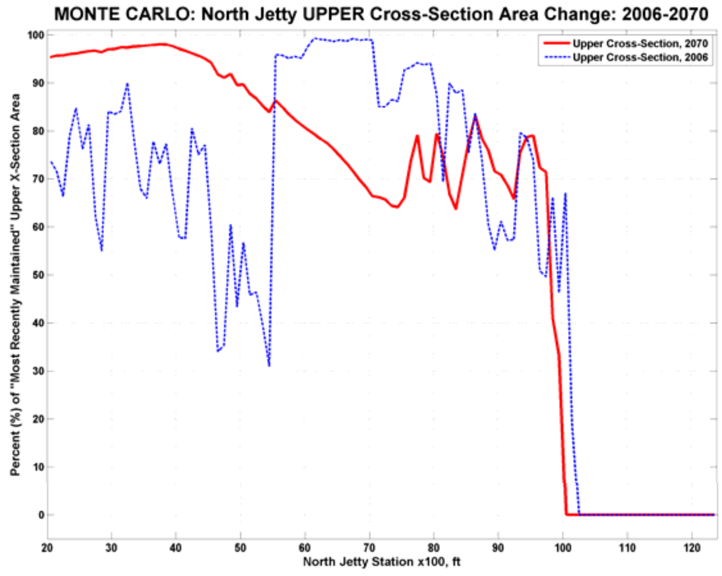

Figure A2-71f. Variation of upper cross-section area for given station of MCR North Jetty. Scheduled Repair w/ Engineering Features.

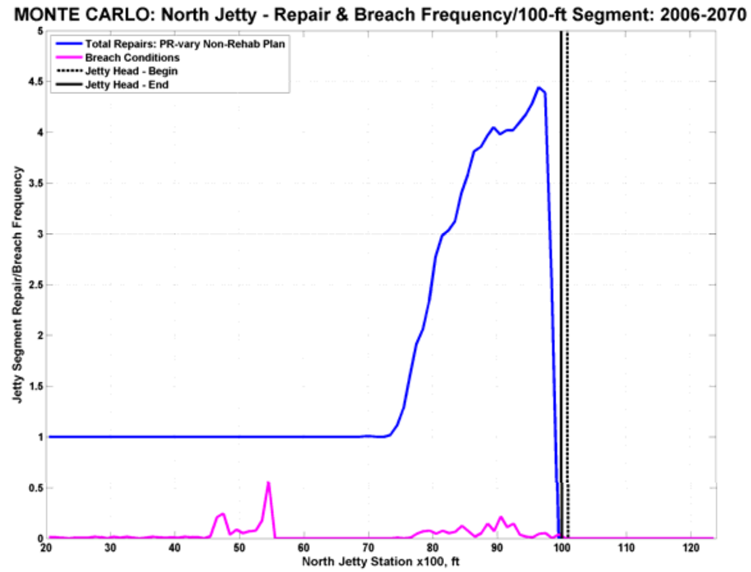

Figure A2-71g. Frequency and location of repairs and breaches for MCR North Jetty. Scheduled Repair w/ Engineering Features.

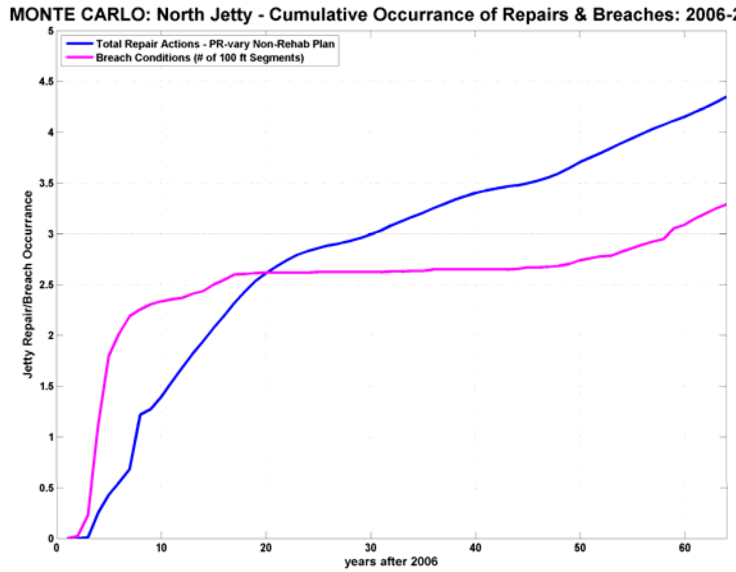

Figure A2-711h. Cumulative occurrence of repairs and breach conditions for MCR North Jetty. Scheduled Repair w/ Engineering Features.

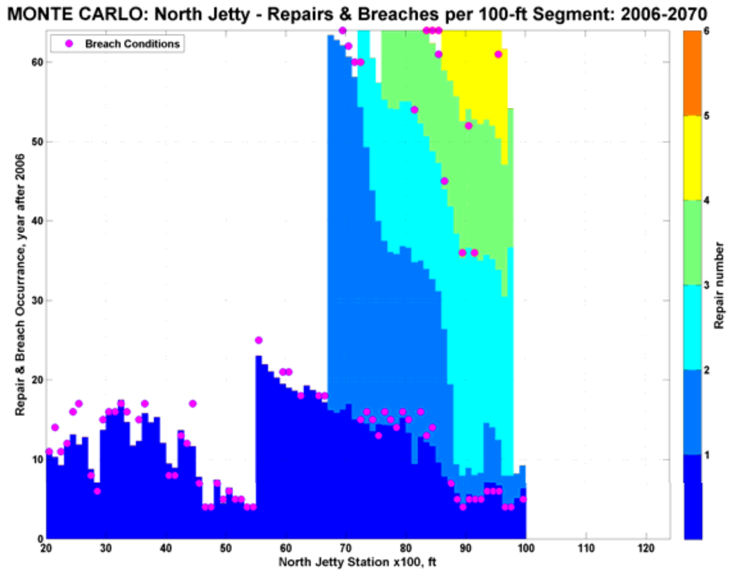

Figure A2-72a. Forecast repair occurrence for MCR North Jetty, shown for each 100 ft jetty segment. Scheduled Repair w/ Spur.

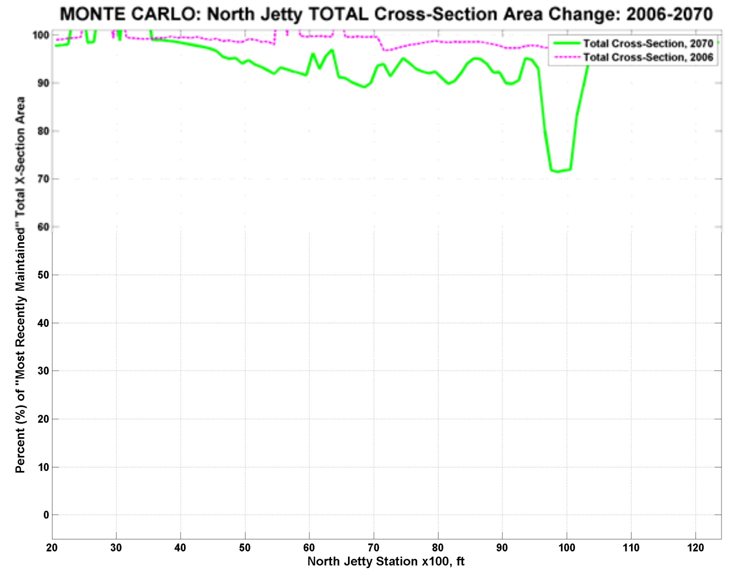

Figure A2-72b. Variation in total cross-section area along MCR North Jetty during forecast period. Scheduled Repair w/ Spur.

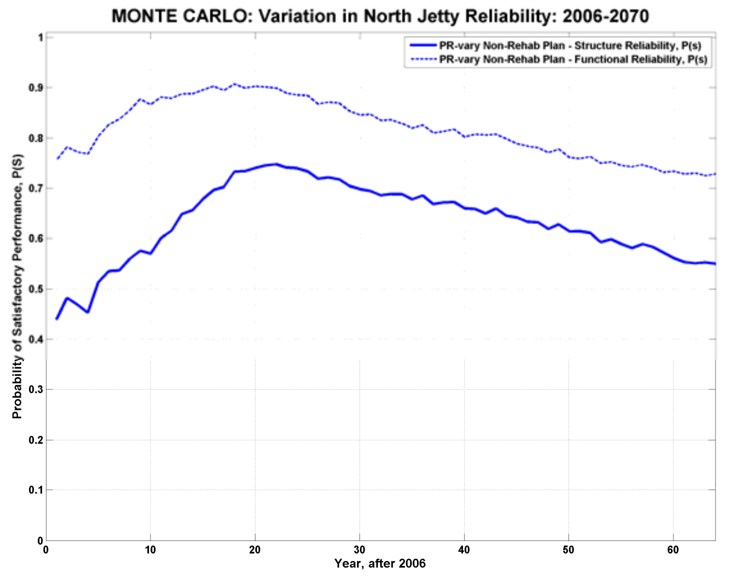

Figure A2-72c. Forecast reliability for MCR North Jetty. Scheduled Repair w/ Spur.

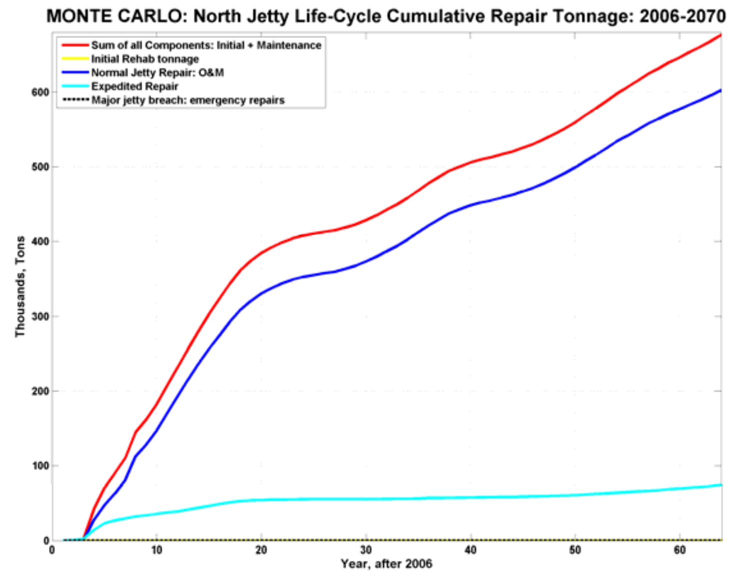

Figure A2-72d. Life-cycle cumulative repair tonnage for MCR North Jetty. Scheduled Repair w/ Spur.

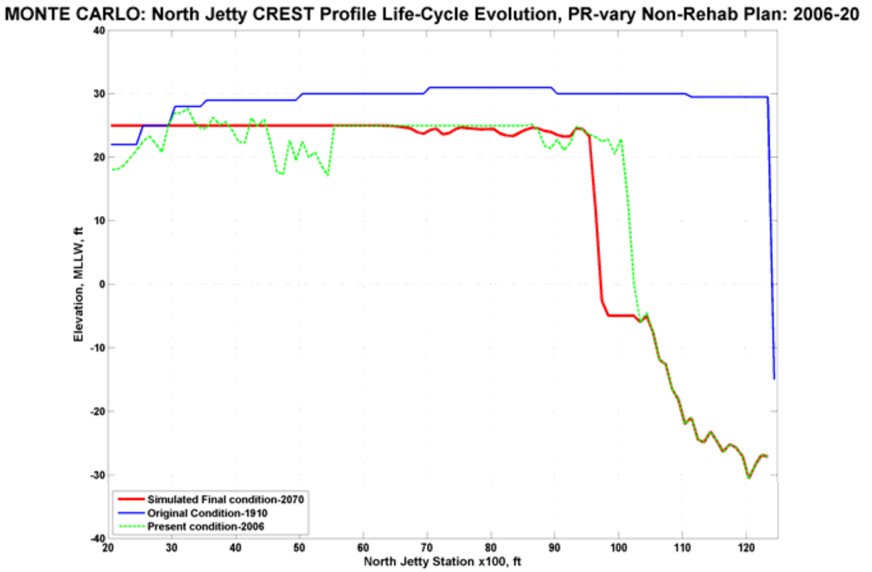

Figure A2-72e. Centerline profile for MCR North Jetty. Scheduled Repair w/ Spur.

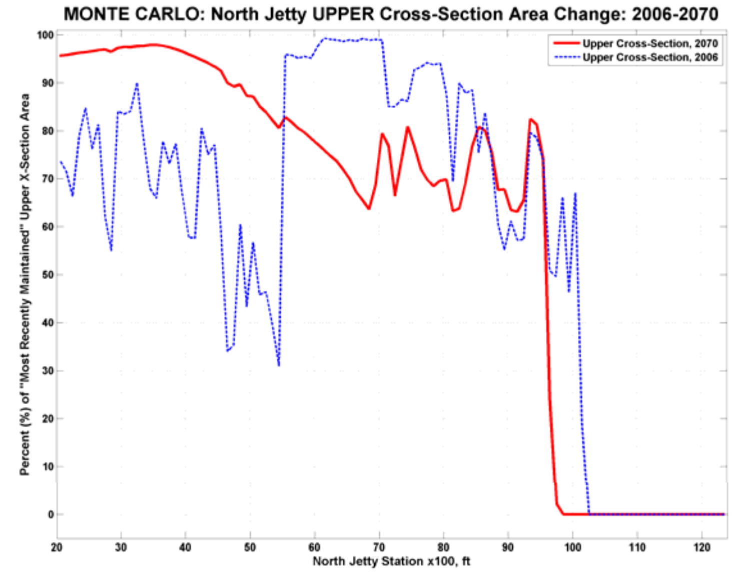

Figure A2-72f. Variation of upper cross-section area for given station of MCR North Jetty. Scheduled Repair w/ Spur.

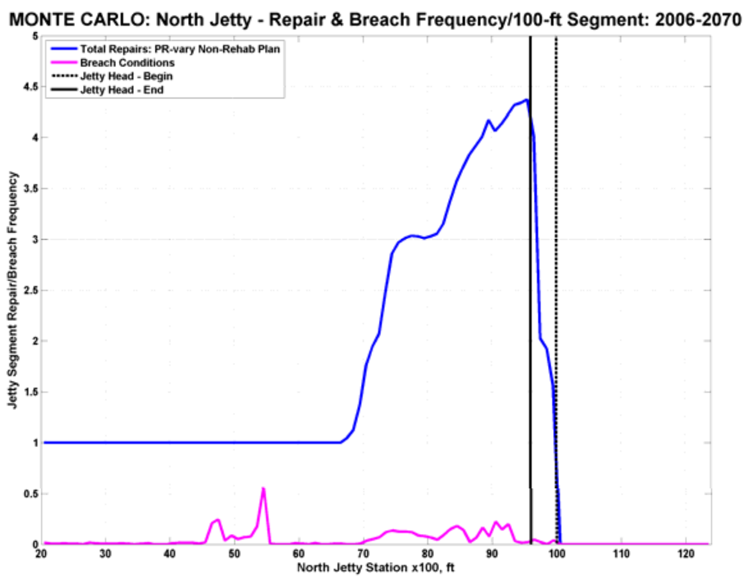

Figure A2-72g. Frequency and location of repairs and breaches for MCR North Jetty. Scheduled Repair w/ Spur.

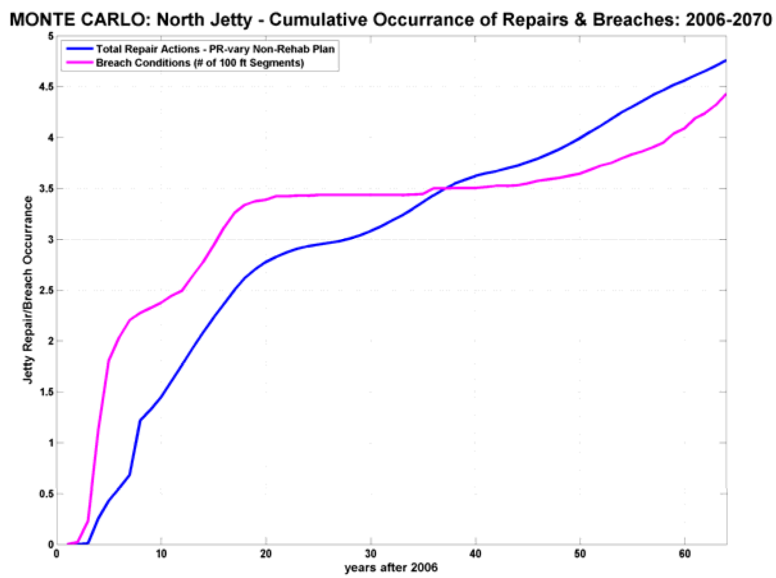

Figure A2-72h. Cumulative occurrence of repairs and breach conditions for MCR North Jetty. Scheduled Repair w/ Spur.

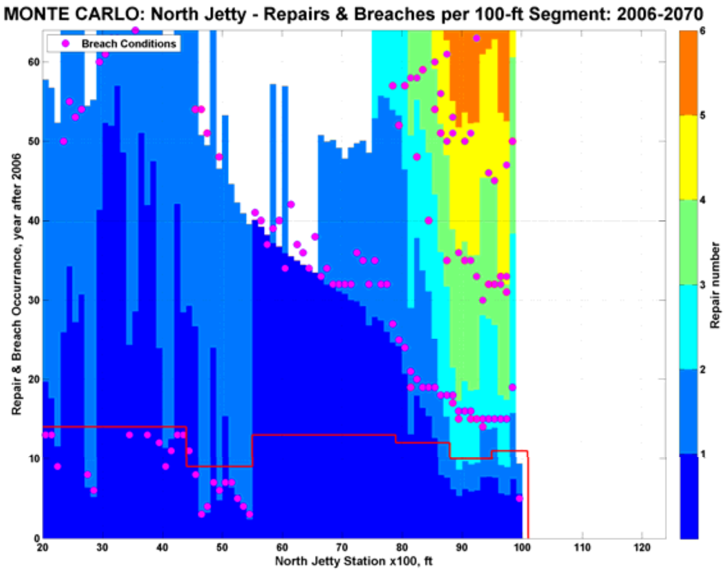

Figure A2-73a. Forecast repair occurrence for MCR North Jetty, shown for each 100 ft jetty segment. Minimum Template Rehab - Immediate. RED line marks time of REHAB phase implementation

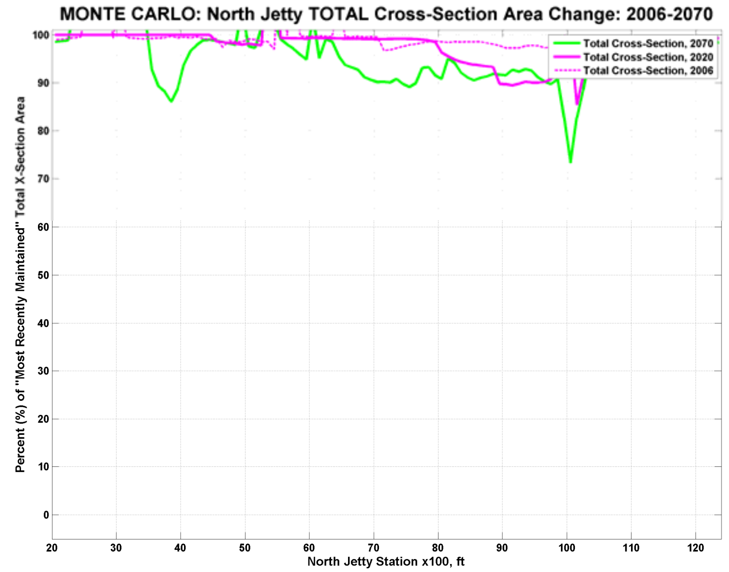

Figure A2-73b. Variation in total cross-section area along MCR North Jetty during forecast period. Minimum Template Rehab - Immediate.RED line marks time of REHAB phase implementation

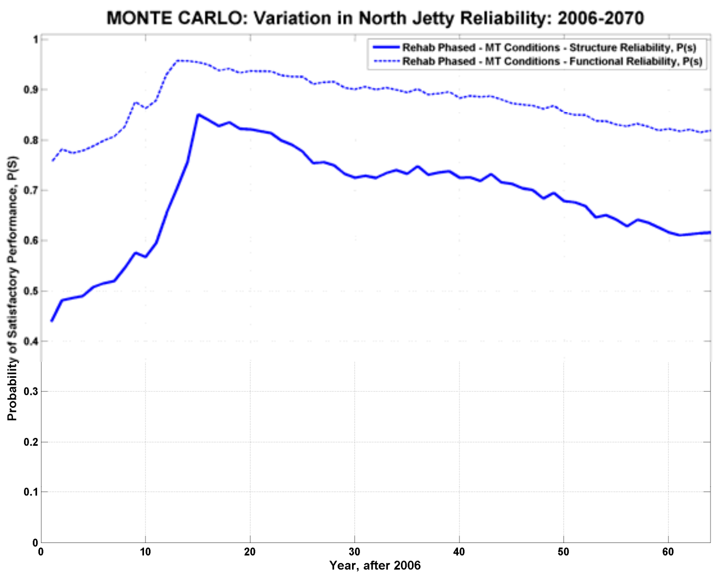

Figure A2-73c. Forecast reliability for MCR North Jetty. Minimum Template Rehab - Immediate.

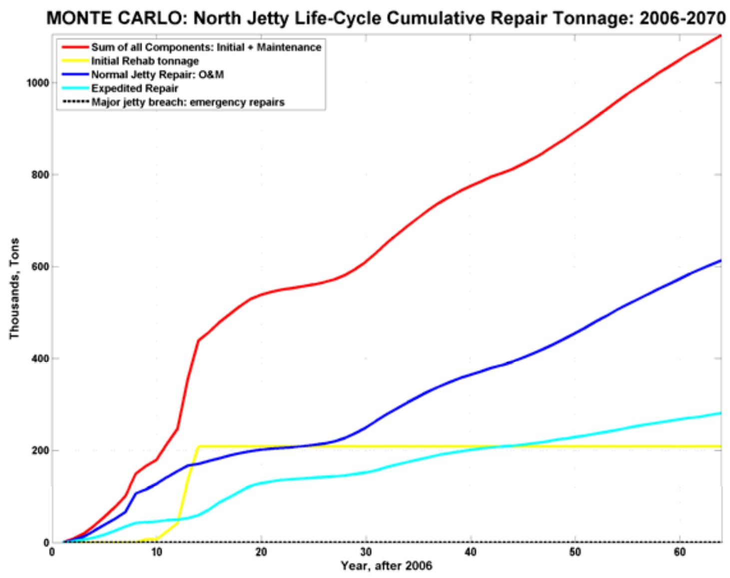

Figure A2-73d. Life-cycle cumulative repair tonnage for MCR North Jetty. Minimum Template Rehab - Immediate.

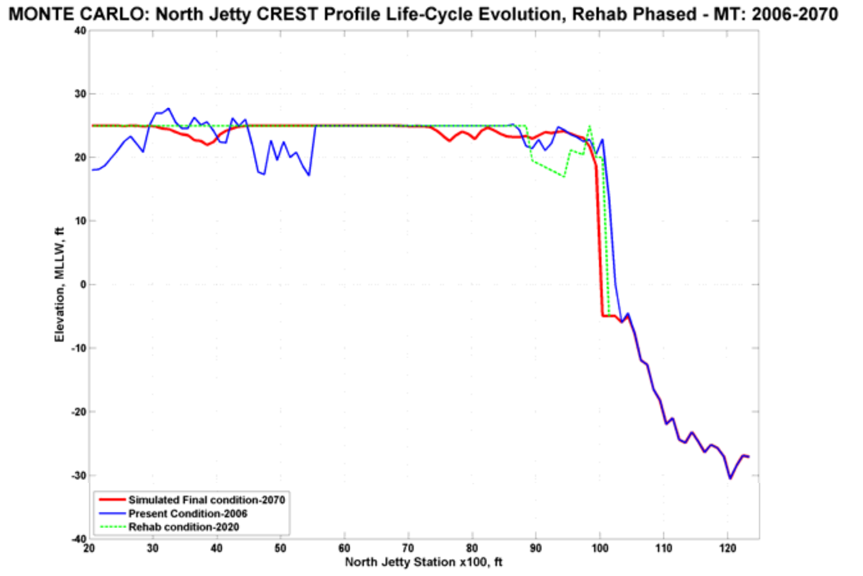

Figure A2-73e. Centerline profile for MCR North Jetty. Minimum Template Rehab - Immediate.

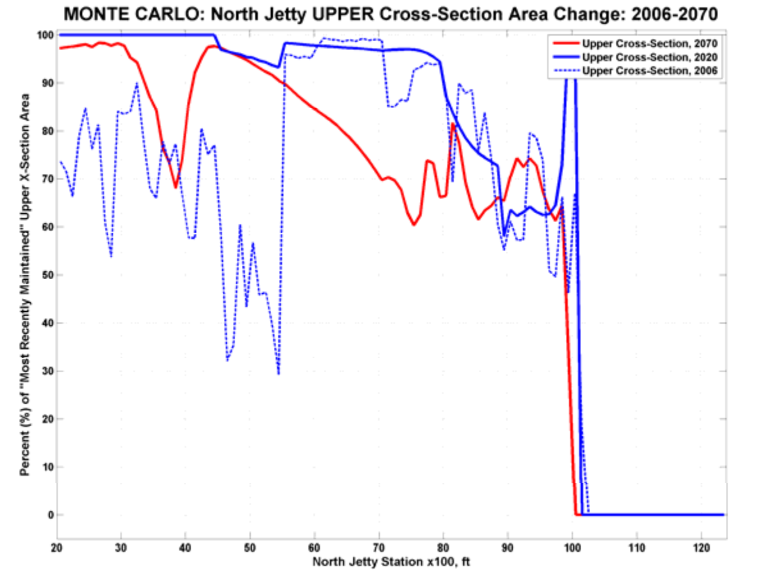

Figure A2-73f. Variation of upper cross-section area for given station of MCR North Jetty. Minimum Template Rehab - Immediate.

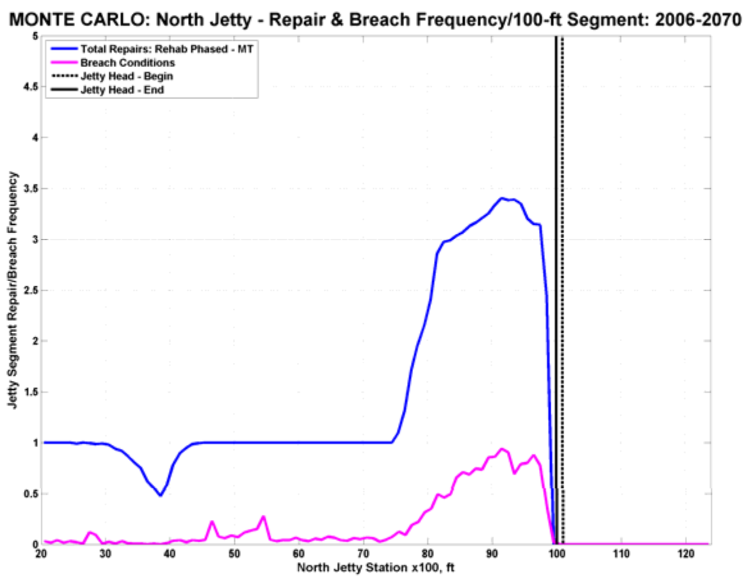

Figure A2-73g. Frequency and location of repairs and breaches for MCR North Jetty. Minimum Template Rehab - Immediate.

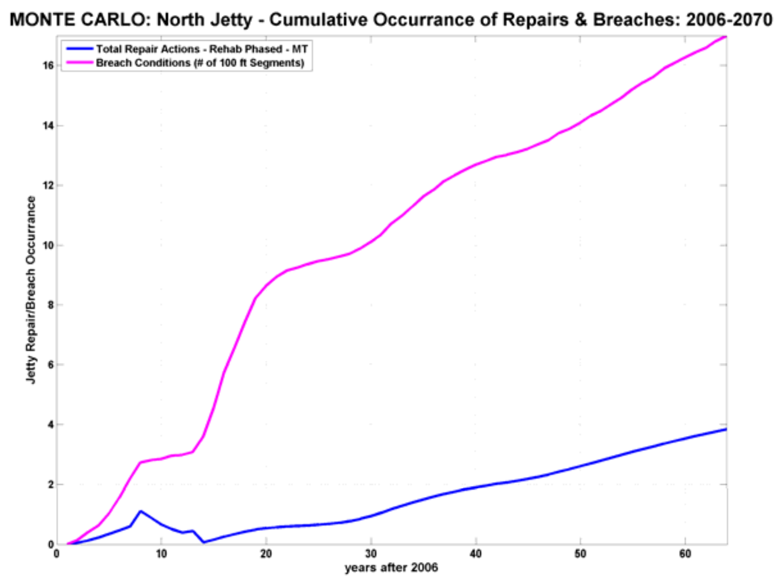

Figure A2-73h. Cumulative occurrence of repairs and breach conditions for MCR North Jetty. Minimum Template Rehab - Immediate.

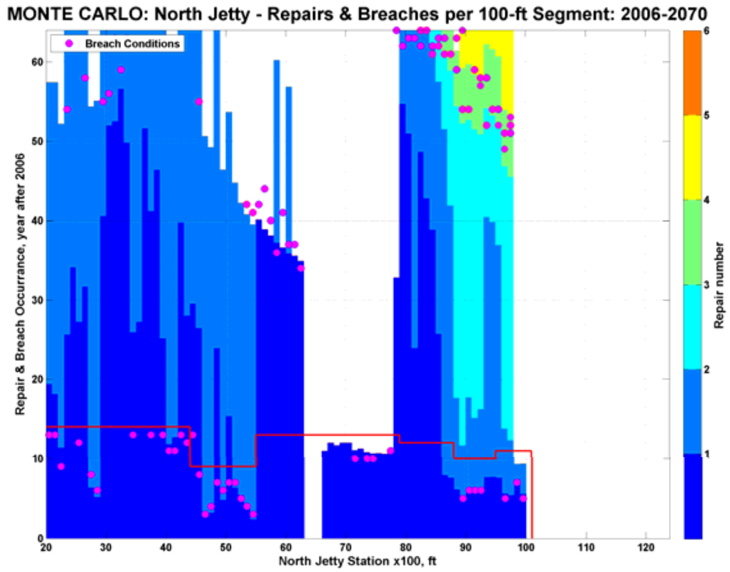

Figure A2-74a. Forecast repair occurrence for MCR North Jetty, shown for each 100 ft jetty segment. Composite 4 Small Rehab - Immediate. RED line marks time of REHAB phase implementation

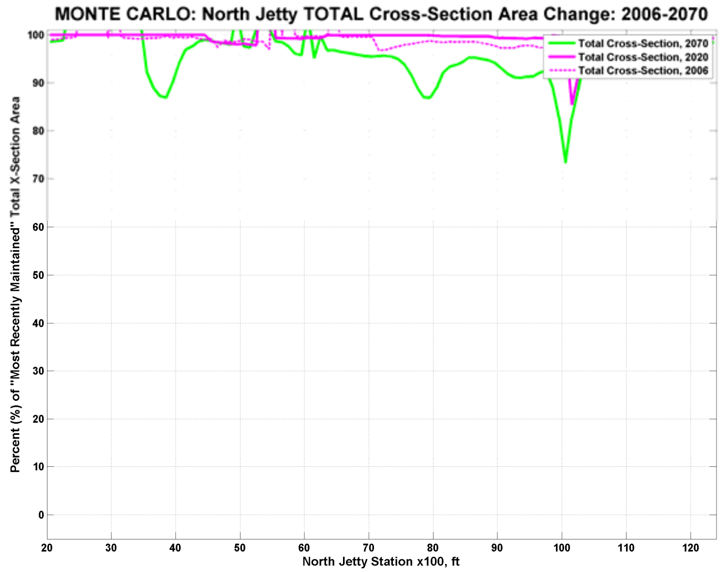

Figure A2-74b. Variation in total cross-section area along MCR North Jetty during forecast period. Composite 4 Small Rehab - Immediate.RED line marks time of REHAB phase implementation

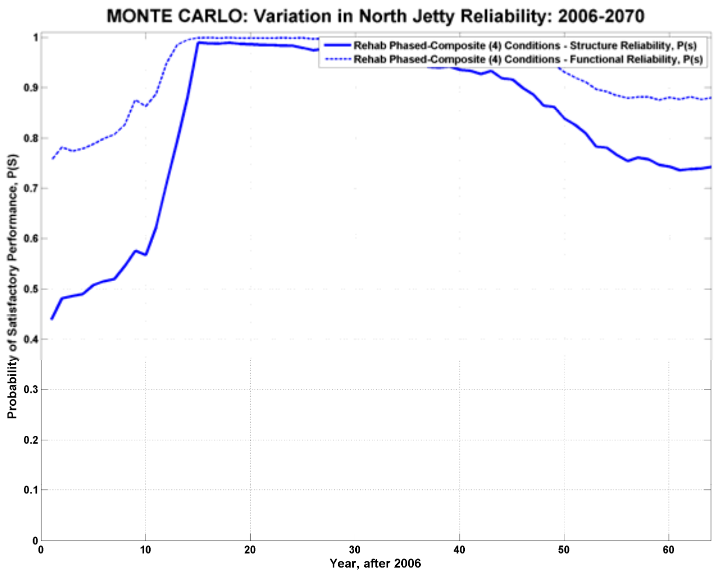

Figure A2-74c. Forecast reliability for MCR North Jetty. Composite 4 Small Rehab - Immediate.

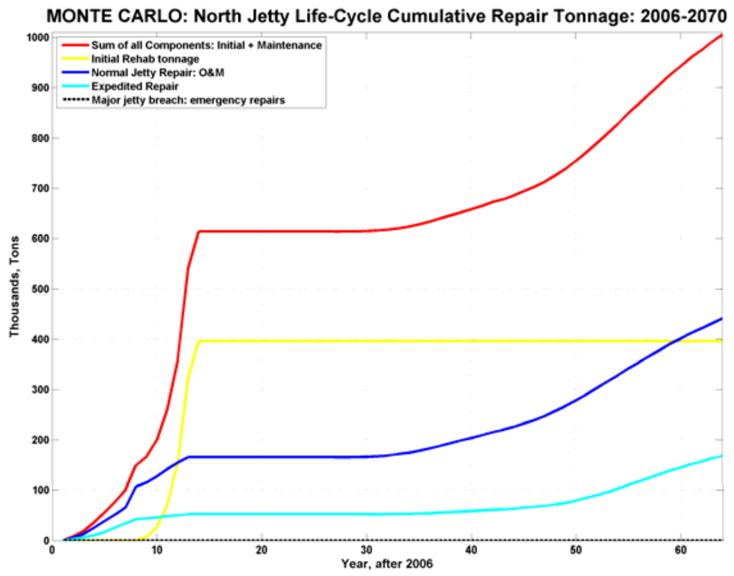

Figure A2-74d. Life-cycle cumulative repair tonnage for MCR North Jetty. Composite 4 Small Rehab - Immediate.

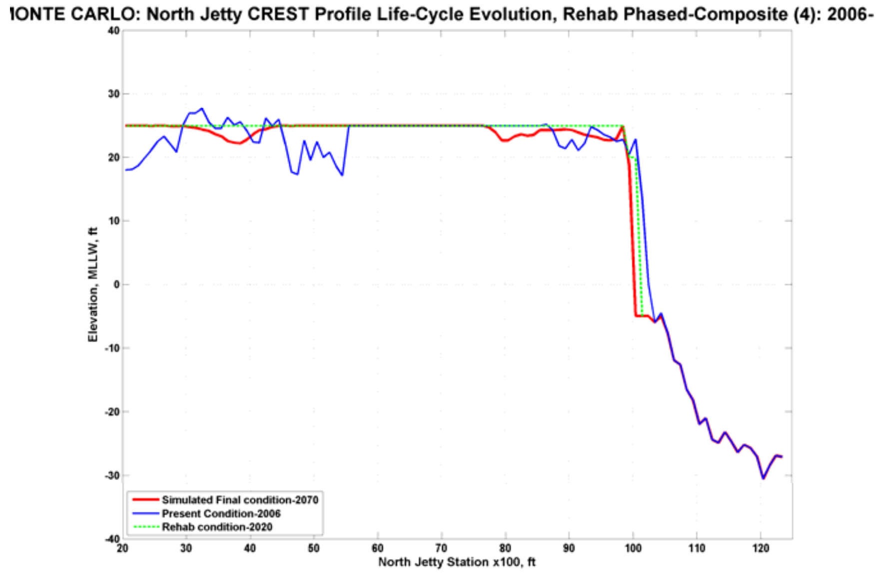

Figure A2-74e. Centerline profile for MCR North Jetty. Composite 4 Small Rehab - Immediate.

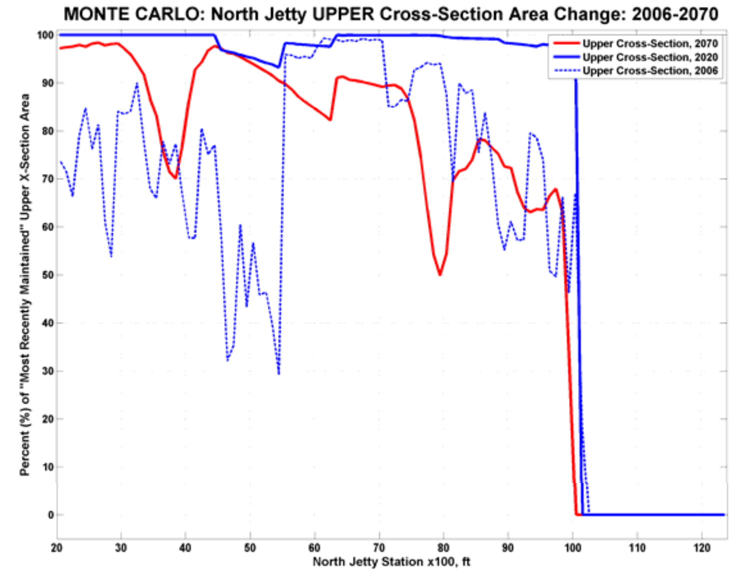

Figure A2-74f. Variation of upper cross-section area for given station of MCR North Jetty. Composite 4 Small Rehab - Immediate.

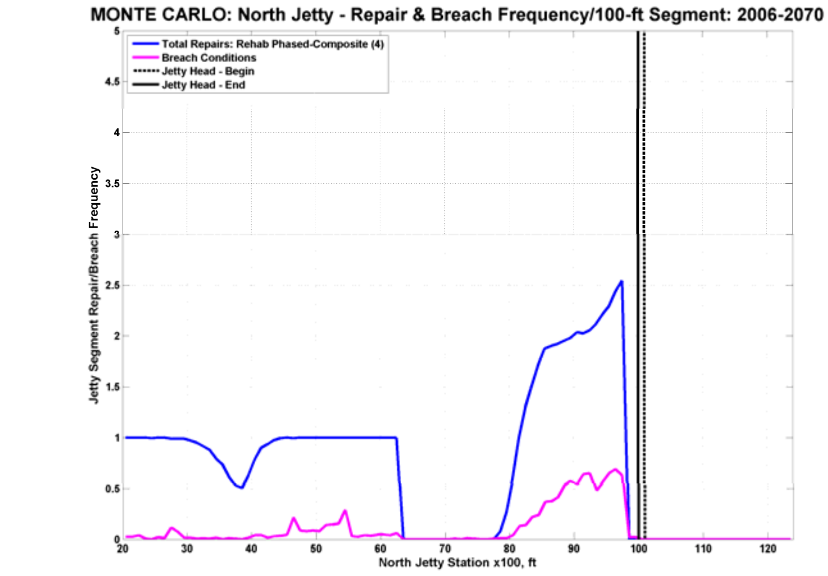

Figure A2-74g. Frequency and location of repairs and breaches for MCR North Jetty. Composite 4 Small Rehab - Immediate.

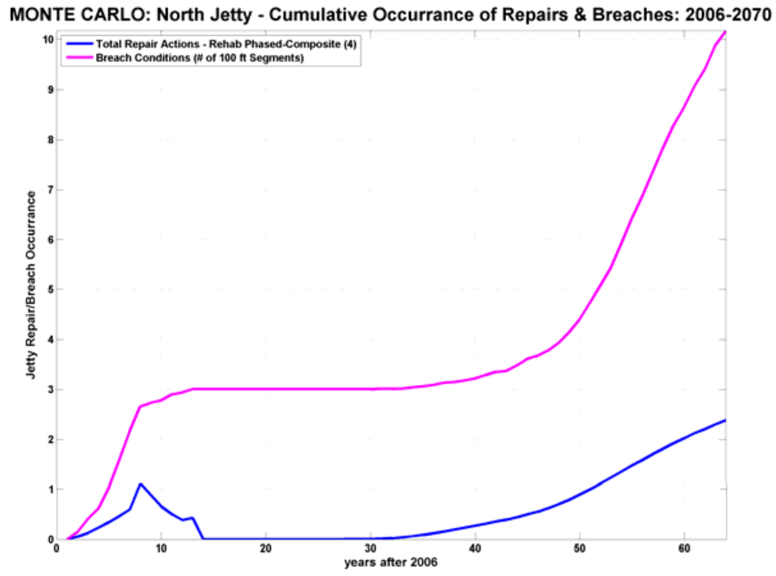

Figure A2-74h. Cumulative occurrence of repairs and breach conditions for MCR North Jetty. Composite 4 Small Rehab - Immediate.

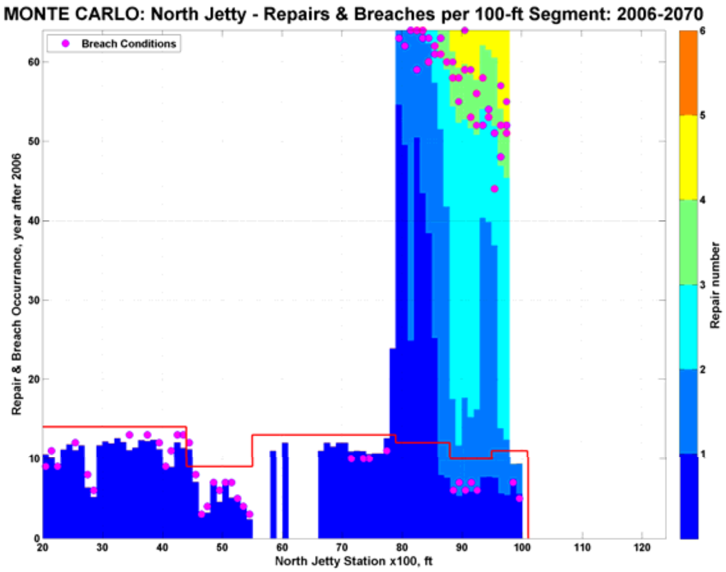

Figure A2-75a. Forecast repair occurrence for MCR North Jetty, shown for each 100 ft jetty segment. Moderate Template Rehab - Immediate. RED line marks time of REHAB phase implementation

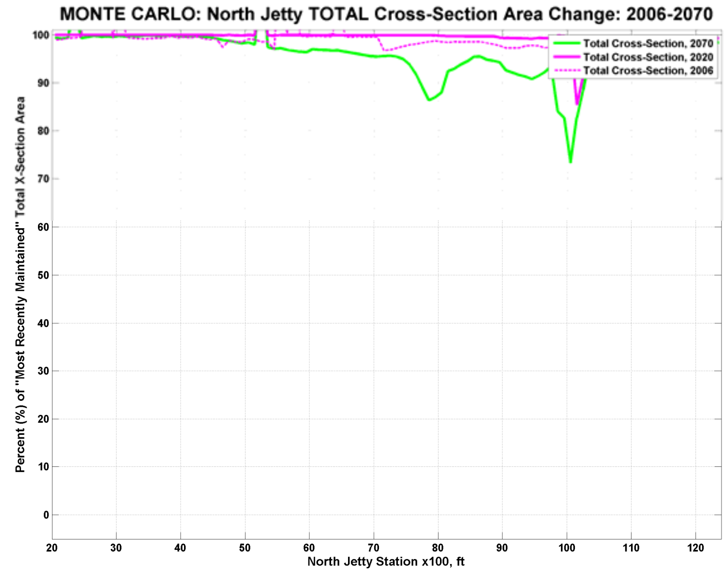

Figure A2-75b. Variation in total cross-section area along MCR North Jetty during forecast period. Moderate Template Rehab - Immediate.RED line marks time of REHAB phase implementation

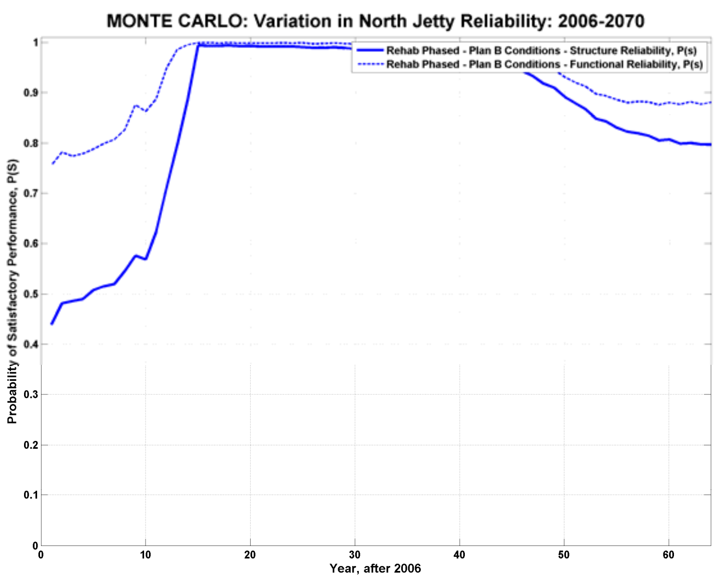

Figure A2-75c. Forecast reliability for MCR North Jetty. Moderate Template Rehab - Immediate.

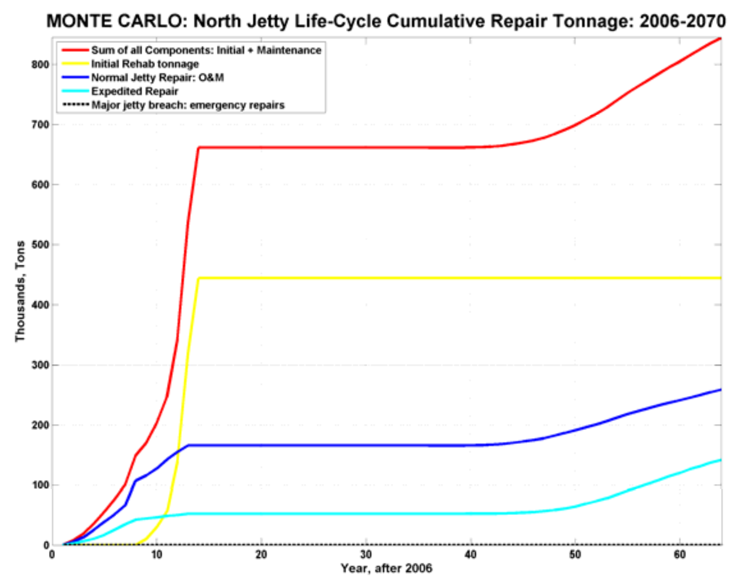

Figure A2-75d. Life-cycle cumulative repair tonnage for MCR North Jetty. Moderate Template Rehab - Immediate.

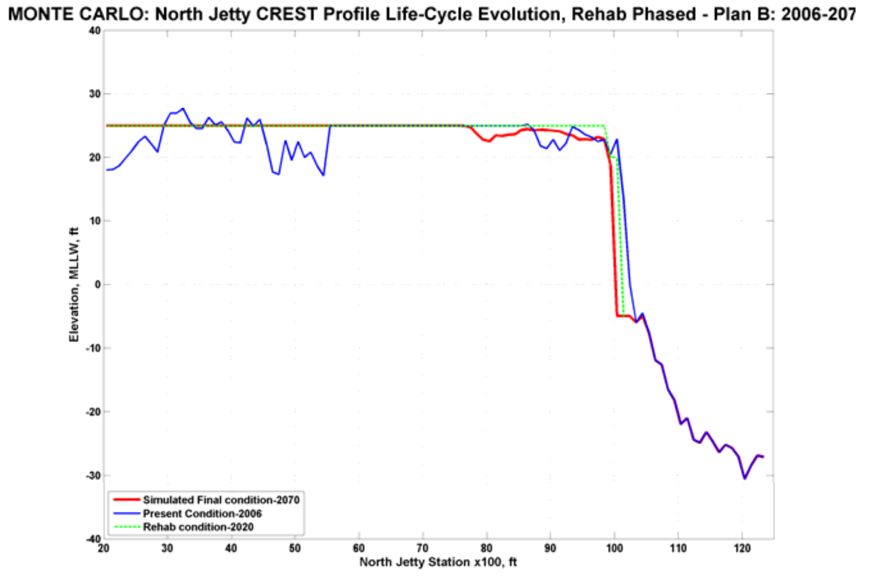

Figure A2-75e. Centerline profile for MCR North Jetty. Moderate Template Rehab - Immediate.

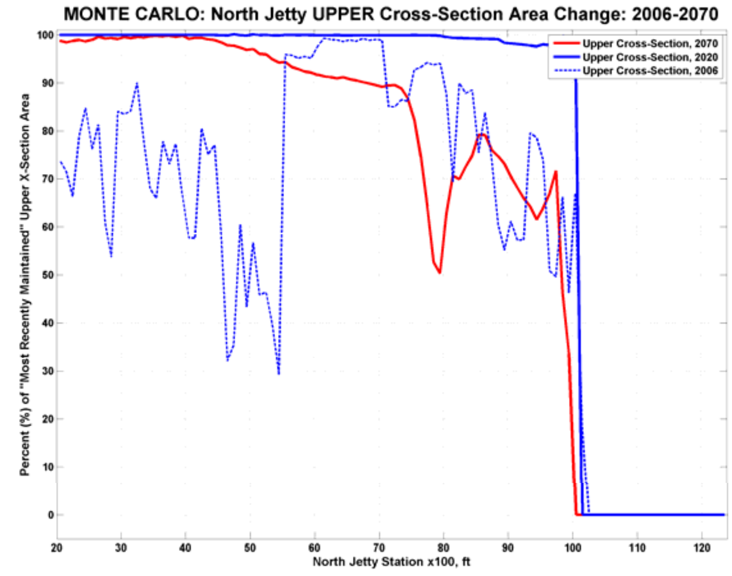

Figure A2-75f. Variation of upper cross-section area for given station of MCR North Jetty. Moderate Template Rehab - Immediate.

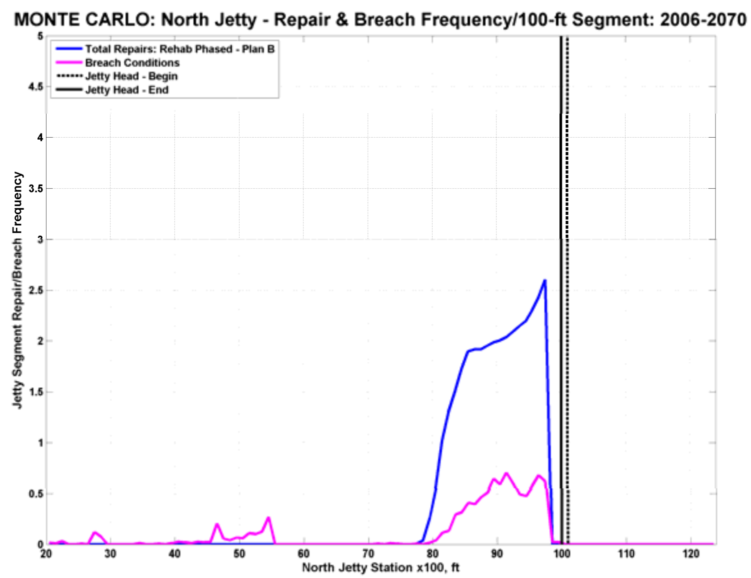

Figure A2-75g. Frequency and location of repairs and breaches for MCR North Jetty. Moderate Template Rehab - Immediate.

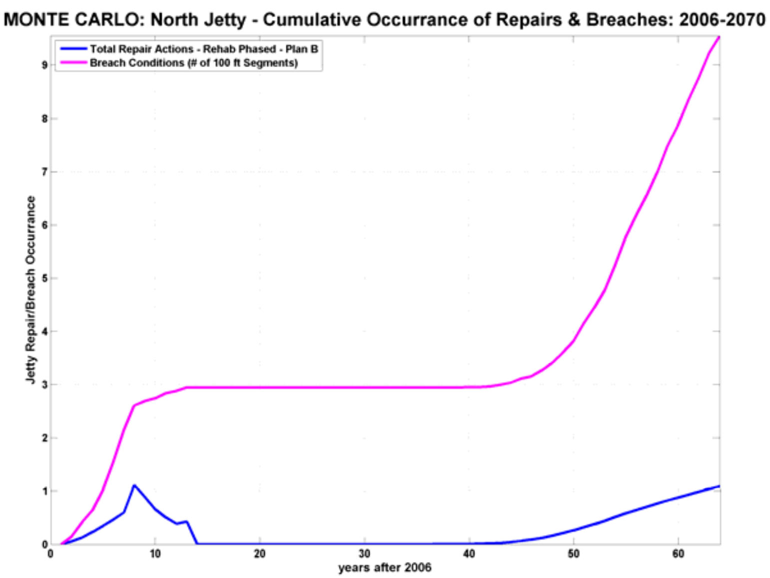

Figure A2-75h. Cumulative occurrence of repairs and breach conditions for MCR North Jetty. Moderate Template Rehab - Immediate.

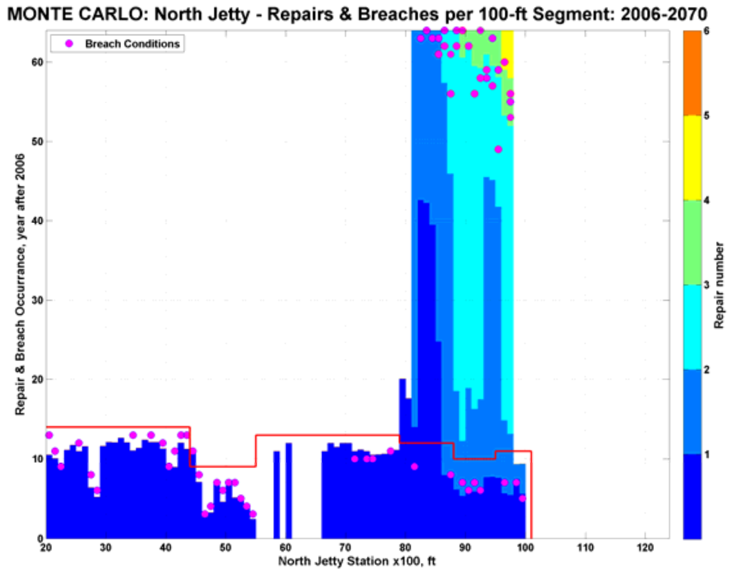

Figure A2-76a. Forecast repair occurrence for MCR North Jetty, shown for each 100 ft jetty segment. Large Template Rehab - Immediate. RED line marks time of REHAB phase implementation

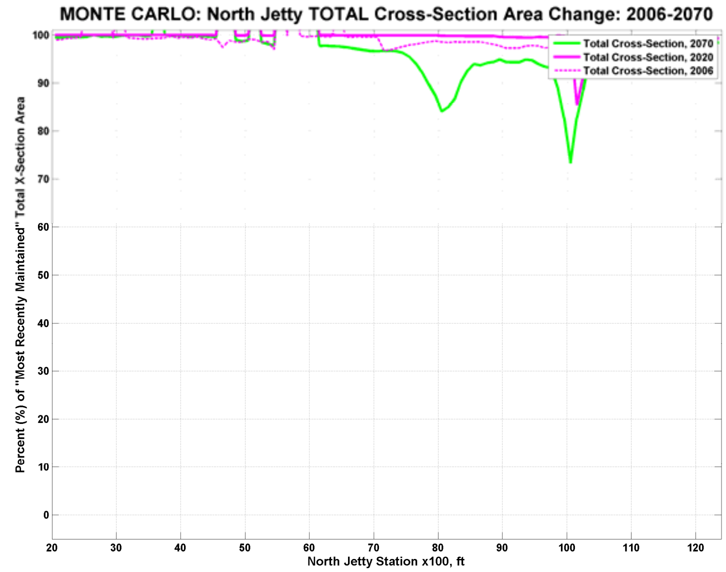

Figure A2-76b. Variation in total cross-section area along MCR North Jetty during forecast period. Large Template Rehab - Immediate.RED line marks time of REHAB phase implementation

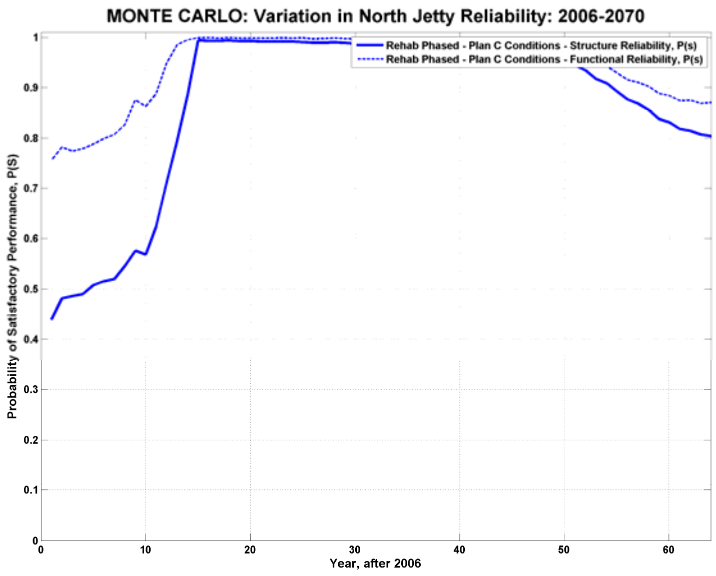

Figure A2-76c. Forecast reliability for MCR North Jetty. Large Template Rehab - Immediate.

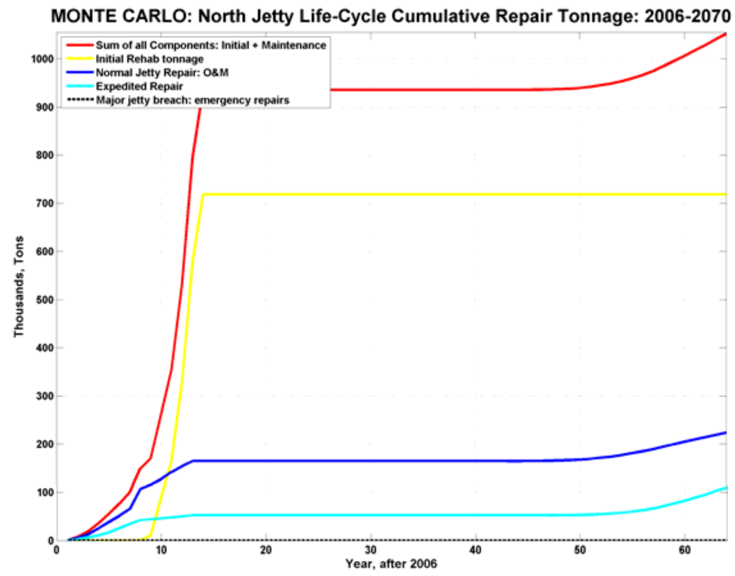

Figure A2-76d. Life-cycle cumulative repair tonnage for MCR North Jetty. Large Template Rehab - Immediate.

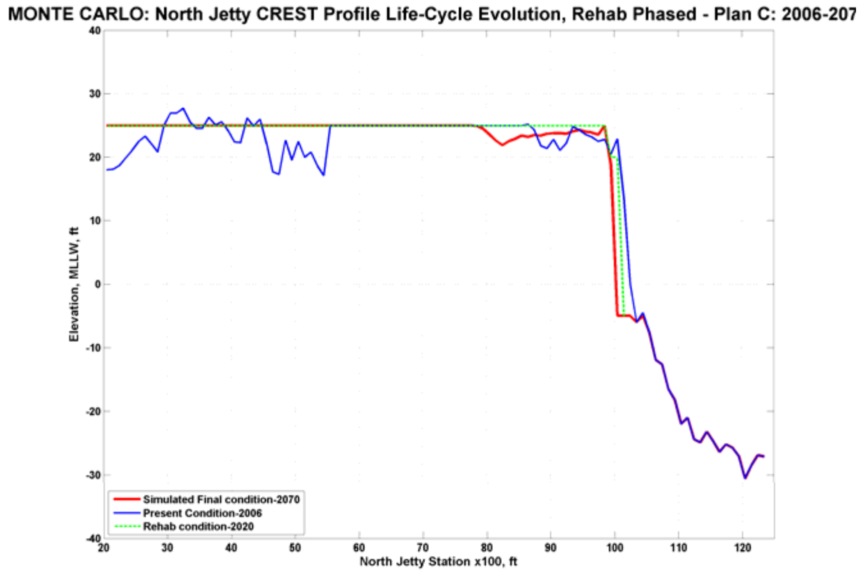

Figure A2-76e. Centerline profile for MCR North Jetty. Large Template Rehab - Immediate.

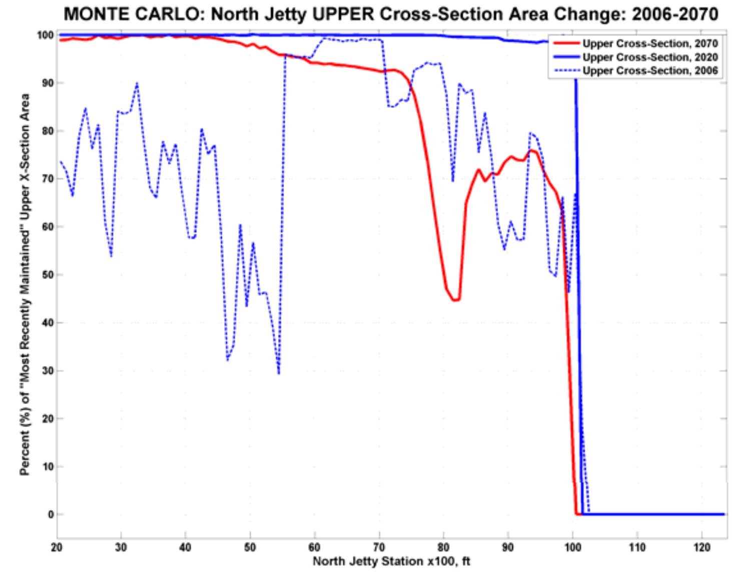

Figure A2-76f. Variation of upper cross-section area for given station of MCR North Jetty. Large Template Rehab - Immediate.

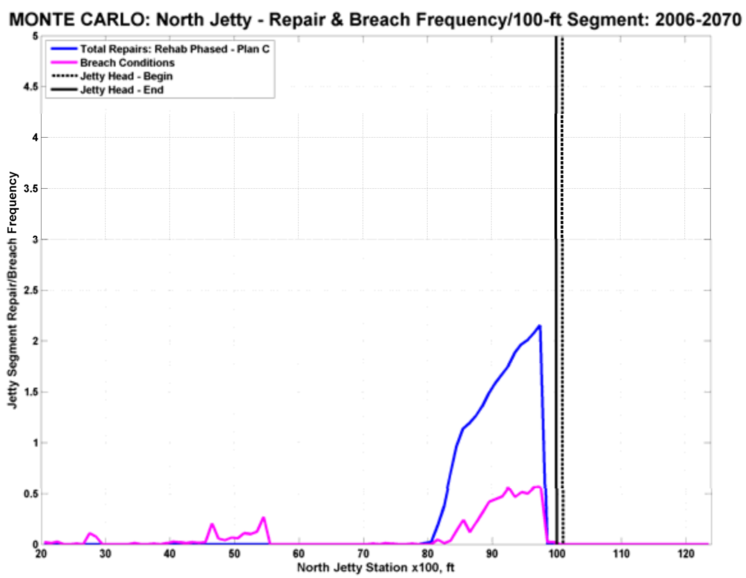

Figure A2-76g. Frequency and location of repairs and breaches for MCR North Jetty. Large Template Rehab - Immediate.

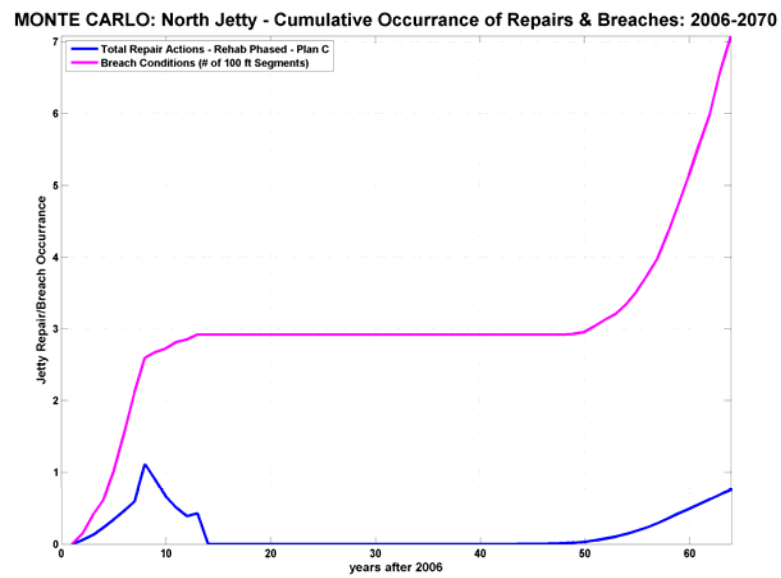

Figure A2-76h. Cumulative occurrence of repairs and breach conditions for MCR North Jetty. Large Template Rehab - Immediate.

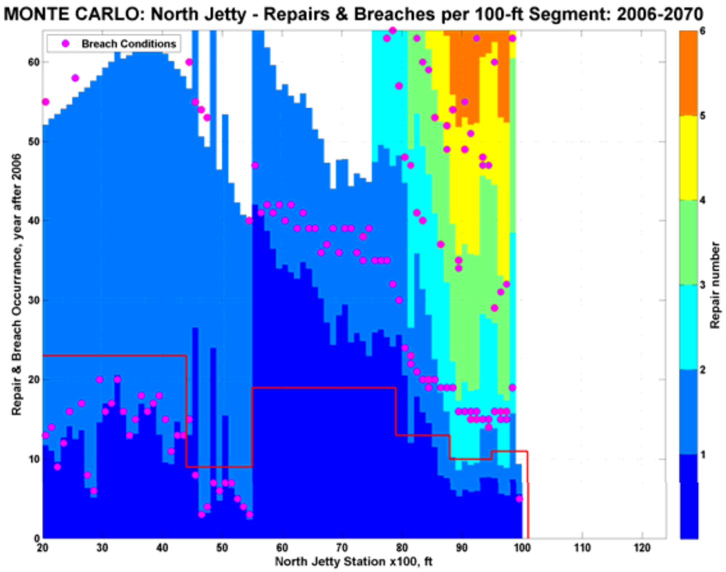

Figure A2-77a. Forecast repair occurrence for MCR North Jetty, shown for each 100 ft jetty segment. Minimum Template Rehab - Scheduled. RED line marks time of REHAB phase implementation

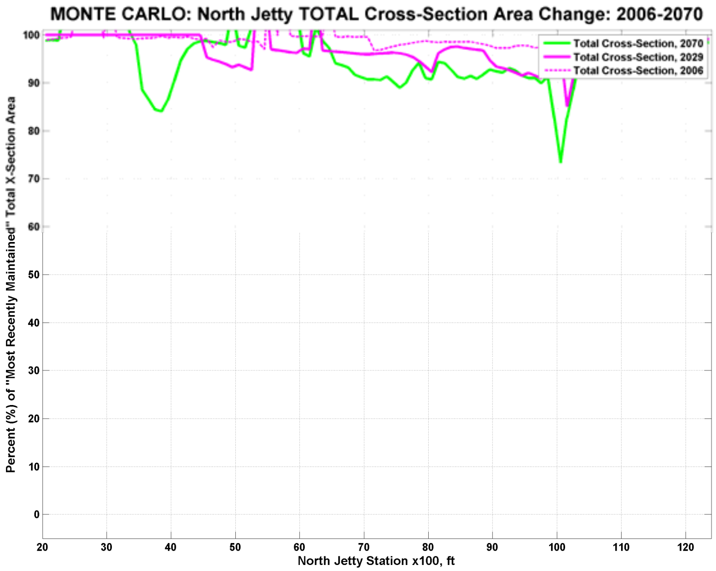

Figure A2-77b. Variation in total cross-section area along MCR North Jetty during forecast period. Minimum Template Rehab - Scheduled.RED line marks time of REHAB phase implementation

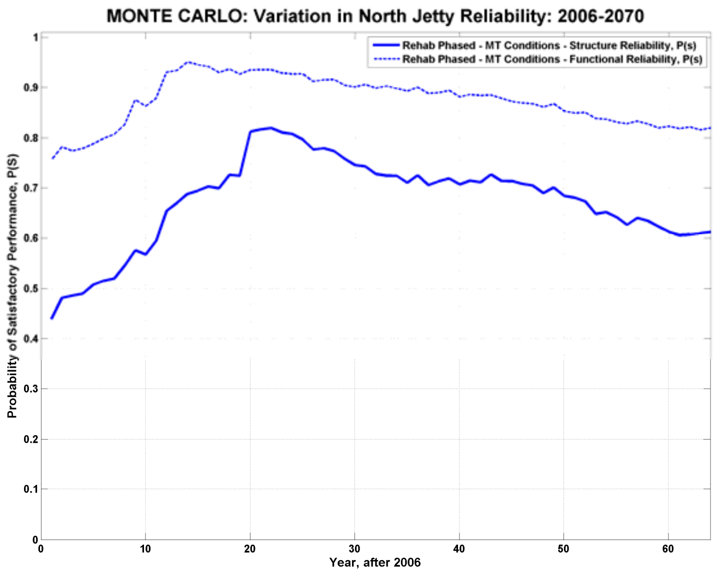

Figure A2-77c. Forecast reliability for MCR North Jetty. Minimum Template Rehab - Scheduled.

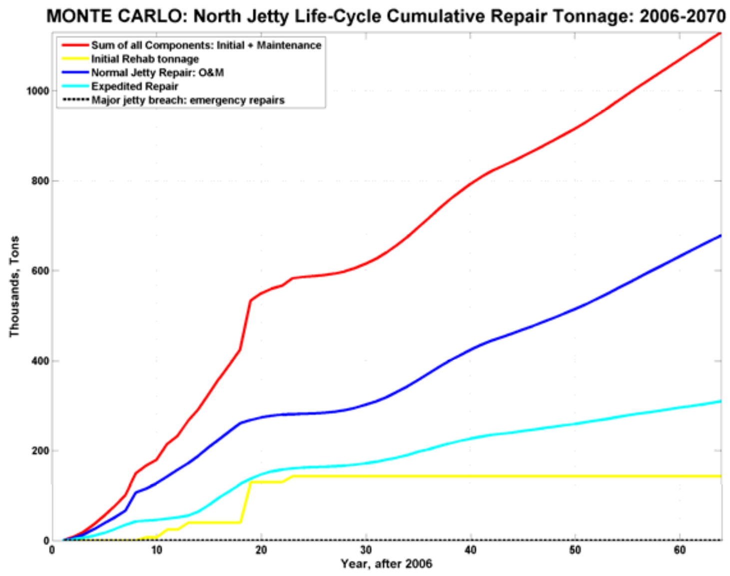

Figure A2-77d. Life-cycle cumulative repair tonnage for MCR North Jetty. Minimum Template Rehab - Scheduled.

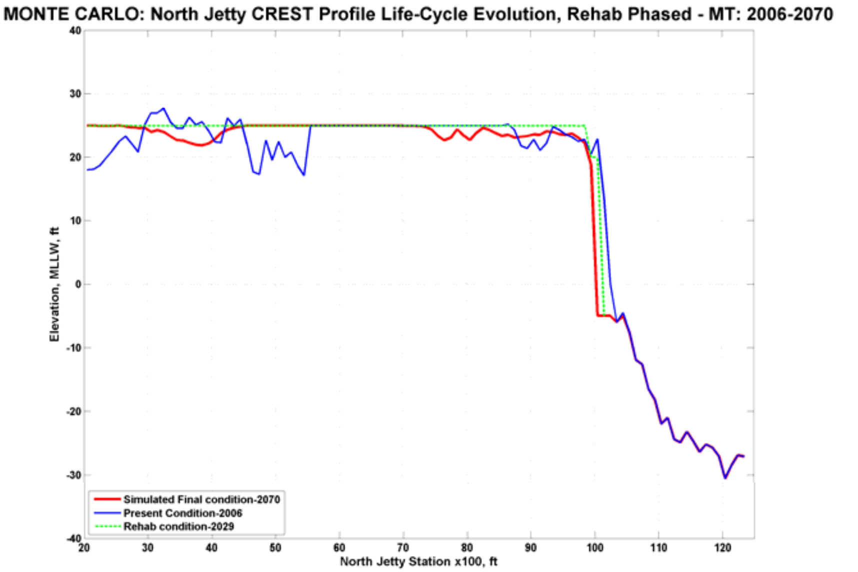

Figure A2-77e. Centerline profile for MCR North Jetty. Minimum Template Rehab - Scheduled.

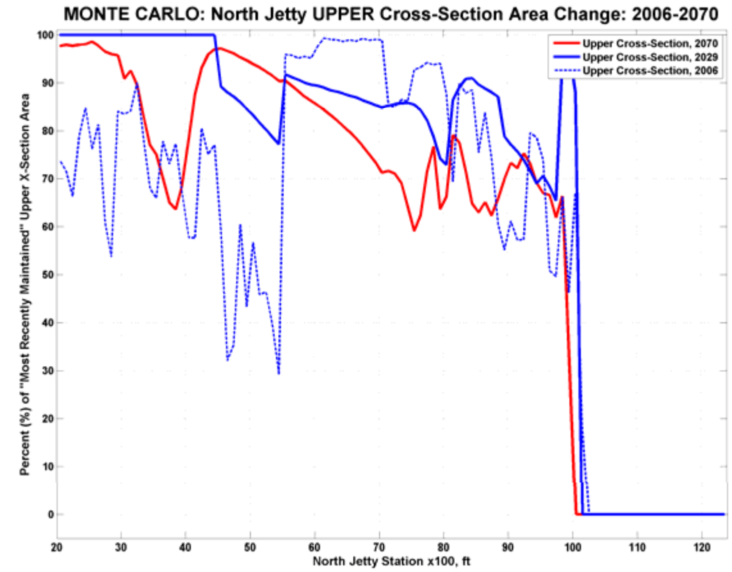

Figure A2-77f. Variation of upper cross-section area for given station of MCR North Jetty. Minimum Template Rehab - Scheduled.

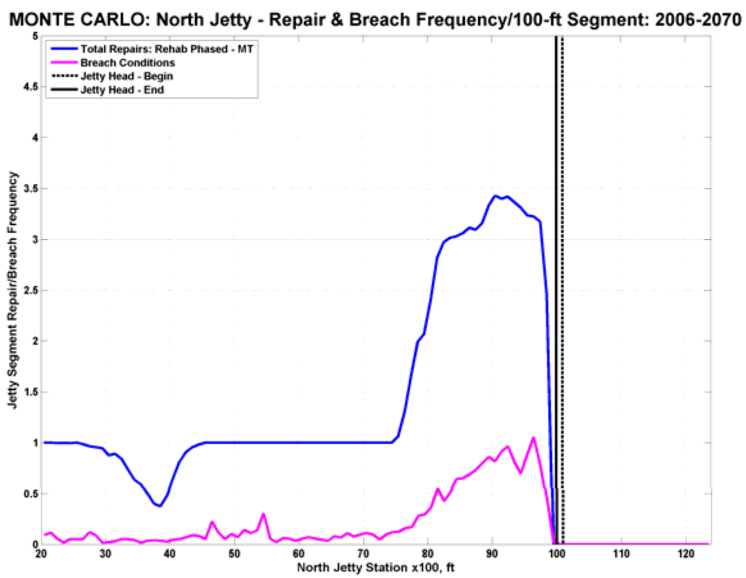

Figure A2-77g. Frequency and location of repairs and breaches for MCR North Jetty. Minimum Template Rehab - Scheduled.

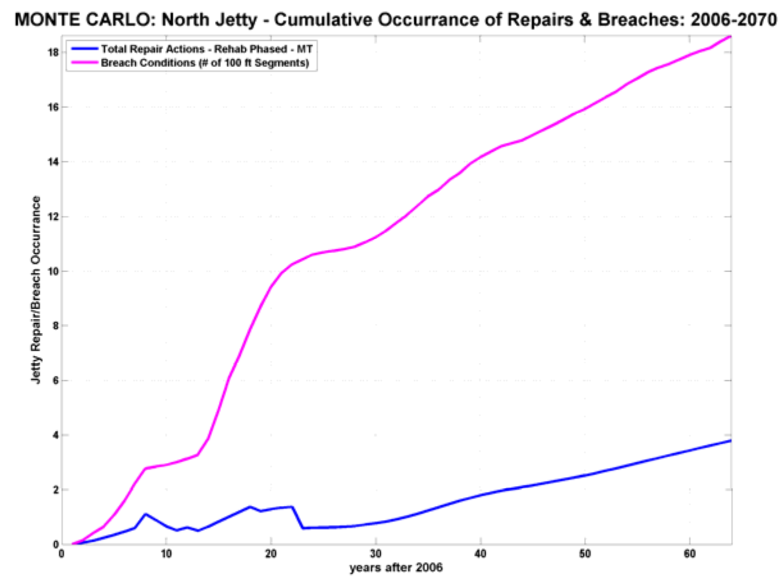

Figure A2-77h. Cumulative occurrence of repairs and breach conditions for MCR North Jetty. Minimum Template Rehab - Scheduled.

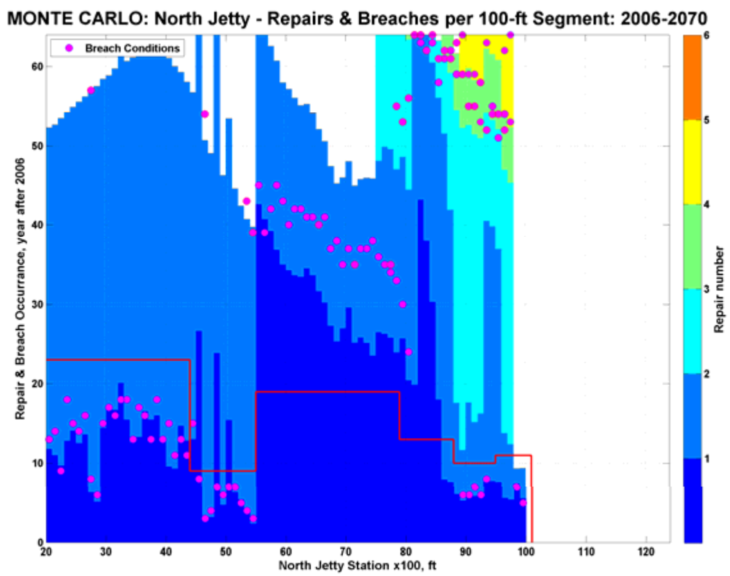

Figure A2-78a. Forecast repair occurrence for MCR North Jetty, shown for each 100 ft jetty segment. Composite 3 Small Rehab - Scheduled. RED line marks time of REHAB phase implementation

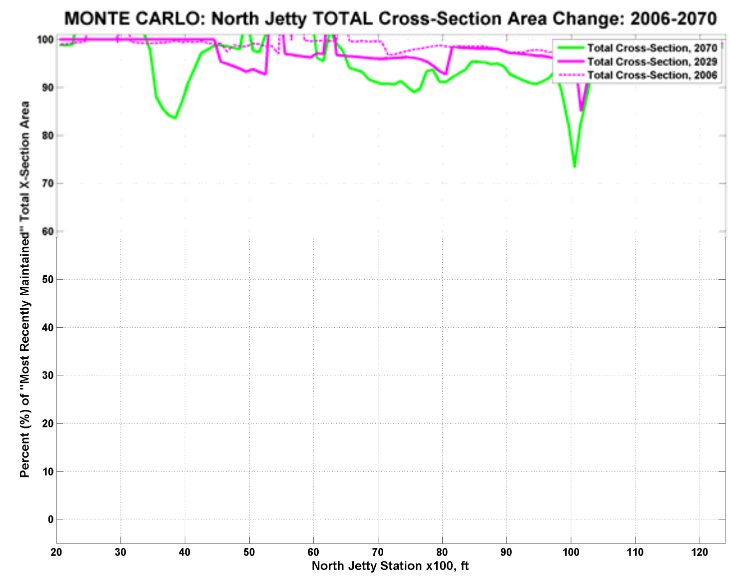

Figure A2-78b. Variation in total cross-section area along MCR North Jetty during forecast period. Composite 3 Small Rehab - Scheduled.RED line marks time of REHAB phase implementation

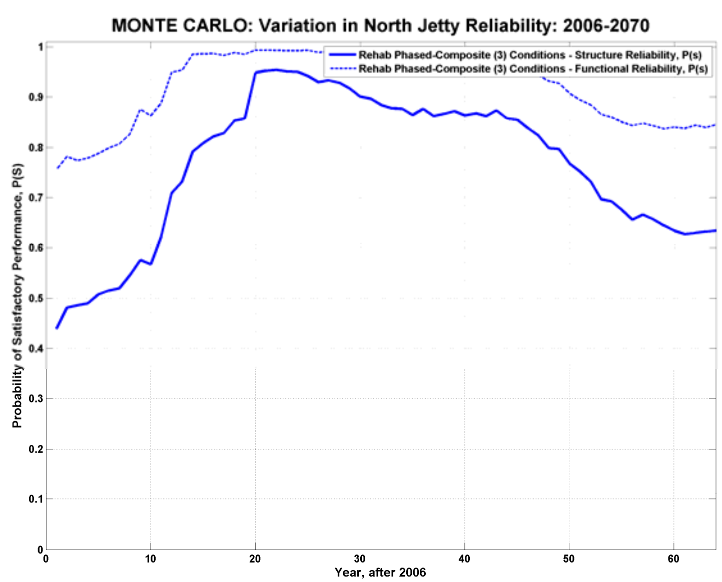

Figure A2-78c. Forecast reliability for MCR North Jetty. Composite 3 Small Rehab - Scheduled.

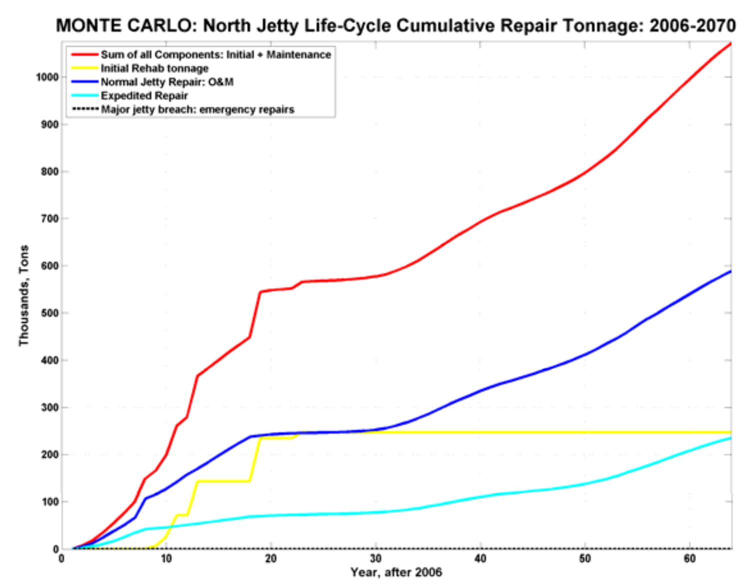

Figure A2-78d. Life-cycle cumulative repair tonnage for MCR North Jetty. Composite 3 Small Rehab - Scheduled.

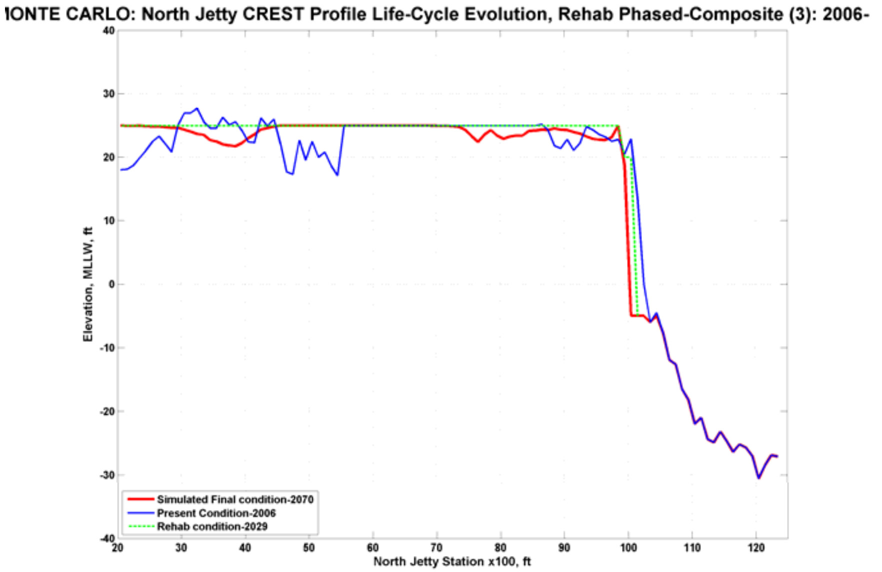

Figure A2-78e. Centerline profile for MCR North Jetty. Composite 3 Small Rehab - Scheduled.

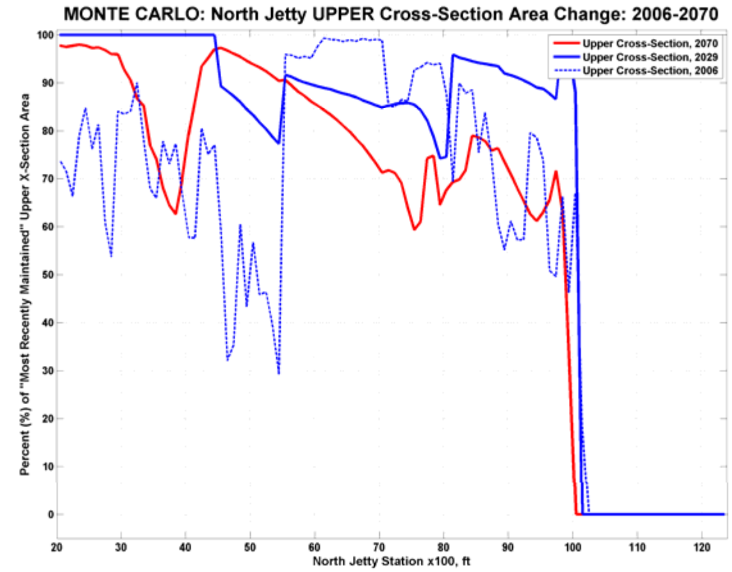

Figure A2-78f. Variation of upper cross-section area for given station of MCR North Jetty. Composite 3 Small Rehab - Scheduled.

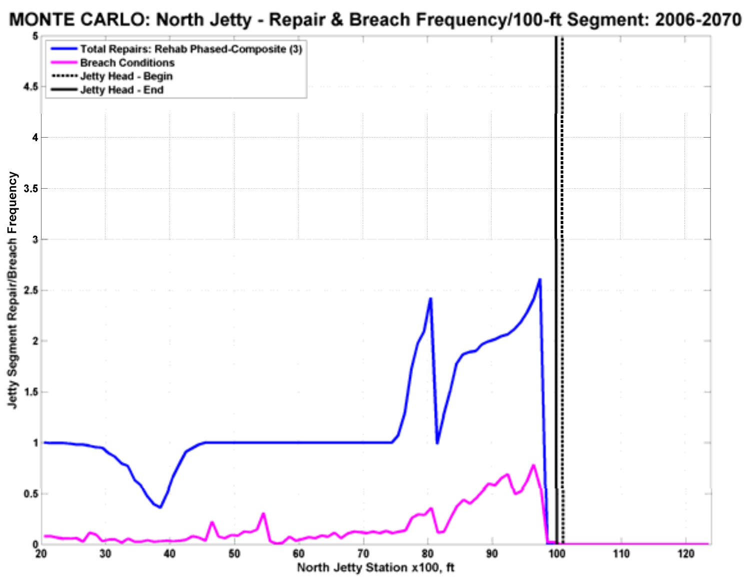

Figure A2-78g. Frequency and location of repairs and breaches for MCR North Jetty. Composite 3 Small Rehab - Scheduled.

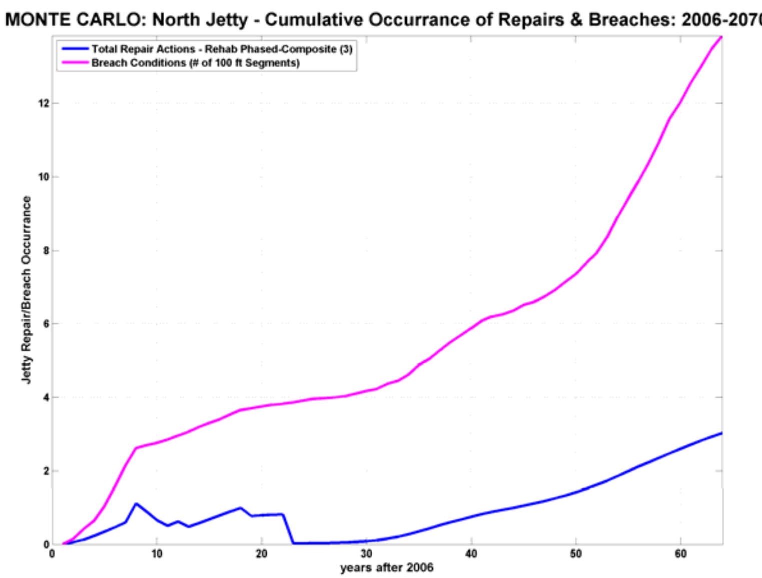

Figure A2-78h. Cumulative occurrence of repairs and breach conditions for MCR North Jetty. Composite 3 Small Rehab - Scheduled.

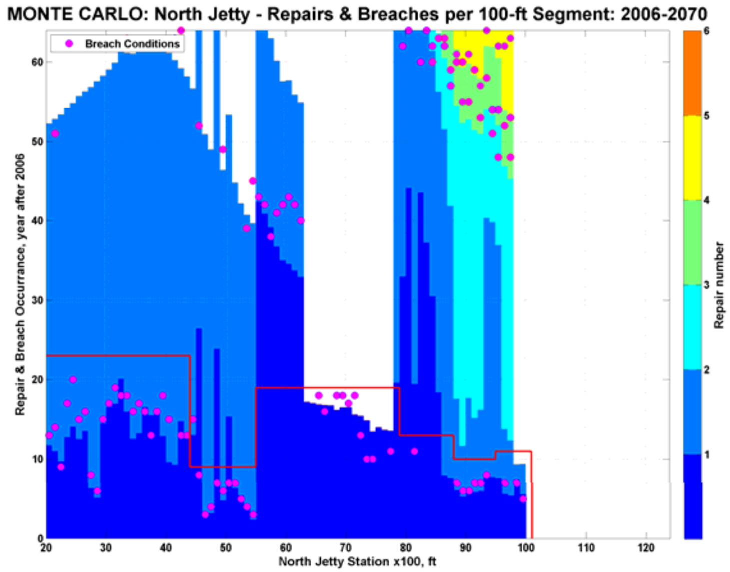

Figure A2-79a. Forecast repair occurrence for MCR North Jetty, shown for each 100 ft jetty segment. Composite 4 Small Modified Rehab - Scheduled. RED line marks time of REHAB phase implementation

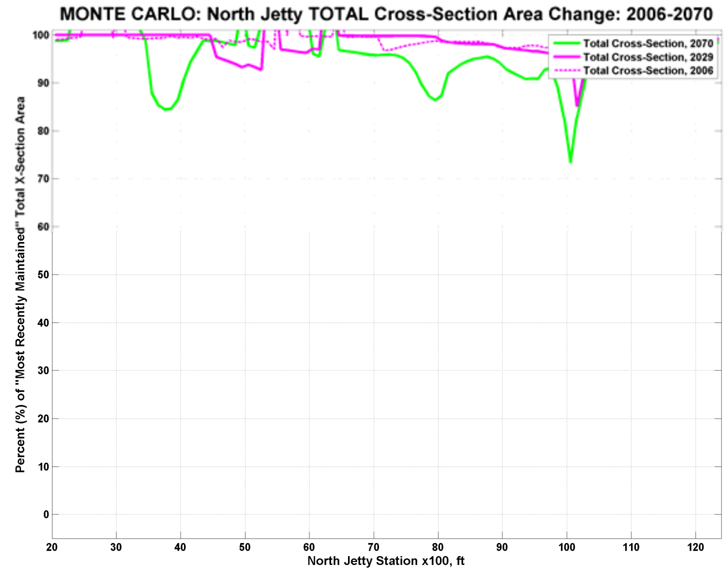

Figure A2-79b. Variation in total cross-section area along MCR North Jetty during forecast period. Composite 4 Small Modified Rehab - Scheduled.RED line marks time of REHAB phase implementation

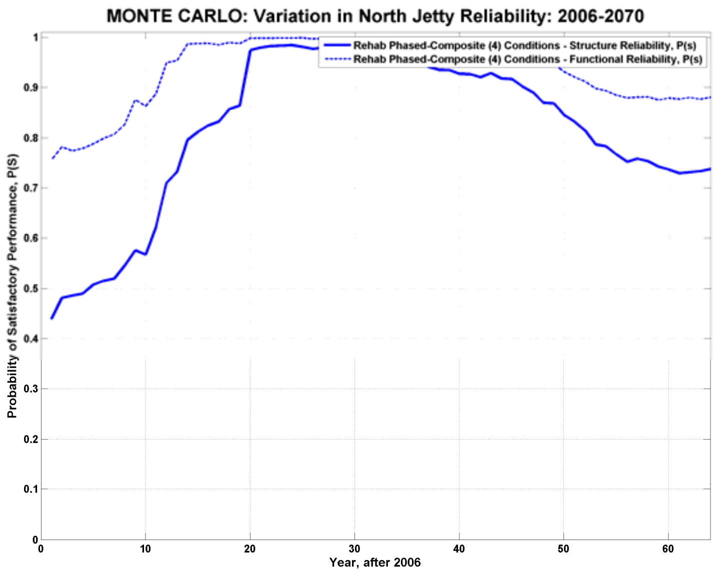

Figure A2-79c. Forecast reliability for MCR North Jetty. Composite 4 Small Modified Rehab - Scheduled.

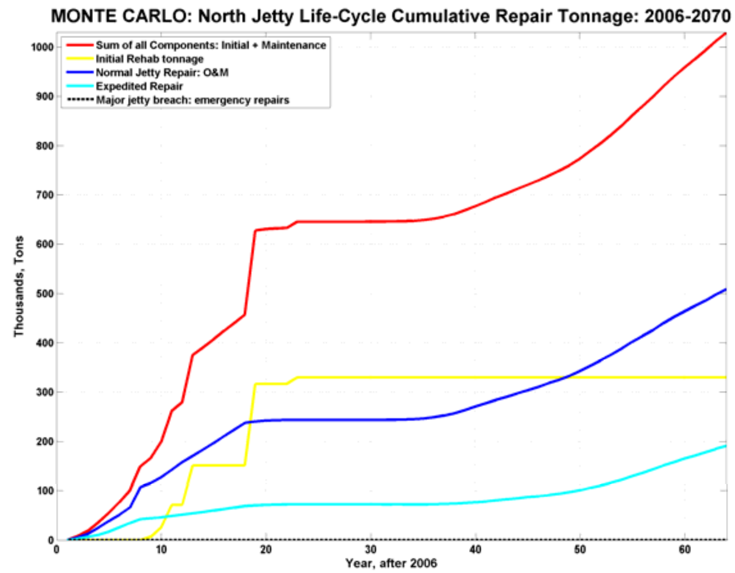

Figure A2-79d. Life-cycle cumulative repair tonnage for MCR North Jetty. Composite 4 Small Modified Rehab - Scheduled.

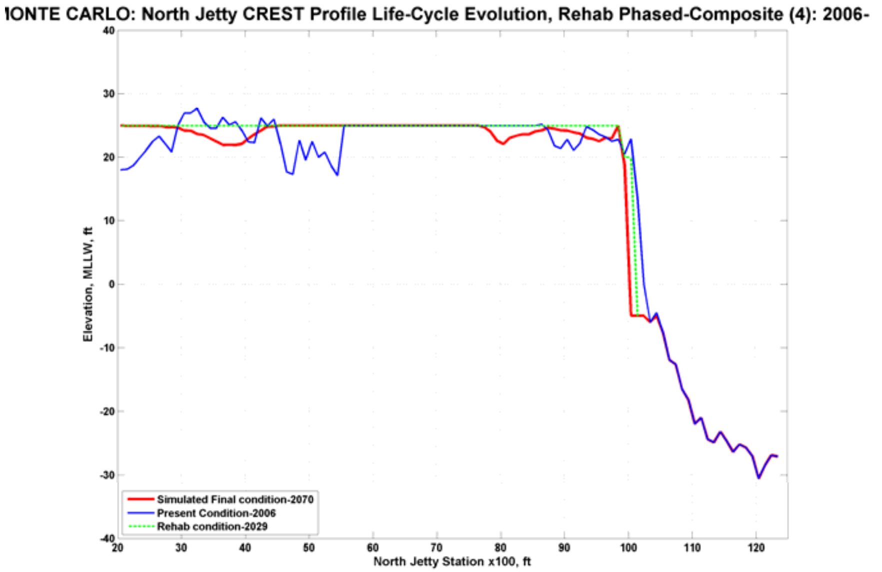

Figure A2-79e. Centerline profile for MCR North Jetty. Composite 4 Small Modified Rehab - Scheduled.

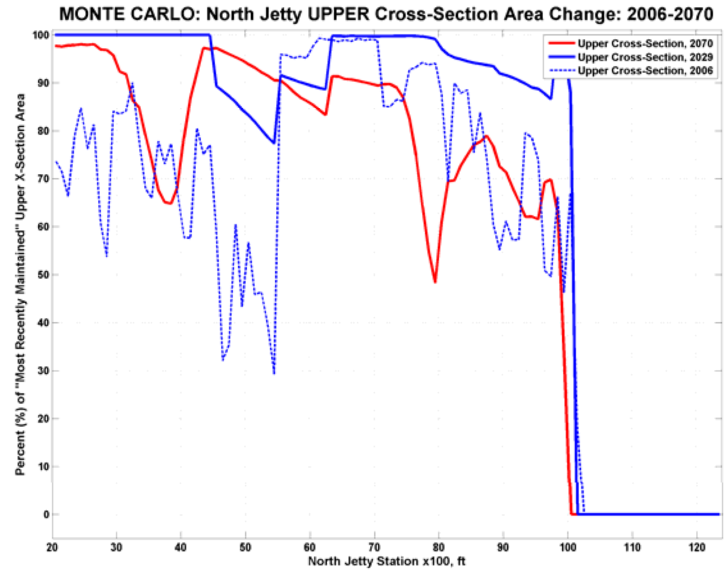

Figure A2-79f. Variation of upper cross-section area for given station of MCR North Jetty. Composite 4 Small Modified Rehab - Scheduled.

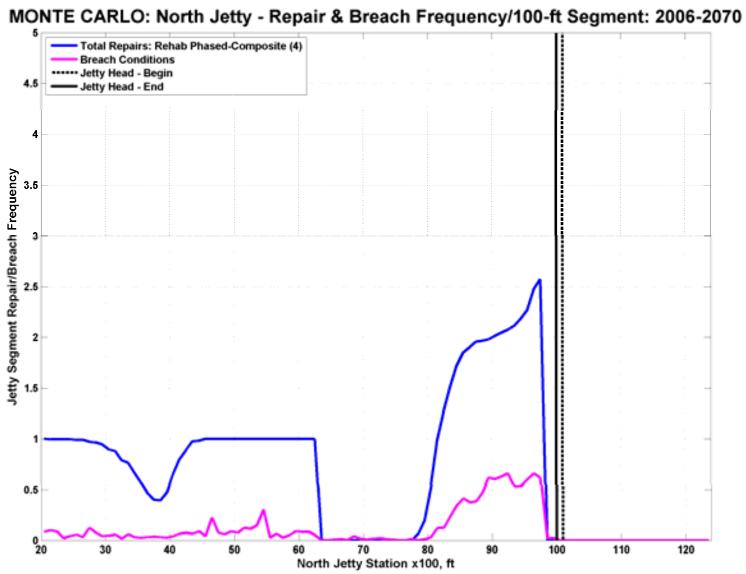

Figure A2-79g. Frequency and location of repairs and breaches for MCR North Jetty. Composite 4 Small Modified Rehab - Scheduled.

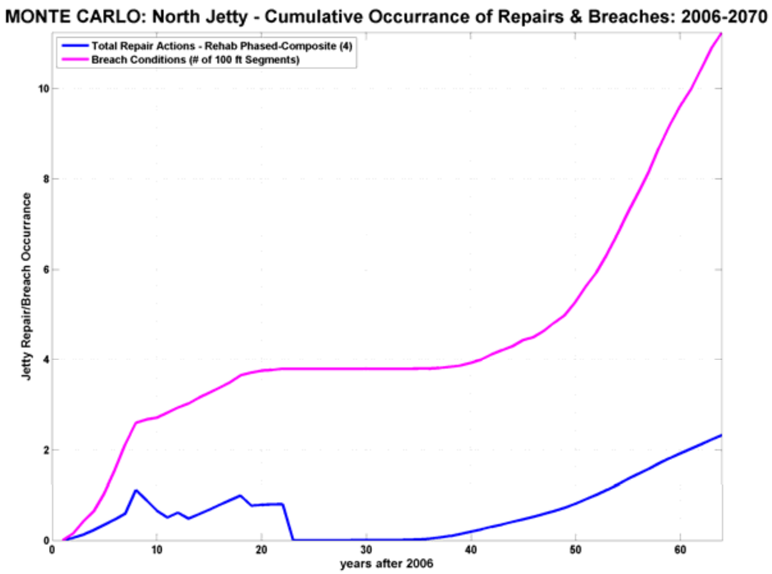

Figure A2-79h. Cumulative occurrence of repairs and breach conditions for MCR North Jetty. Composite 4 Small Modified Rehab - Scheduled.

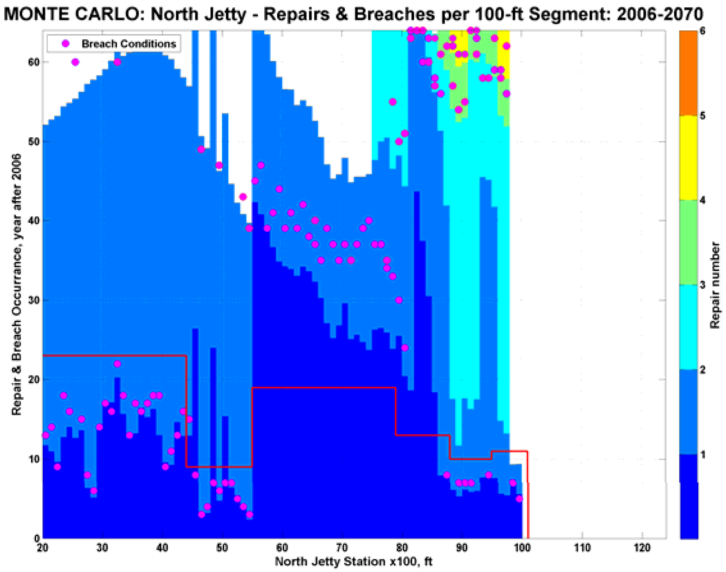

Figure A2-80a. Forecast repair occurrence for MCR North Jetty, shown for each 100 ft jetty segment. Composite 2 Medium Rehab - Scheduled. RED line marks time of REHAB phase implementation

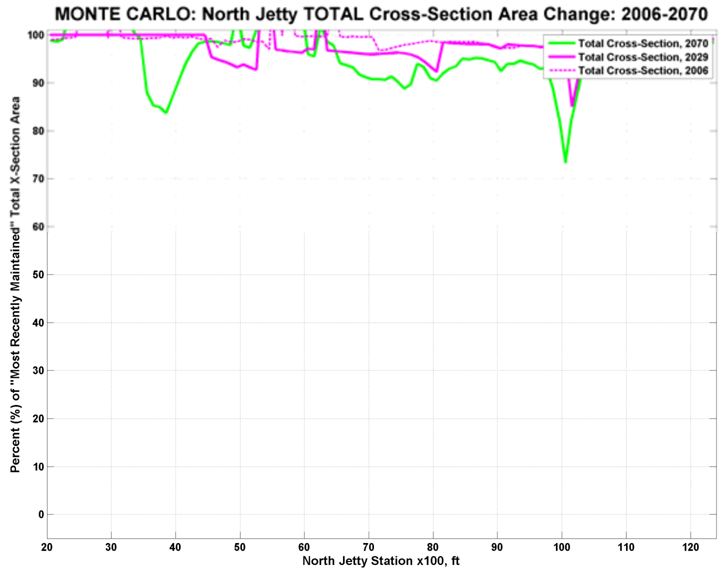

Figure A2-80b. Variation in total cross-section area along MCR North Jetty during forecast period. Composite 2 Medium Rehab - Scheduled.RED line marks time of REHAB phase implementation

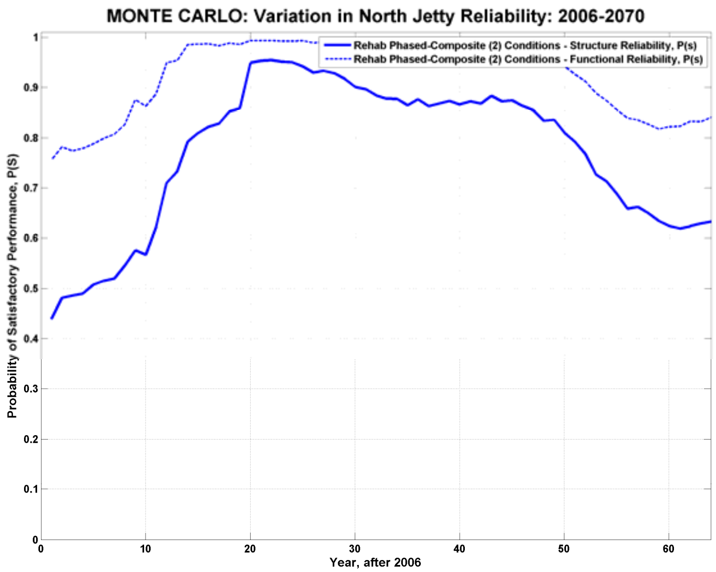

Figure A2-80c. Forecast reliability for MCR North Jetty. Composite 2 Medium Rehab - Scheduled.

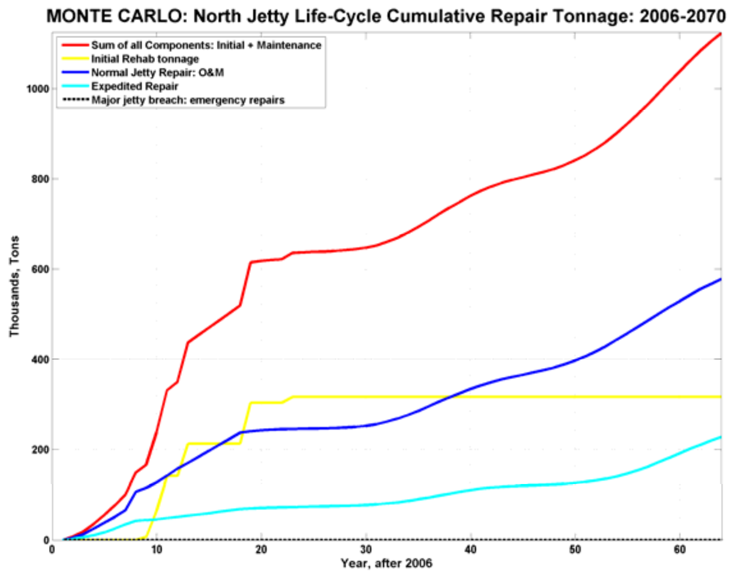

Figure A2-80d. Life-cycle cumulative repair tonnage for MCR North Jetty. Composite 2 Medium Rehab - Scheduled.

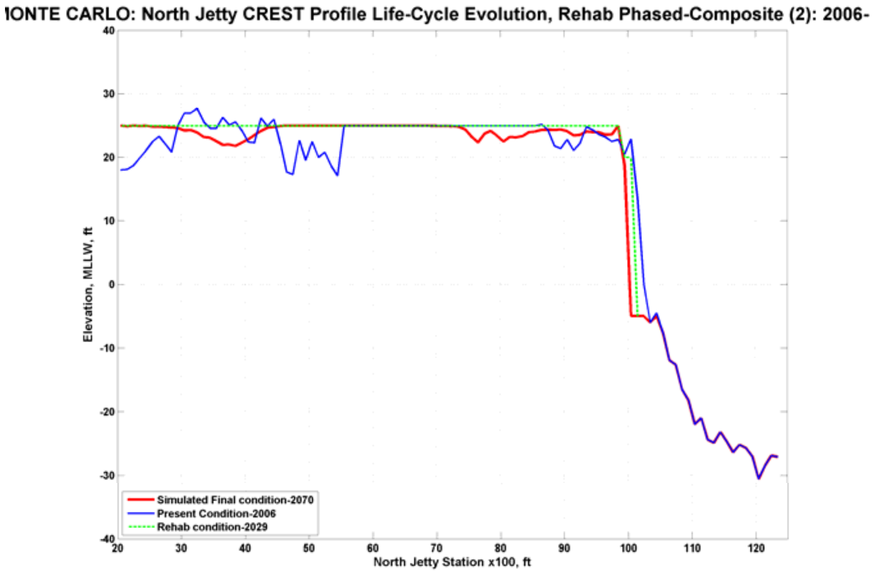

Figure A2-80e. Centerline profile for MCR North Jetty. Composite 2 Medium Rehab - Scheduled.

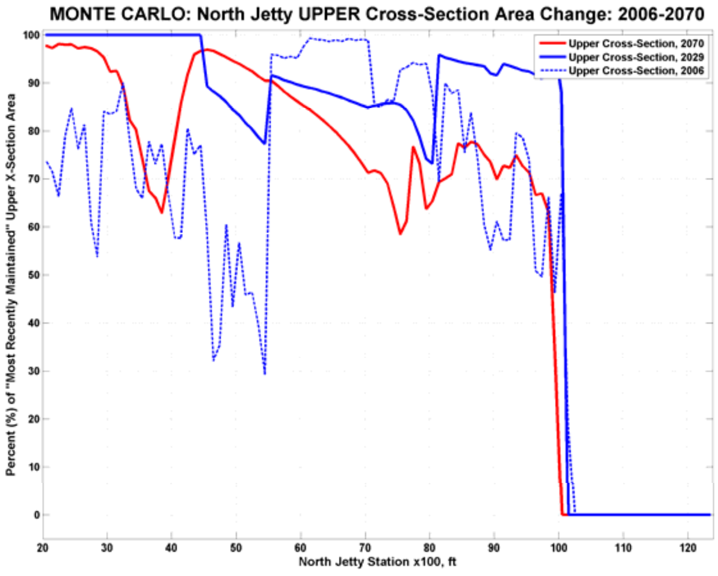

Figure A2-80f. Variation of upper cross-section area for given station of MCR North Jetty. Composite 2 Medium Rehab - Scheduled.

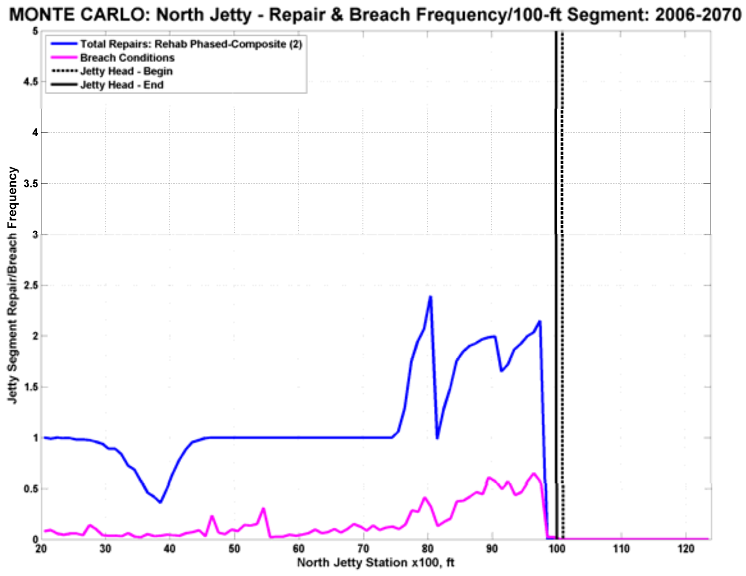

Figure A2-80g. Frequency and location of repairs and breaches for MCR North Jetty. Composite 2 Medium Rehab - Scheduled.

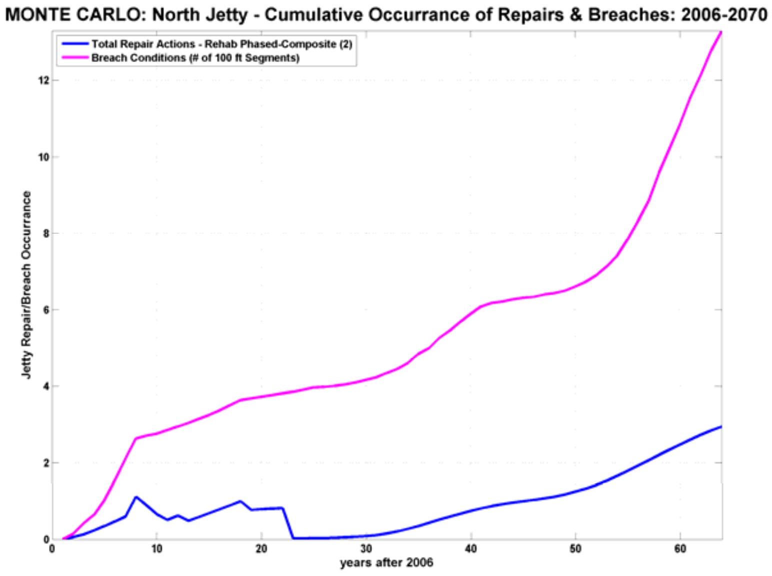

Figure A2-80h. Cumulative occurrence of repairs and breach conditions for MCR North Jetty. Composite 2 Medium Rehab - Scheduled.

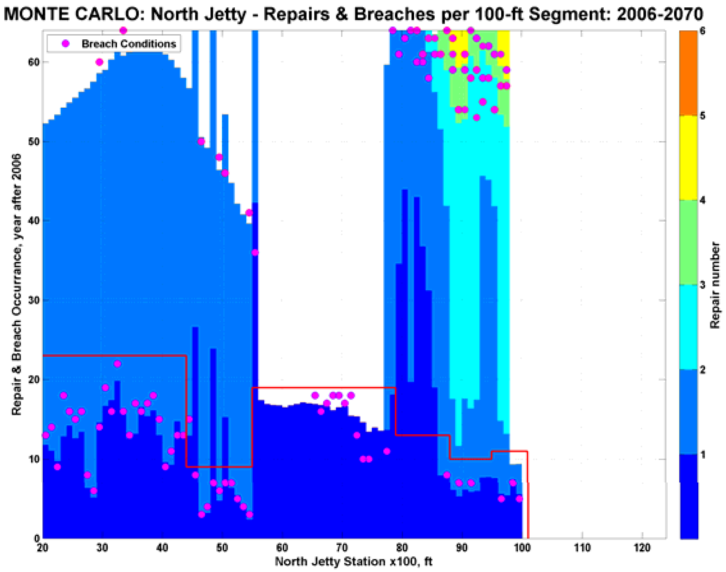

Figure A2-81a. Forecast repair occurrence for MCR North Jetty, shown for each 100 ft jetty segment. Composite 1 Large Rehab - Scheduled. RED line marks time of REHAB phase implementation

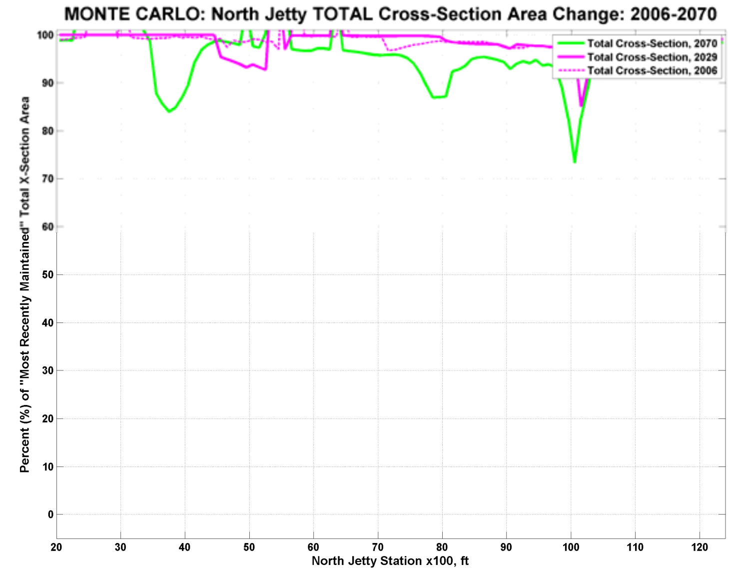

Figure A2-81b. Variation in total cross-section area along MCR North Jetty during forecast period. Composite 1 Large Rehab - Scheduled.RED line marks time of REHAB phase implementation

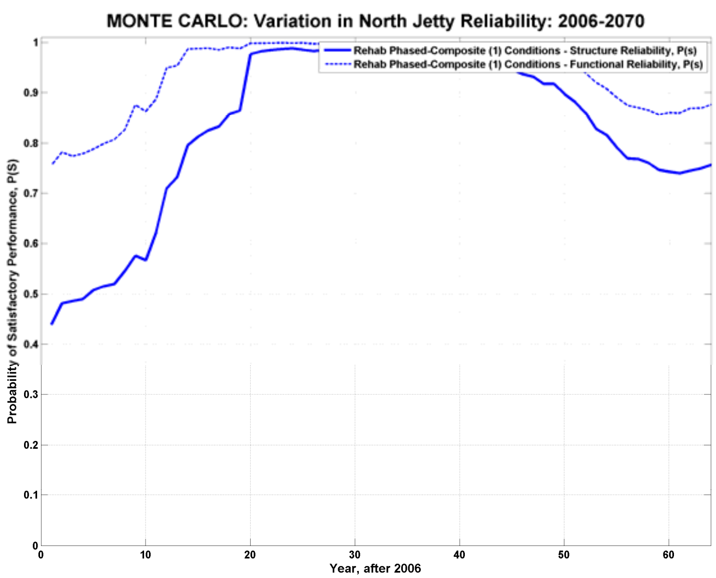

Figure A2-81c. Forecast reliability for MCR North Jetty. Composite 1 Large Rehab - Scheduled.

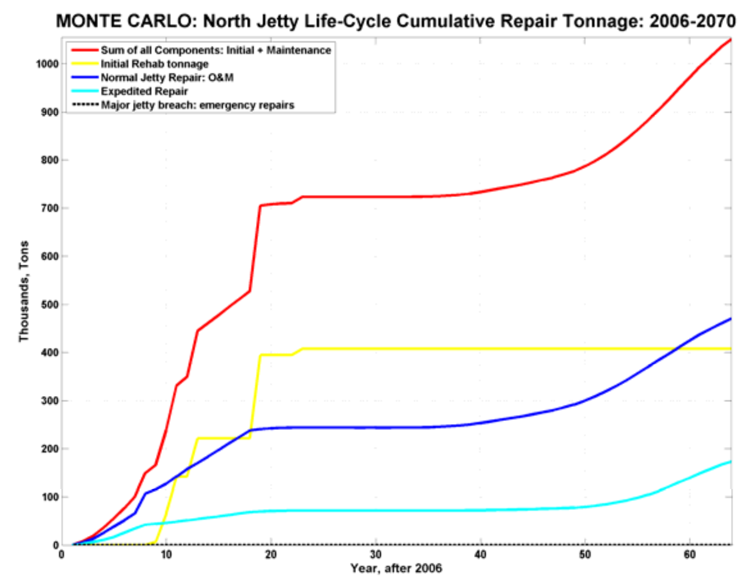

Figure A2-81d. Life-cycle cumulative repair tonnage for MCR North Jetty. Composite 1 Large Rehab - Scheduled.

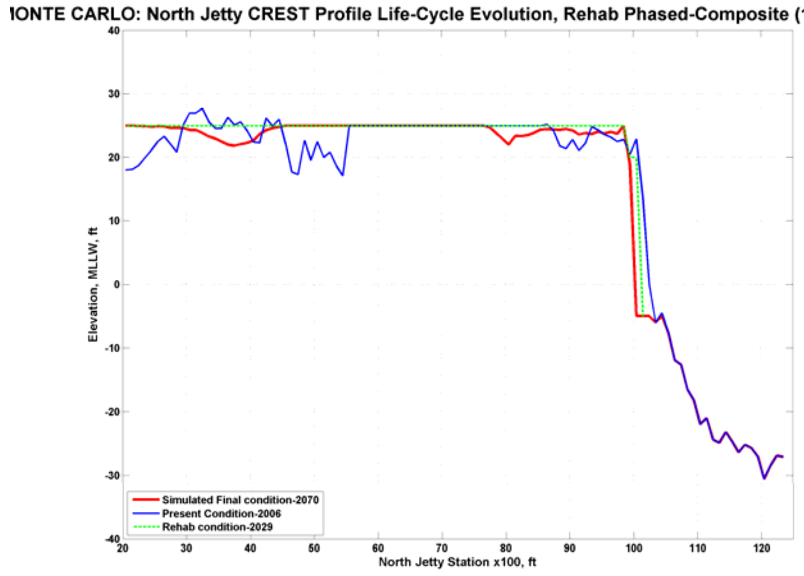

Figure A2-81e. Centerline profile for MCR North Jetty. Composite 1 Large Rehab - Scheduled.

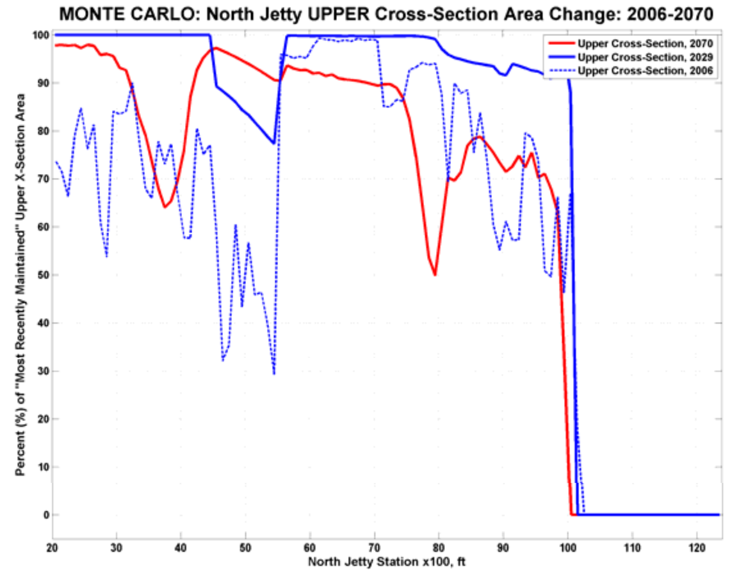

Figure A2-81f. Variation of upper cross-section area for given station of MCR North Jetty. Composite 1 Large Rehab - Scheduled.

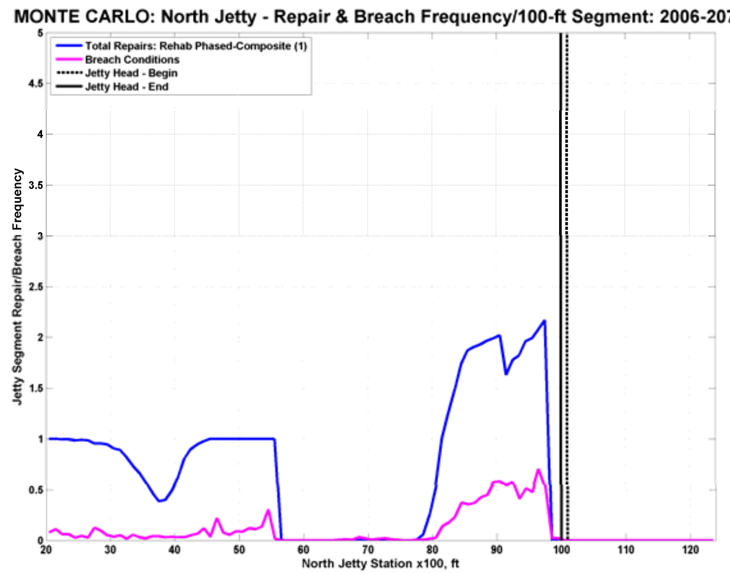

Figure A2-81g. Frequency and location of repairs and breaches for MCR North Jetty. Composite 1 Large Rehab - Scheduled.

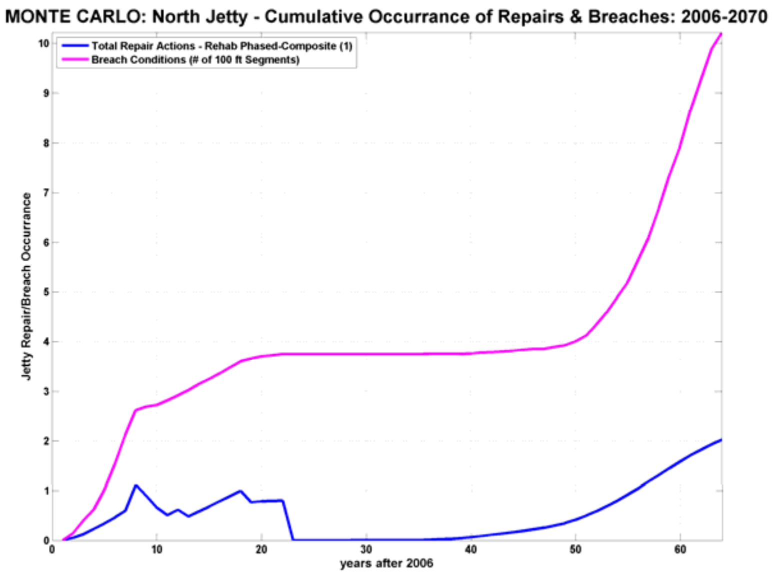

Figure A2-81h. Cumulative occurrence of repairs and breach conditions for MCR North Jetty. Composite 1 Large Rehab - Scheduled.

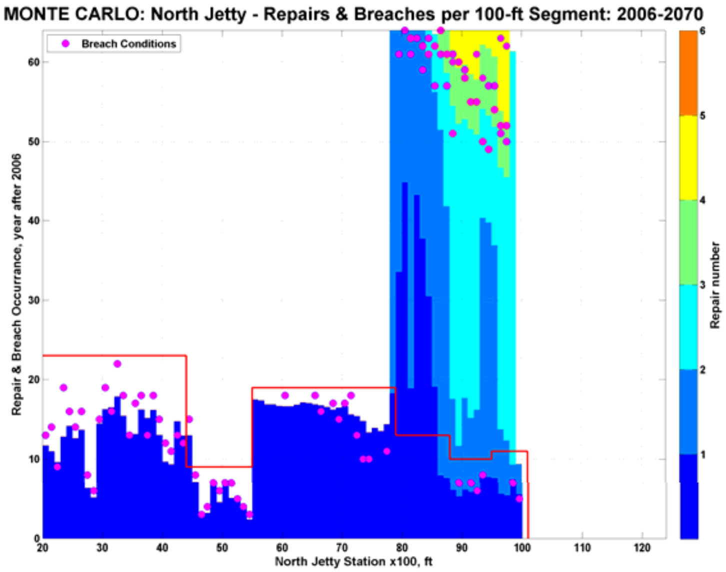

Figure A2-82a. Forecast repair occurrence for MCR North Jetty, shown for each 100 ft jetty segment. Moderate Template Rehab - Scheduled. RED line marks time of REHAB phase implementation

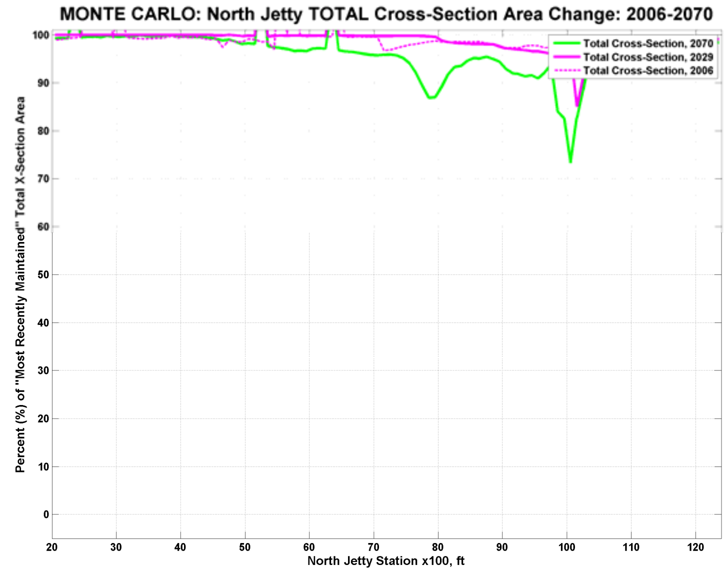

Figure A2-82b. Variation in total cross-section area along MCR North Jetty during forecast period. Moderate Template Rehab - Scheduled.RED line marks time of REHAB phase implementation

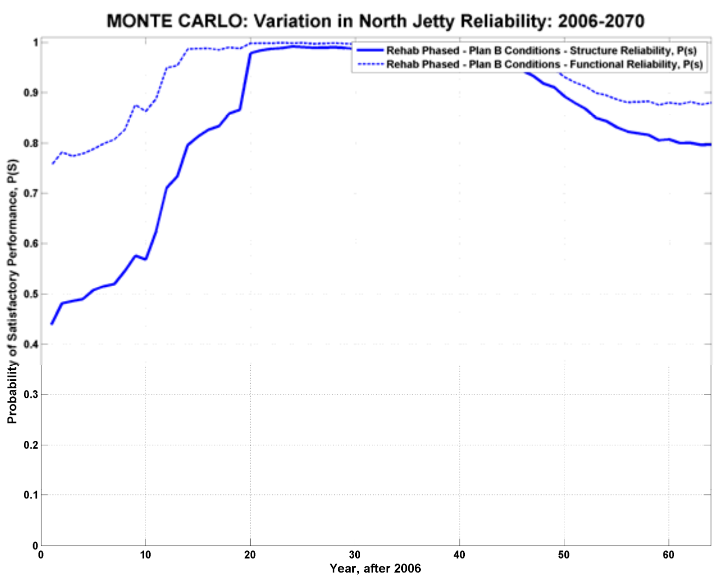

Figure A2-82c. Forecast reliability for MCR North Jetty. Moderate Template Rehab - Scheduled.

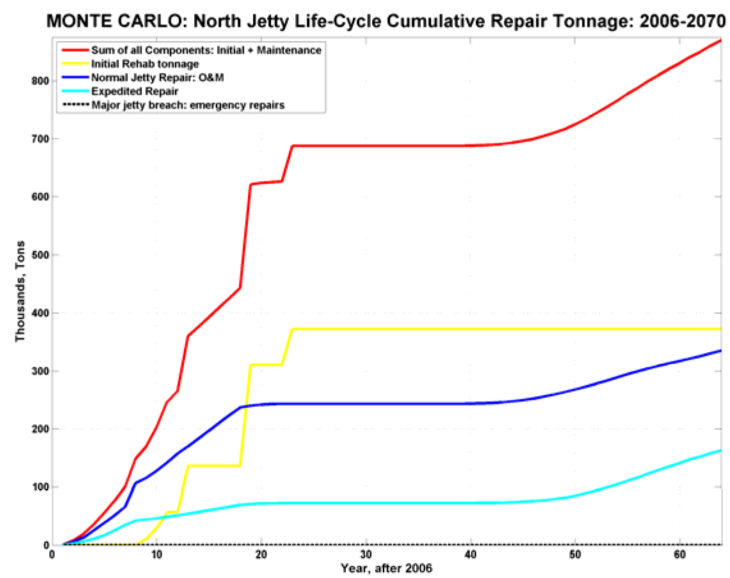

Figure A2-82d. Life-cycle cumulative repair tonnage for MCR North Jetty. Moderate Template Rehab - Scheduled.

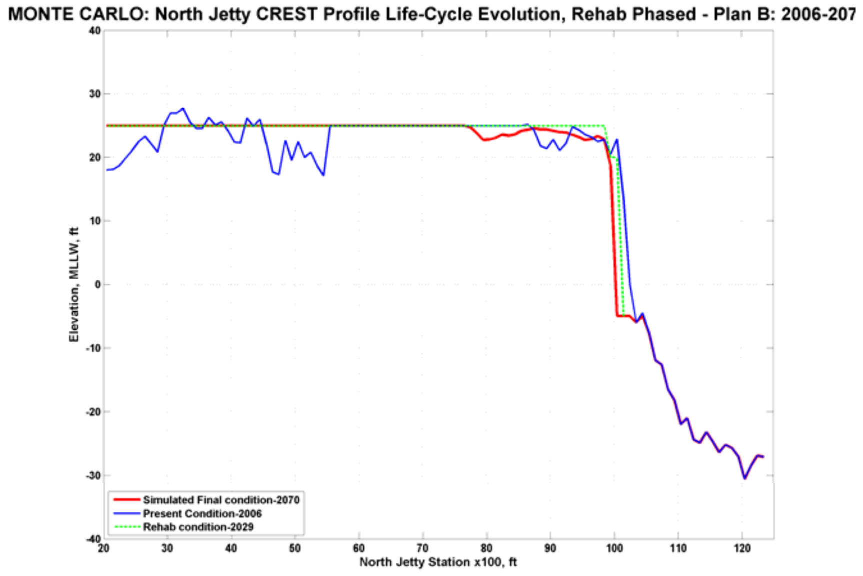

Figure A2-82e. Centerline profile for MCR North Jetty. Moderate Template Rehab - Scheduled.

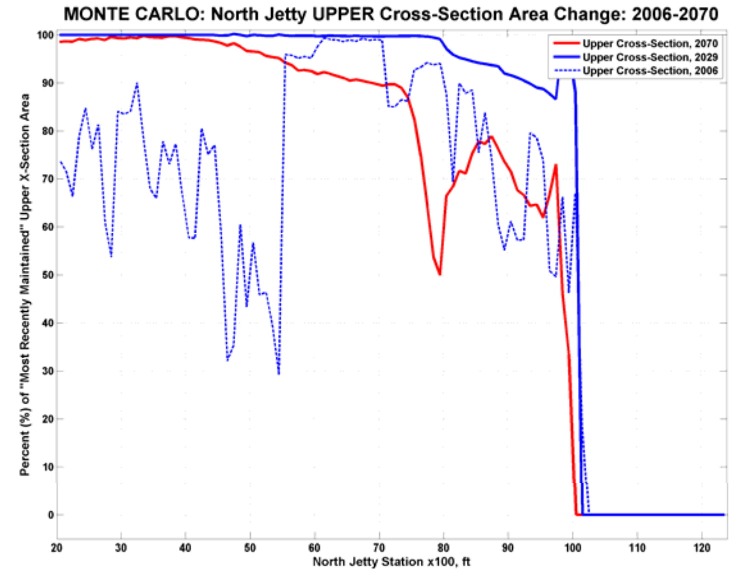

Figure A2-82f. Variation of upper cross-section area for given station of MCR North Jetty. Moderate Template Rehab - Scheduled.

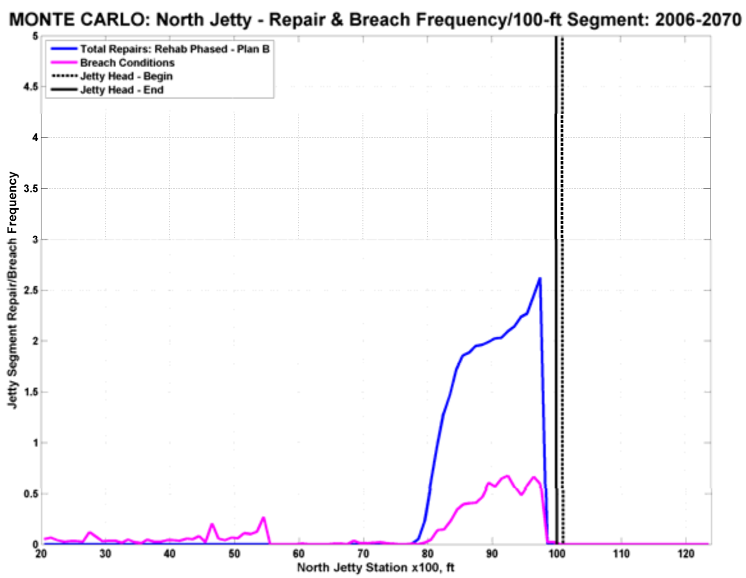

Figure A2-82g. Frequency and location of repairs and breaches for MCR North Jetty. Moderate Template Rehab - Scheduled.

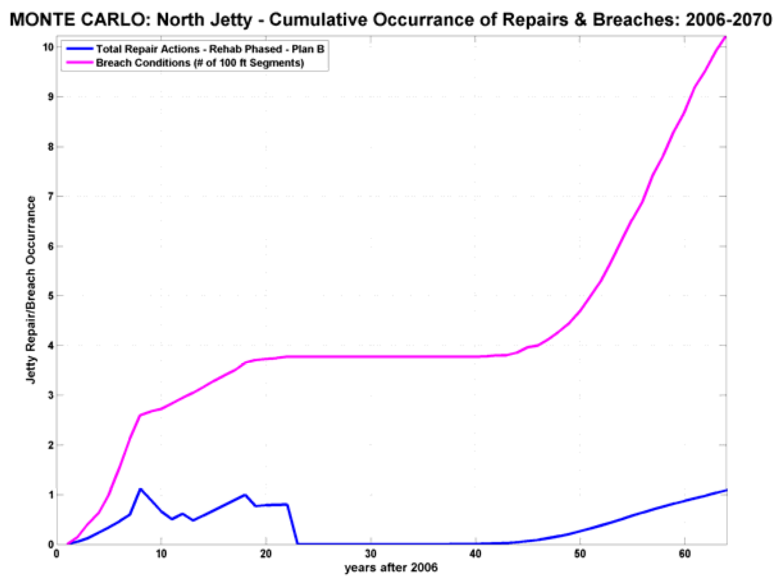

Figure A2-82h. Cumulative occurrence of repairs and breach conditions for MCR North Jetty. Moderate Template Rehab - Scheduled.

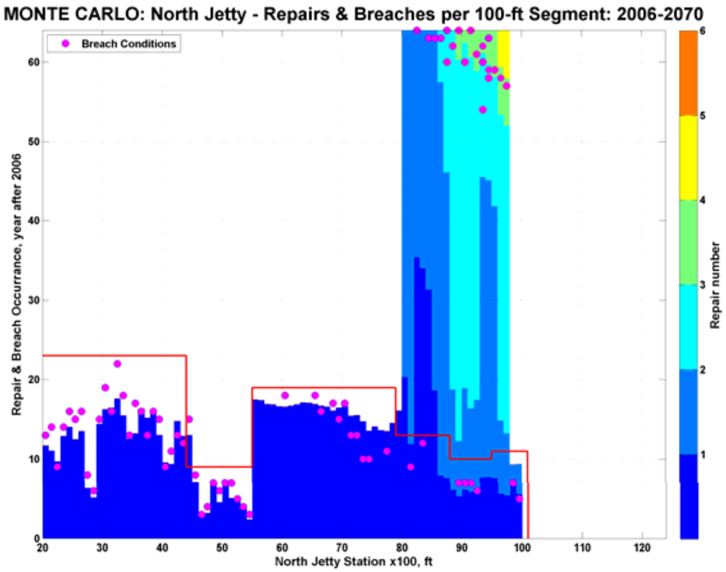

Figure A2-83a. Forecast repair occurrence for MCR North Jetty, shown for each 100 ft jetty segment. Large Template Rehab - Scheduled. RED line marks time of REHAB phase implementation

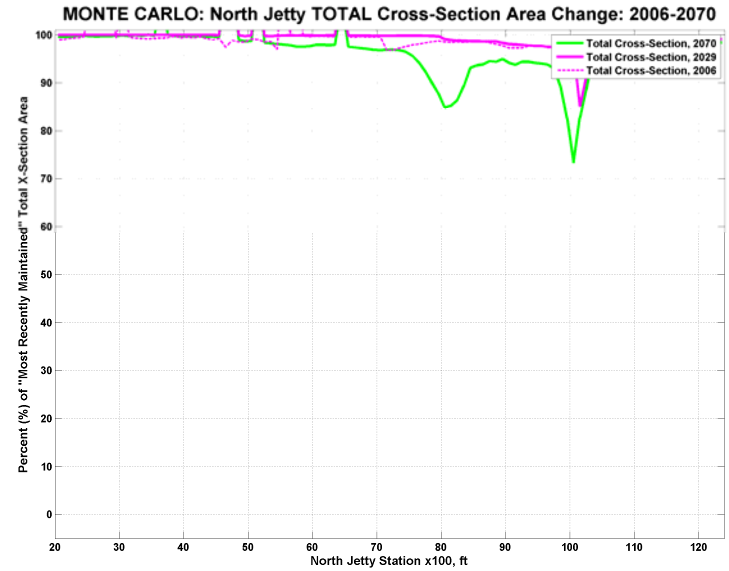

Figure A2-83b. Variation in total cross-section area along MCR North Jetty during forecast period. Large Template Rehab - Scheduled.RED line marks time of REHAB phase implementation

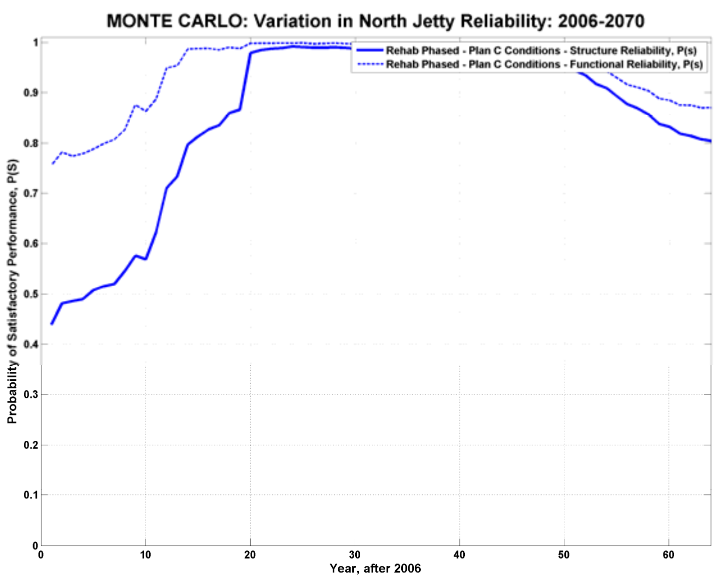

Figure A2-83c. Forecast reliability for MCR North Jetty. Large Template Rehab - Scheduled.

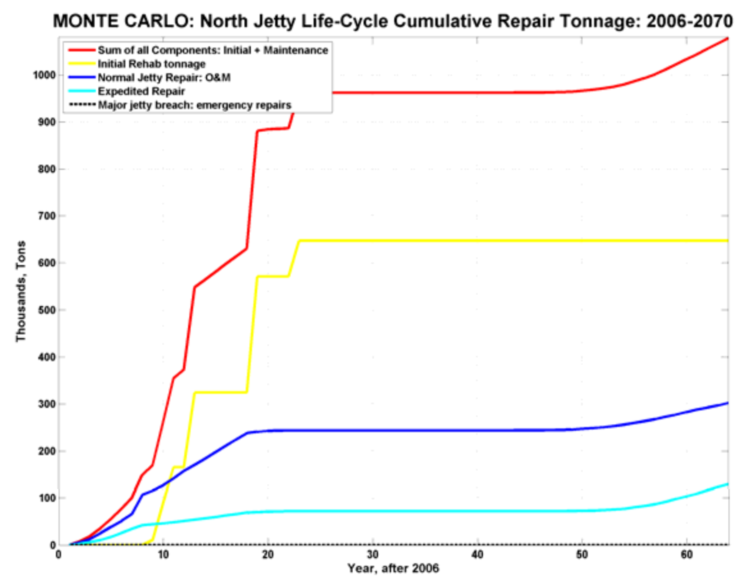

Figure A2-83d. Life-cycle cumulative repair tonnage for MCR North Jetty. Large Template Rehab - Scheduled.

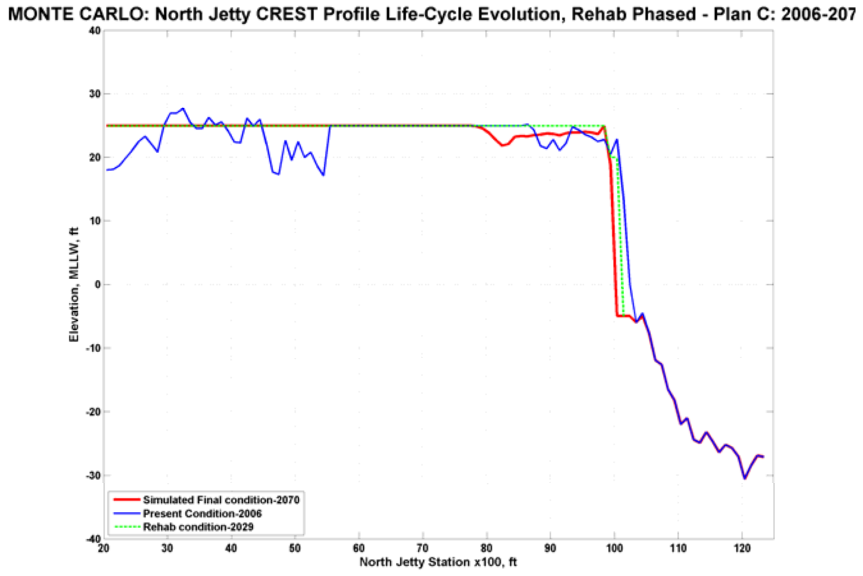

Figure A2-83e. Centerline profile for MCR North Jetty. Large Template Rehab - Scheduled.

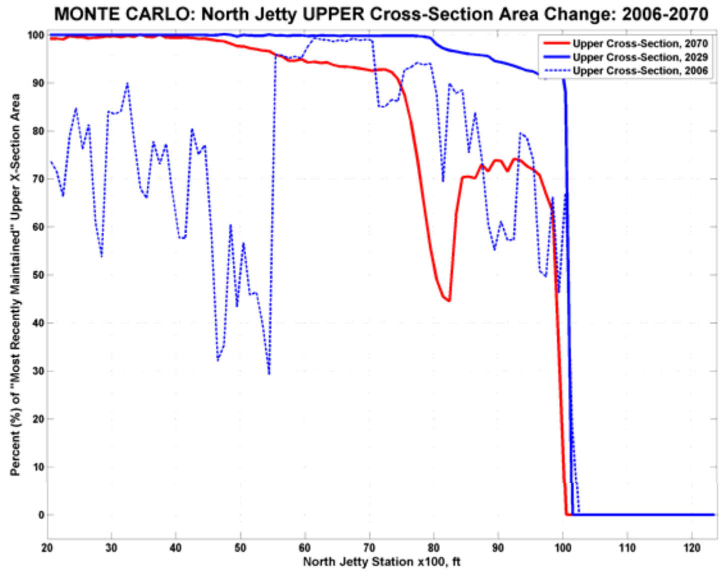

Figure A2-83f. Variation of upper cross-section area for given station of MCR North Jetty. Large Template Rehab - Scheduled.

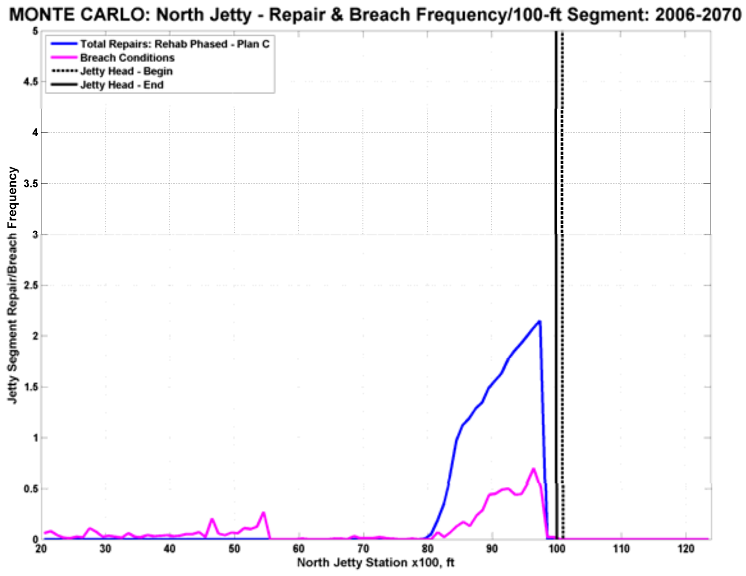

Figure A2-83g. Frequency and location of repairs and breaches for MCR North Jetty. Large Template Rehab - Scheduled.

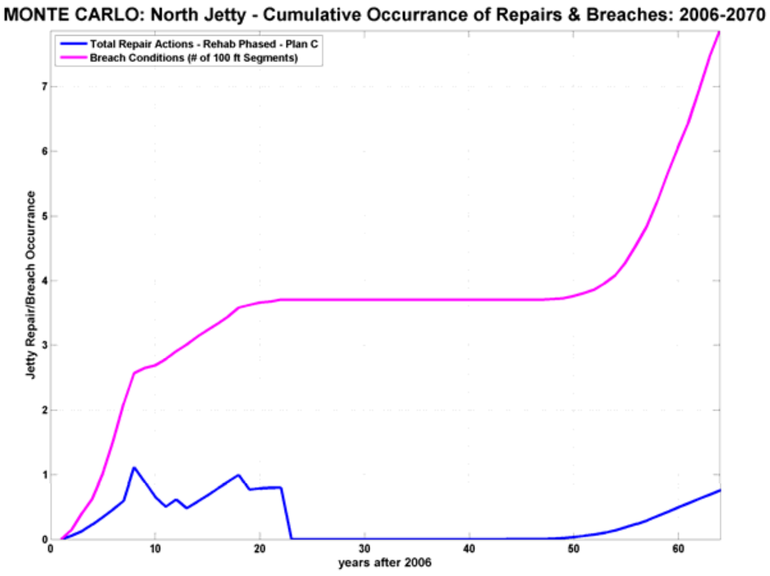

Figure A2-83h. Cumulative occurrence of repairs and breach conditions for MCR North Jetty. Large Template Rehab - Scheduled.

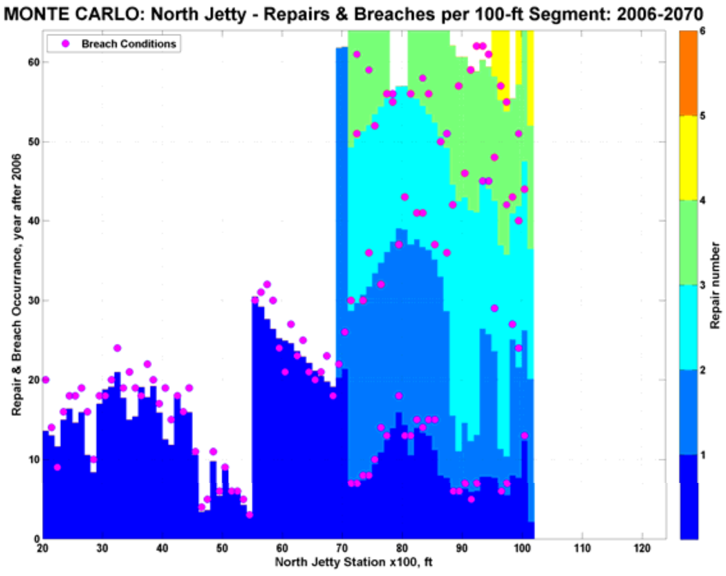

Figure A2-84a. Forecast repair occurrence for MCR North Jetty, shown for each 100 ft jetty segment. Base Condition (Hold Head).

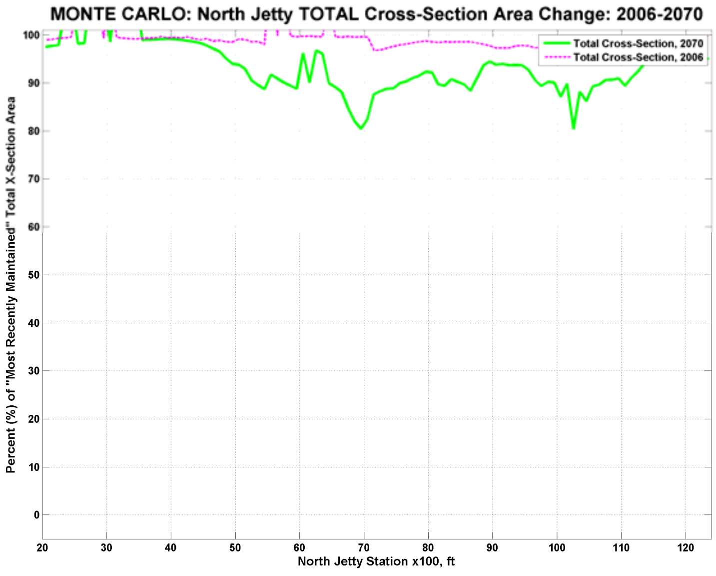

Figure A2-84b. Variation in total cross-section area along MCR North Jetty during forecast period. Base Condition (Hold Head).

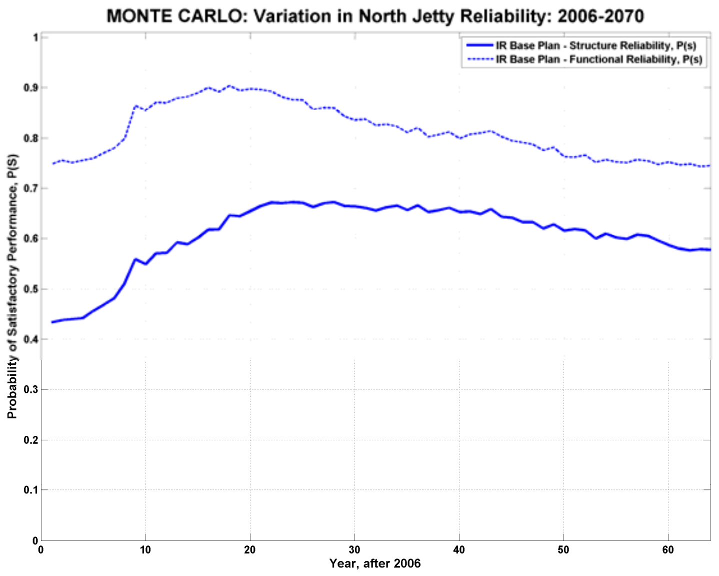

Figure A2-84c. Forecast reliability for MCR North Jetty. Base Condition (Hold Head).

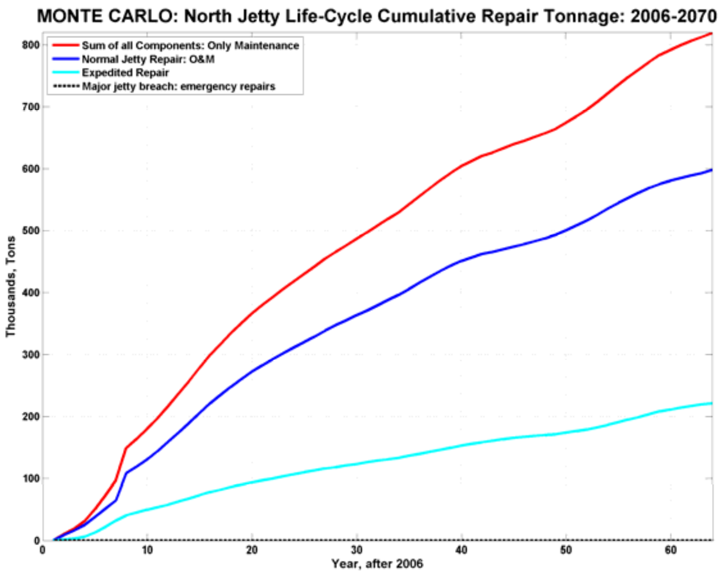

Figure A2-84d. Life-cycle cumulative repair tonnage for MCR North Jetty. Base Condition (Hold Head).

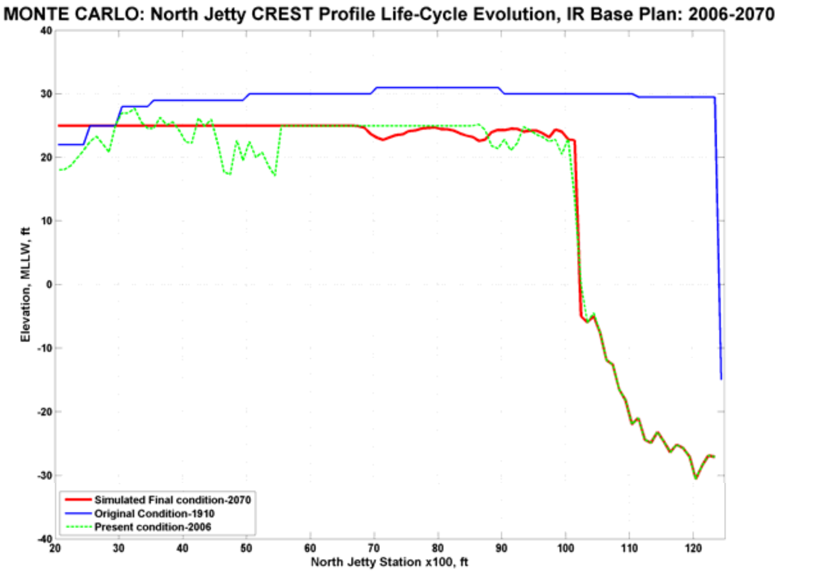

Figure A2-84e. Centerline profile for MCR North Jetty. Base Condition (Hold Head).

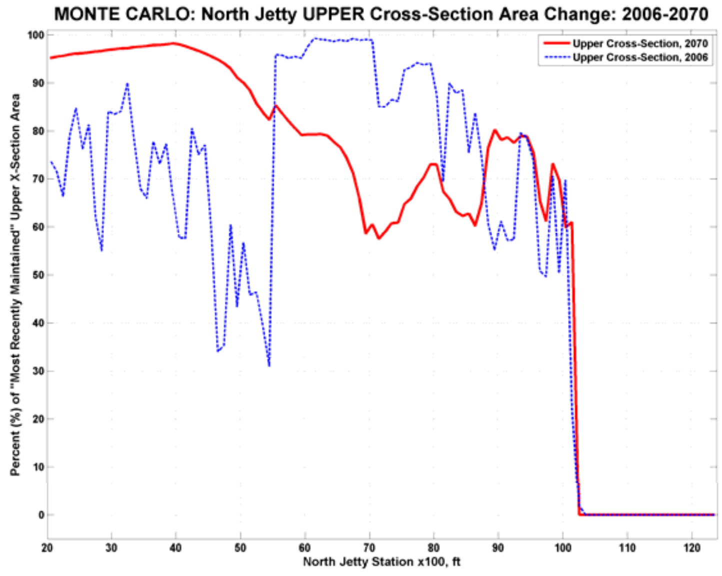

Figure A2-84f. Variation of upper cross-section area for given station of MCR North Jetty. Base Condition (Hold Head).

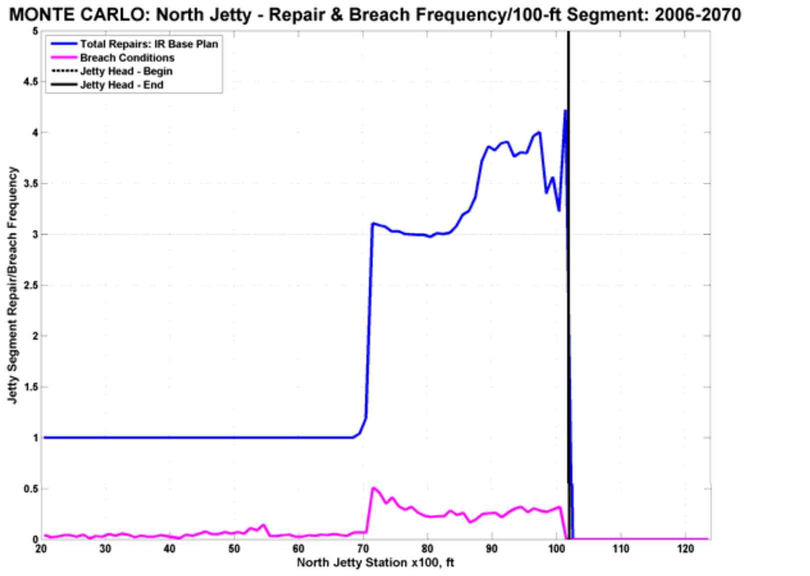

Figure A2-84g. Frequency and location of repairs and breaches for MCR North Jetty. Base Condition (Hold Head).

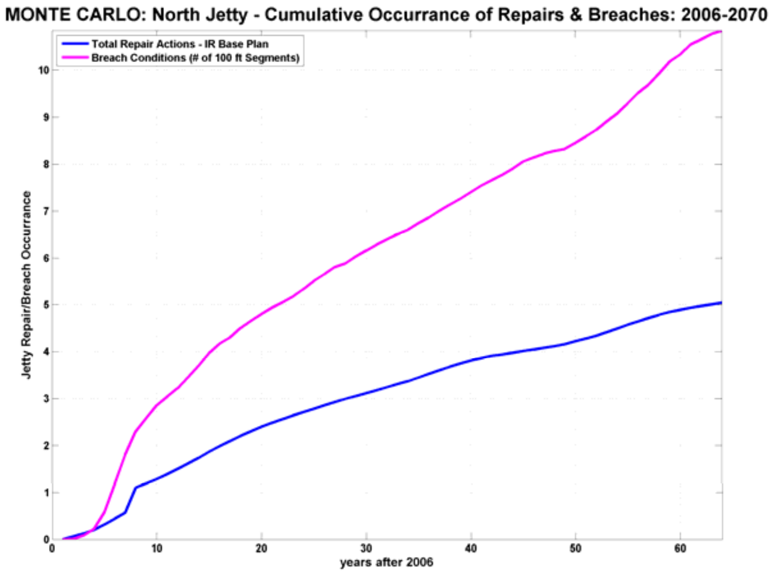

Figure A2-84h. Cumulative occurrence of repairs and breach conditions for MCR North Jetty. Base Condition (Hold Head).

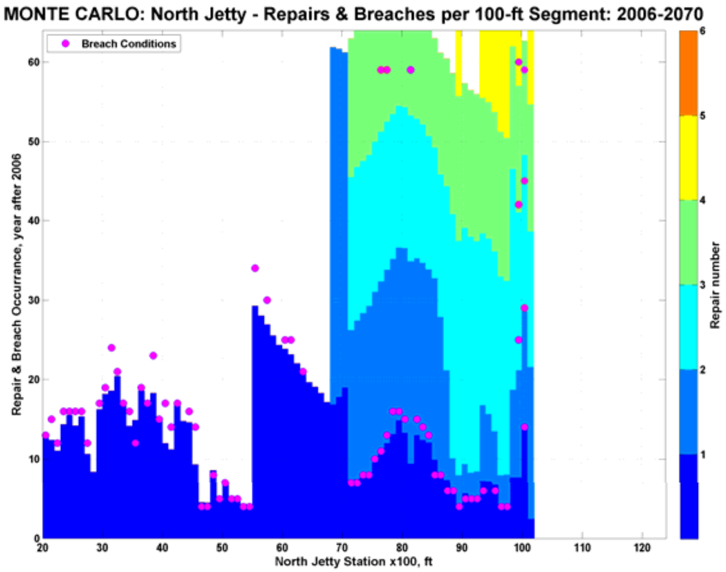

Figure A2-85a. Forecast repair occurrence for MCR North Jetty, shown for each 100 ft jetty segment. Scheduled Repair (Hold Head).

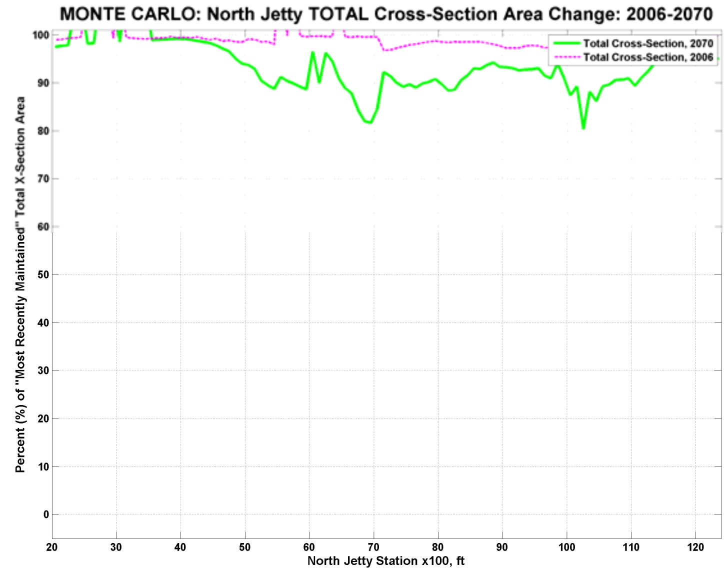

Figure A2-85b. Variation in total cross-section area along MCR North Jetty during forecast period. Scheduled Repair (Hold Head).

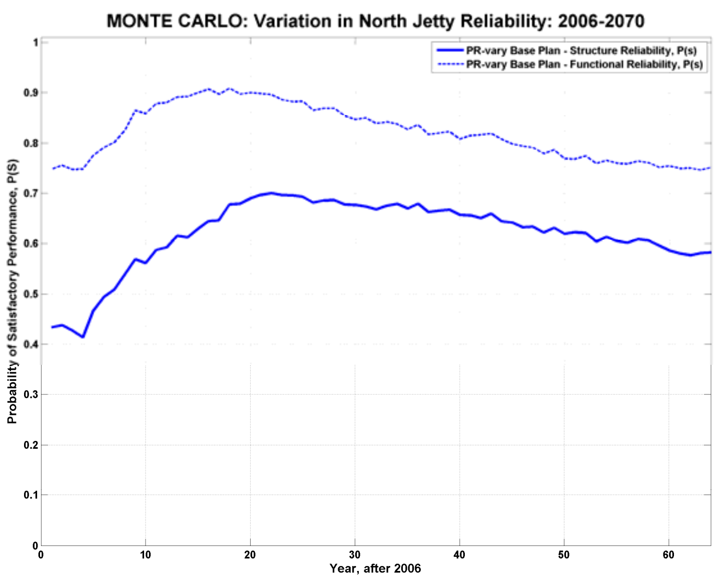

Figure A2-85c. Forecast reliability for MCR North Jetty. Scheduled Repair (Hold Head).

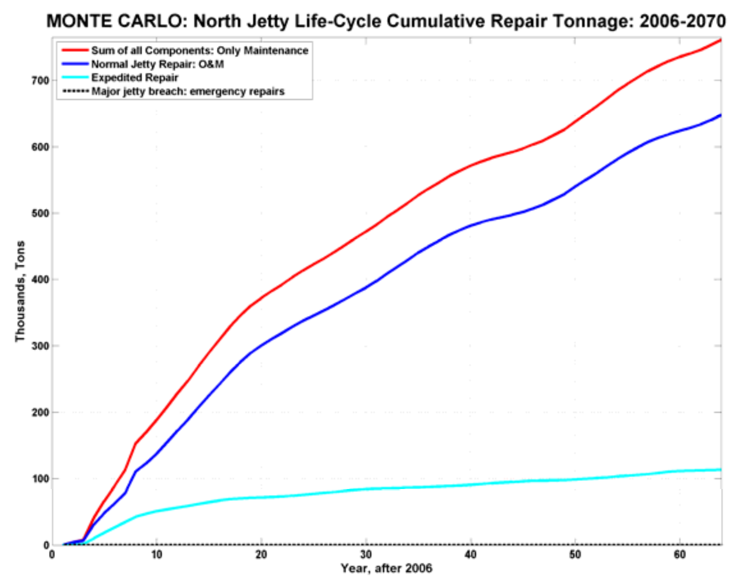

Figure A2-85d. Life-cycle cumulative repair tonnage for MCR North Jetty. Scheduled Repair (Hold Head).

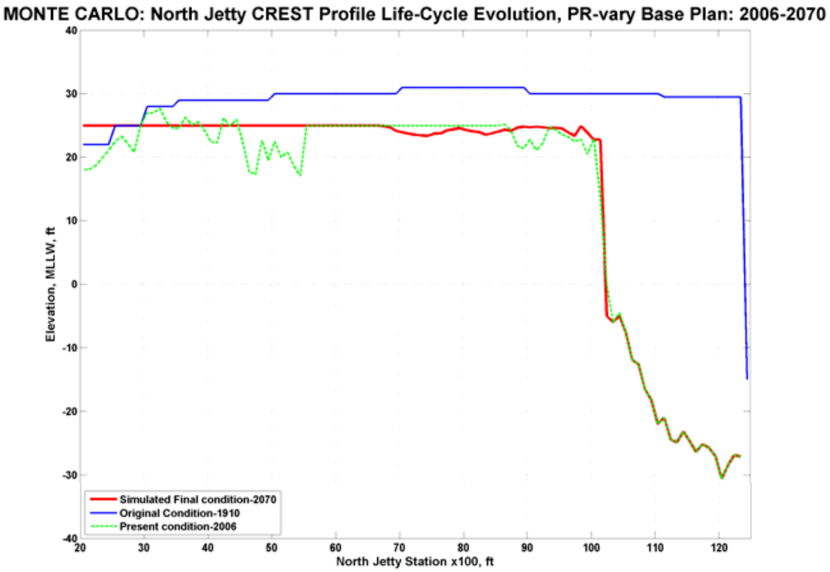

Figure A2-85e. Centerline profile for MCR North Jetty. Scheduled Repair (Hold Head).

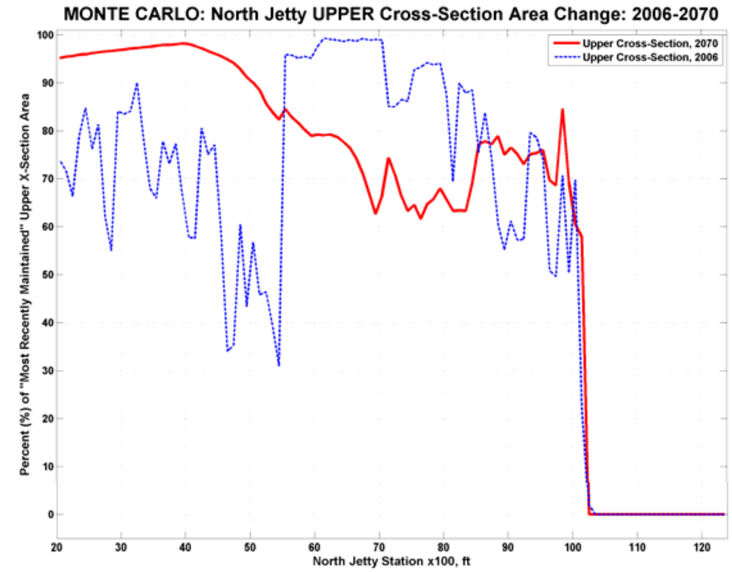

Figure A2-85f. Variation of upper cross-section area for given station of MCR North Jetty. Scheduled Repair (Hold Head).

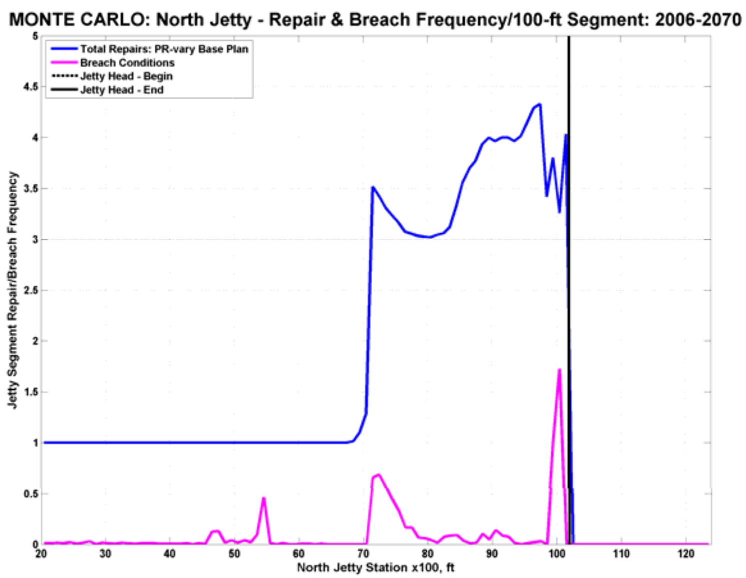

Figure A2-85g. Frequency and location of repairs and breaches for MCR North Jetty. Scheduled Repair (Hold Head).

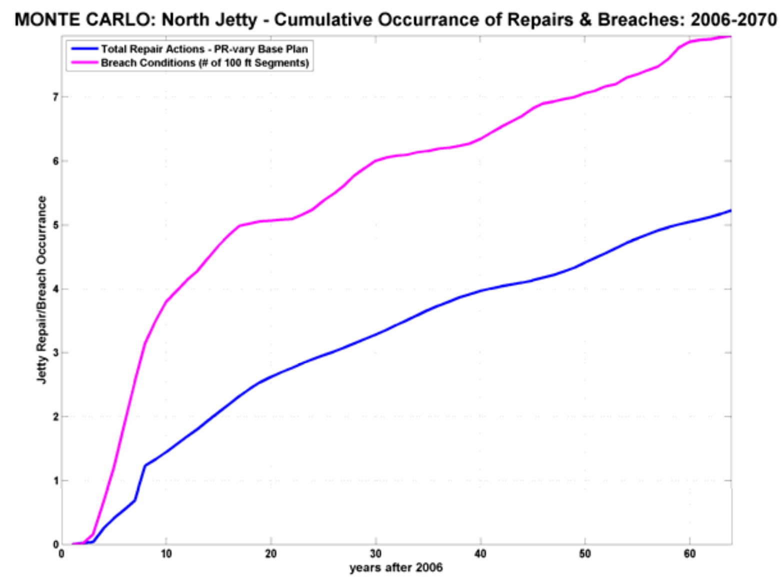

Figure A2-85h. Cumulative occurrence of repairs and breach conditions for MCR North Jetty. Scheduled Repair (Hold Head).

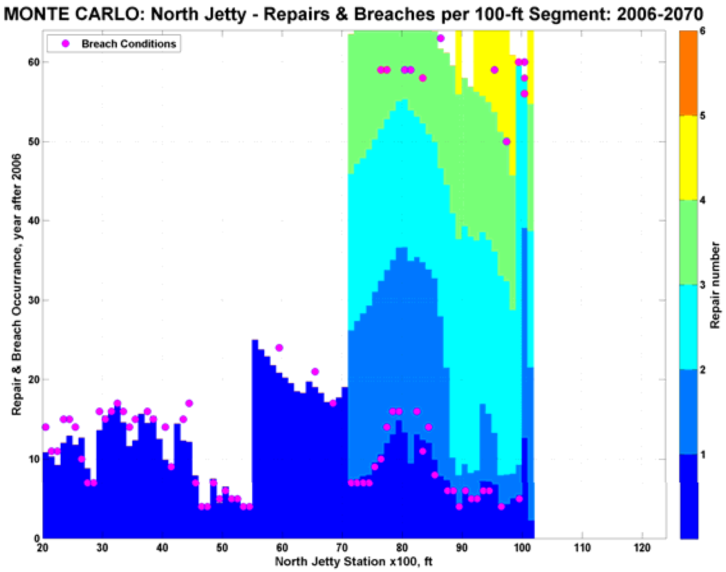

Figure A2-86a. Forecast repair occurrence for MCR North Jetty, shown for each 100 ft jetty segment. Scheduled Repair w/ Engineering Features (Hold Head)

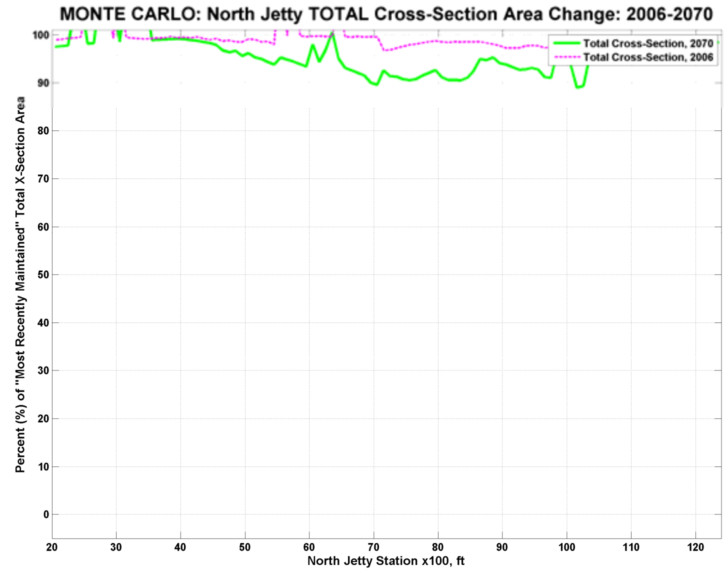

Figure A2-86b. Variation in total cross-section area along MCR North Jetty during forecast period. Scheduled Repair w/ Engineering Features (Hold Head)

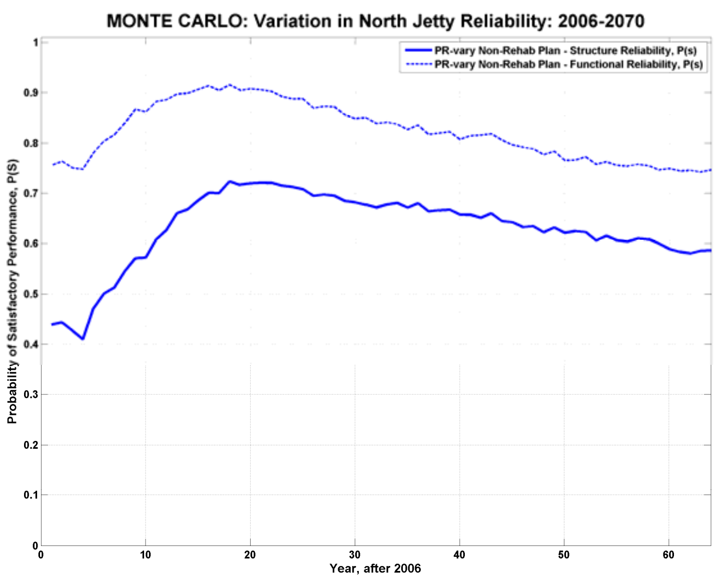

Figure A2-86c. Forecast reliability for MCR North Jetty. Scheduled Repair w/ Engineering Features (Hold Head).

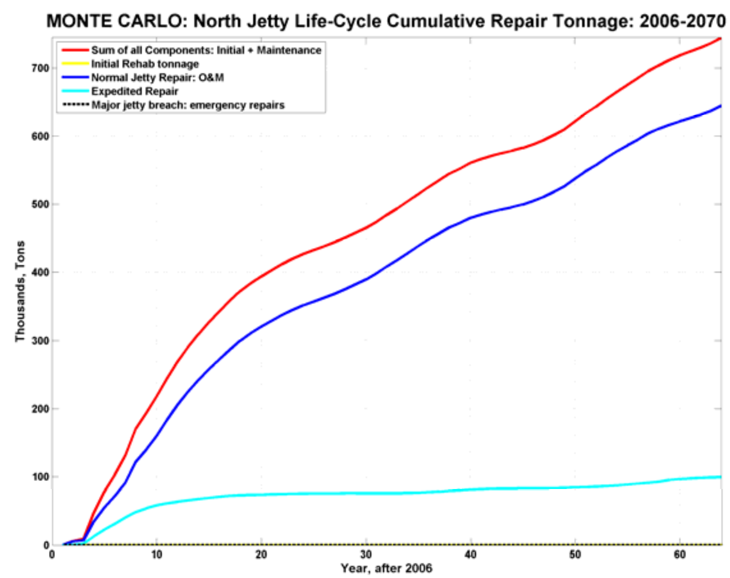

Figure A2-86d. Life-cycle cumulative repair tonnage for MCR North Jetty. Scheduled Repair w/ Engineering Features (Hold Head).

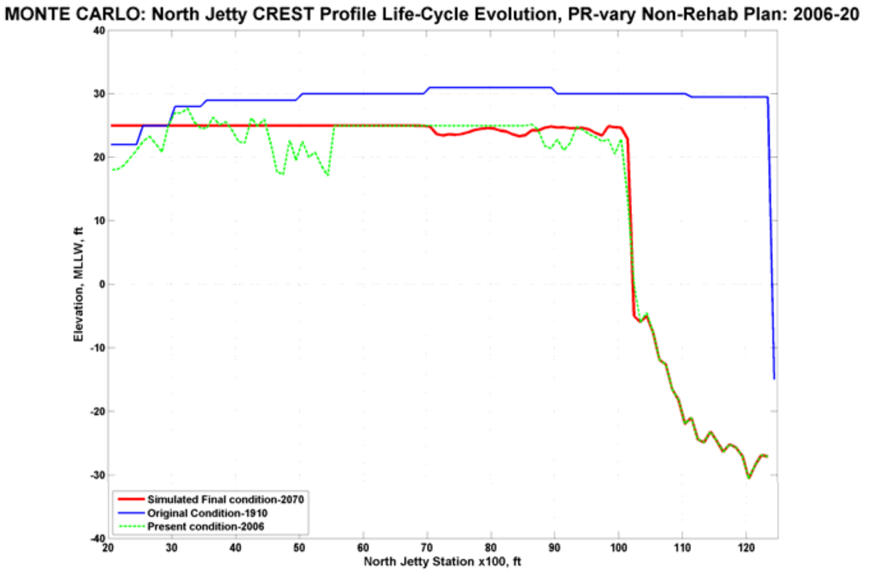

Figure A2-86e. Centerline profile for MCR North Jetty. Scheduled Repair w/ Engineering Features (Hold Head).

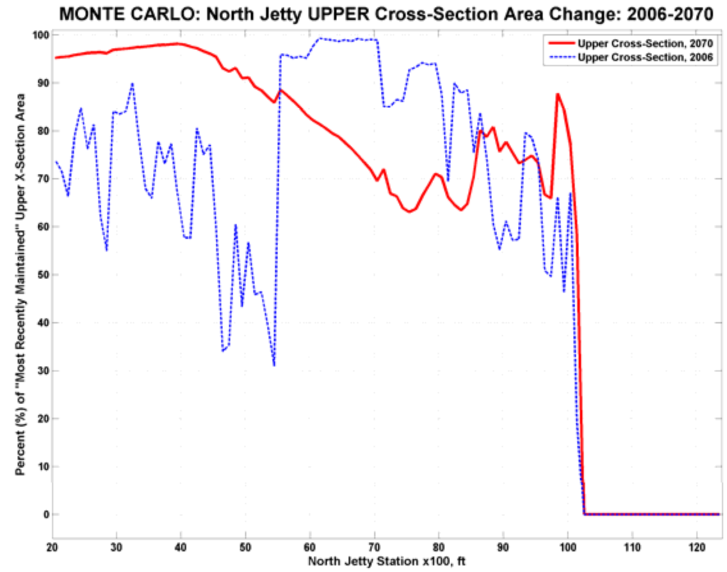

Figure A2-86f. Variation of upper cross-section area for given station of MCR North Jetty. Scheduled Repair w/ Engineering Features (Hold Head).

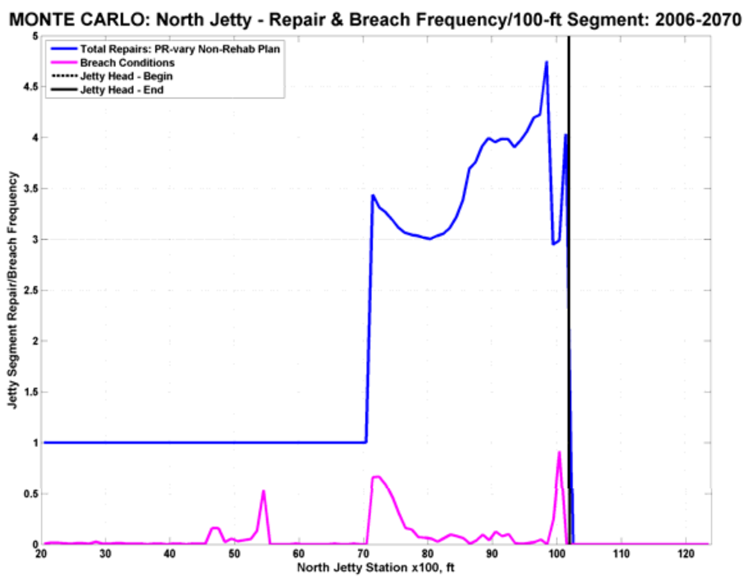

Figure A2-86g. Frequency and location of repairs and breaches for MCR North Jetty. Scheduled Repair w/ Engineering Features (Hold Head).

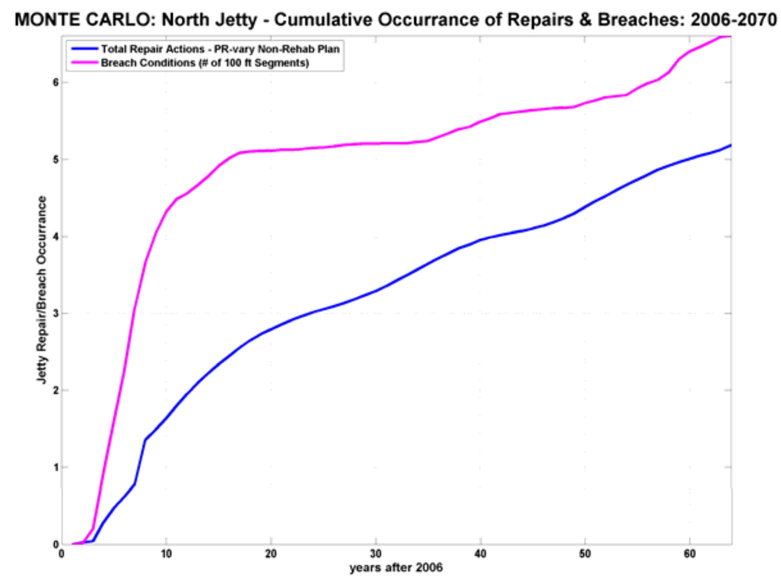

Figure A2-86h. Cumulative occurrence of repairs and breach conditions for MCR North Jetty. Scheduled Repair w/ Engineering Features (Hold Head).

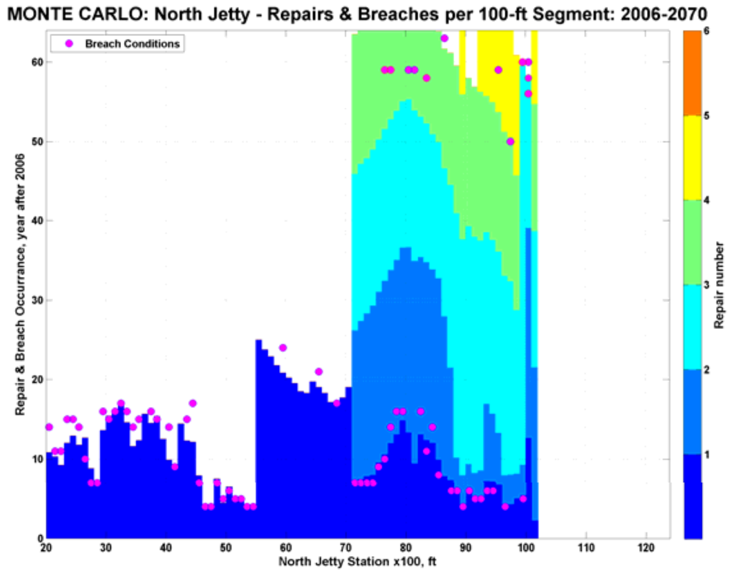

Figure A2-87a. Forecast repair occurrence for MCR North Jetty, shown for each 100 ft jetty segment. Scheduled Repair w/ Spur (Hold Head).

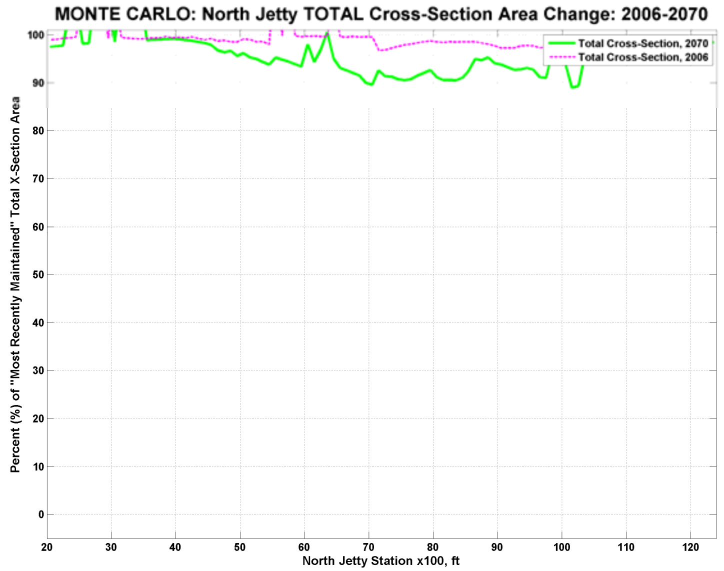

Figure A2-87b. Variation in total cross-section area along MCR North Jetty during forecast period. Scheduled Repair w/ Spur (Hold Head).

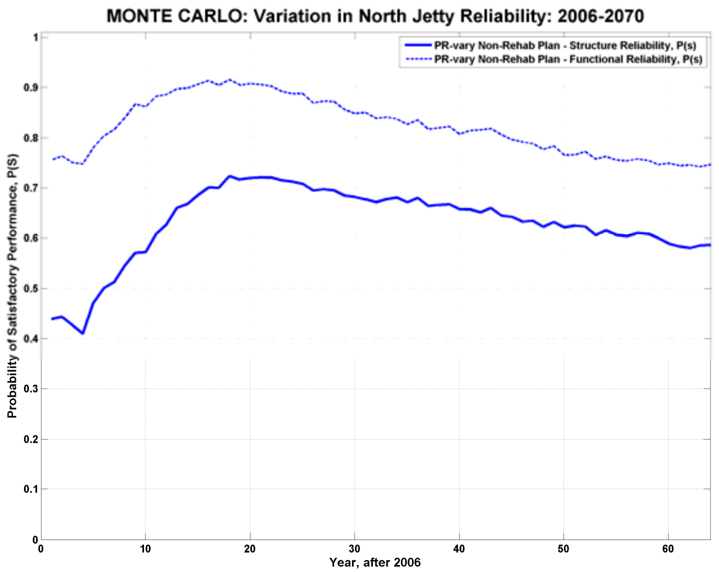

Figure A2-87c. Forecast reliability for MCR North Jetty. Scheduled Repair w/ Spur (Hold Head).

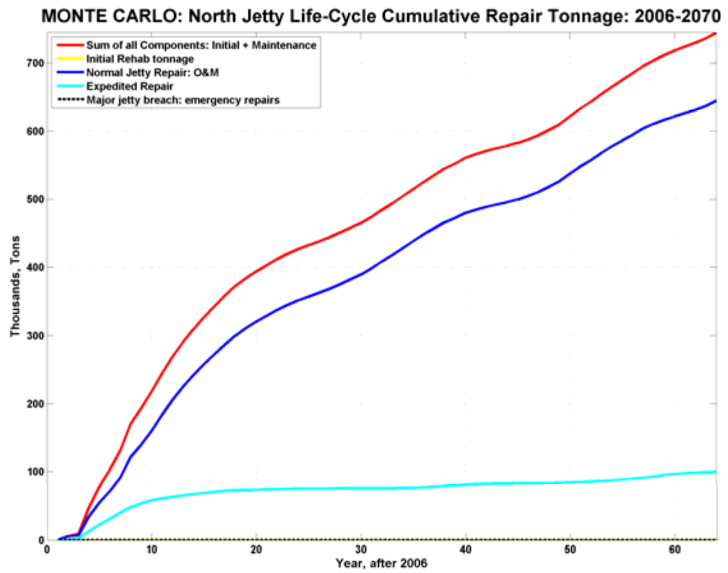

Figure A2-87d. Life-cycle cumulative repair tonnage for MCR North Jetty. Scheduled Repair w/ Spur (Hold Head).

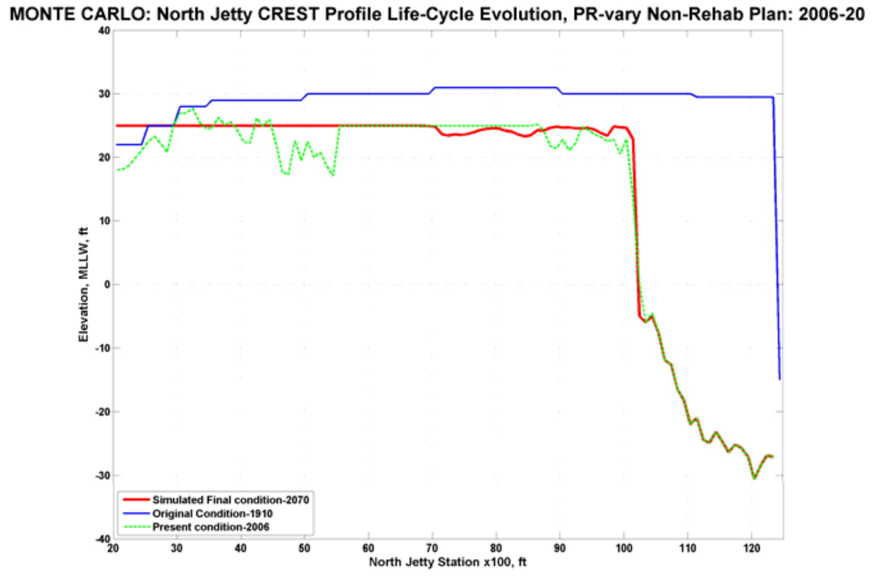

Figure A2-87e. Centerline profile for MCR North Jetty. Scheduled Repair w/ Spur (Hold Head).

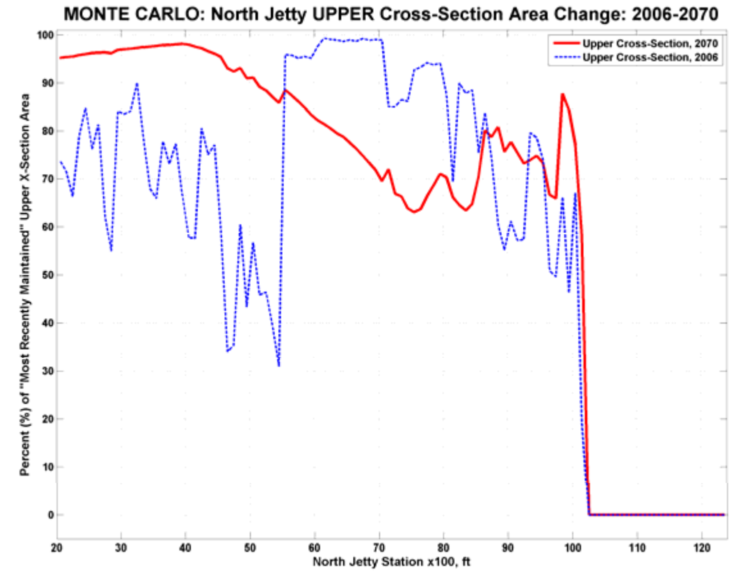

Figure A2-87f. Variation of upper cross-section area for given station of MCR North Jetty. Scheduled Repair w/ Spur (Hold Head).

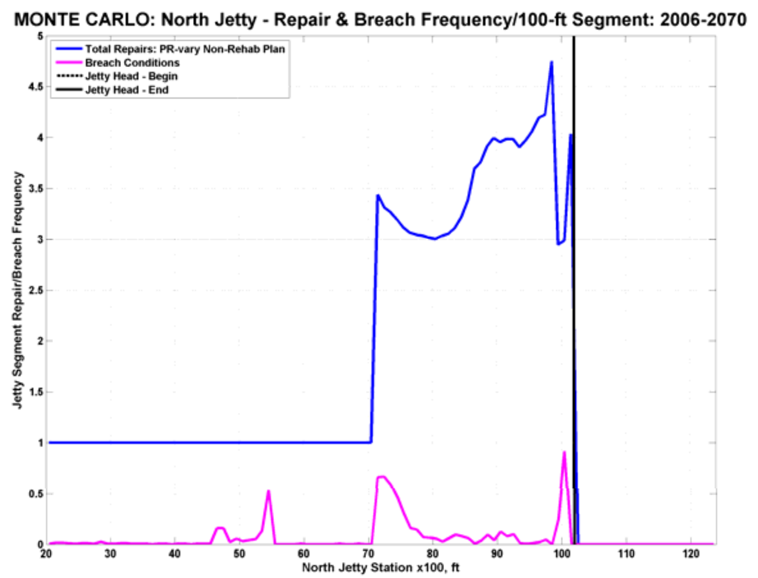

Figure A2-87g. Frequency and location of repairs and breaches for MCR North Jetty. Scheduled Repair w/ Spur (Hold Head).

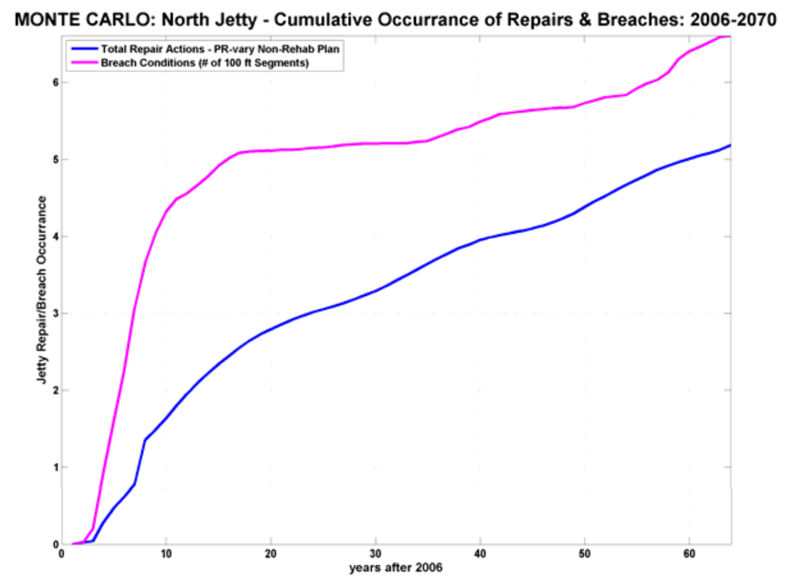

Figure A2-87h. Cumulative occurrence of repairs and breach conditions for MCR North Jetty. Scheduled Repair w/ Spur (Hold Head).

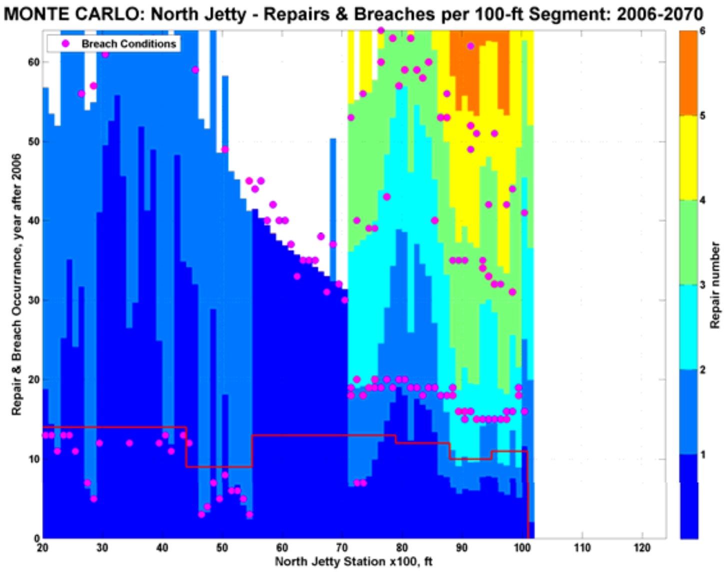

Figure A2-88a. Forecast repair occurrence for MCR North Jetty, shown for each 100 ft jetty segment. Minimum Template Rehab - Immediate (Hold Head). RED line marks time of REHAB phase implementation

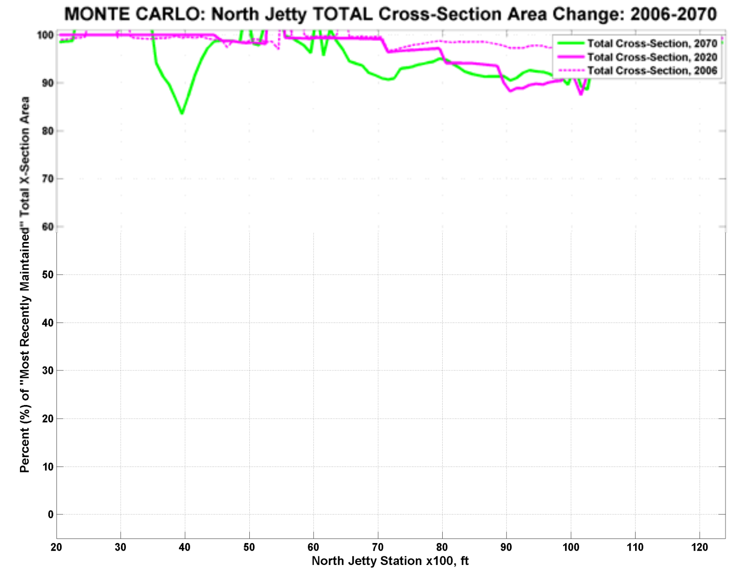

Figure A2-88b. Variation in total cross-section area along MCR North Jetty during forecast period. Minimum Template Rehab - Immediate (Hold Head).RED line marks time of REHAB phase implementation

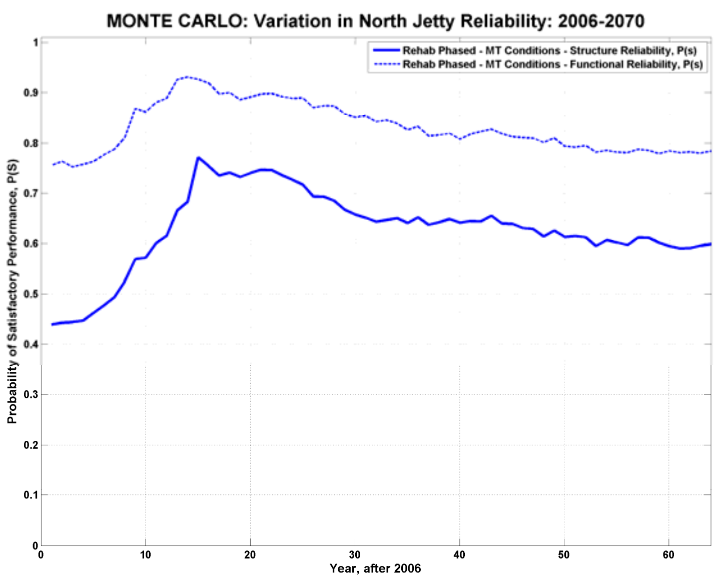

Figure A2-88c. Forecast reliability for MCR North Jetty. Minimum Template Rehab - Immediate (Hold Head).

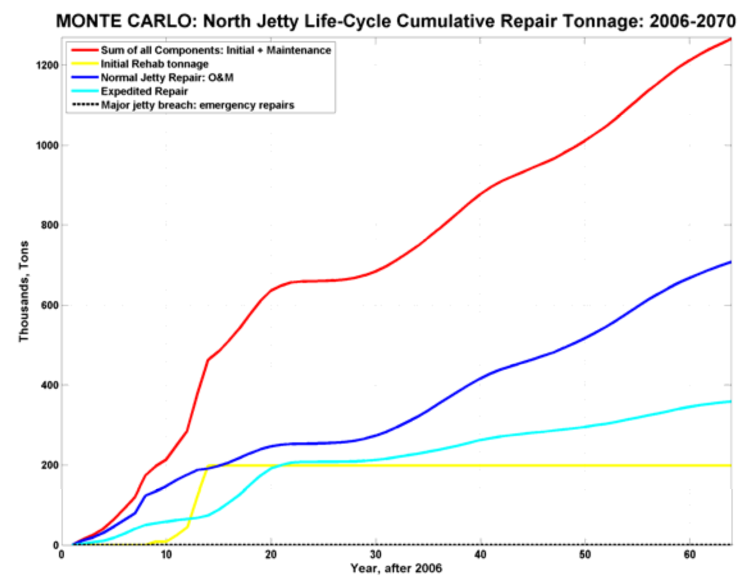

Figure A2-88d. Life-cycle cumulative repair tonnage for MCR North Jetty. Minimum Template Rehab - Immediate (Hold Head).

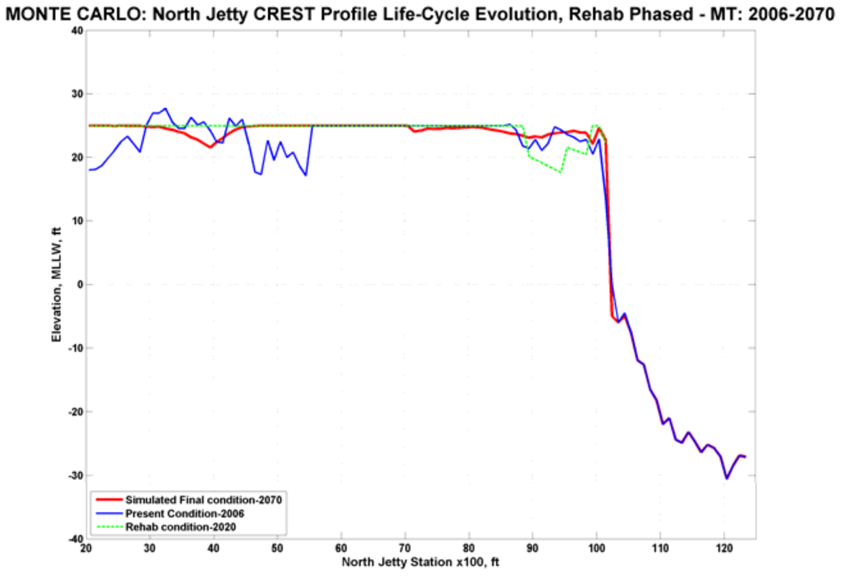

Figure A2-88e. Centerline profile for MCR North Jetty. Minimum Template Rehab - Immediate (Hold Head).

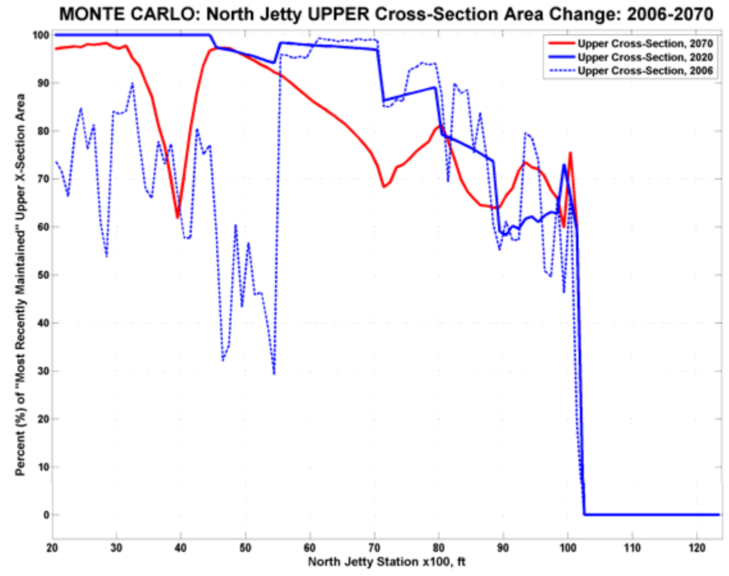

Figure A2-88f. Variation of upper cross-section area for given station of MCR North Jetty. Minimum Template Rehab - Immediate (Hold Head).

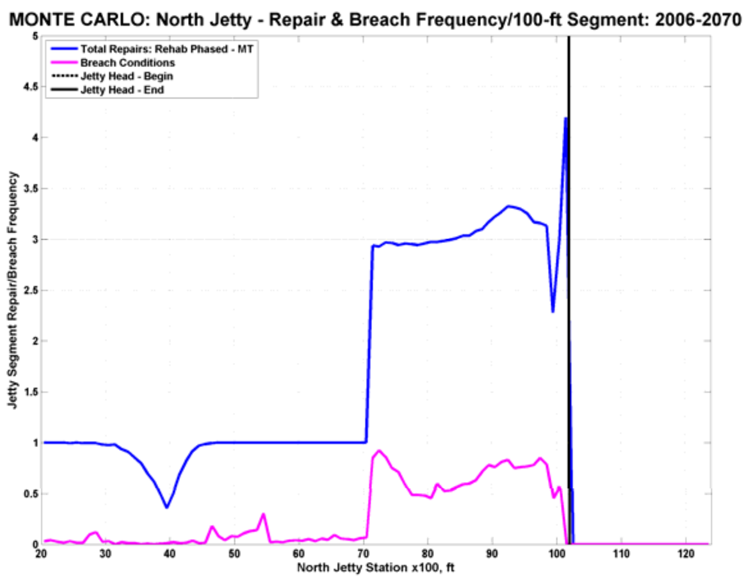

Figure A2-88g. Frequency and location of repairs and breaches for MCR North Jetty. Minimum Template Rehab - Immediate (Hold Head).

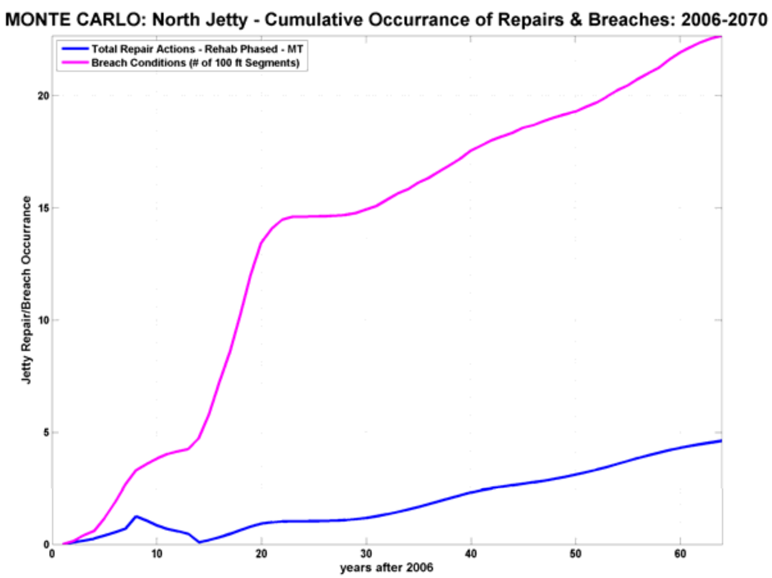

Figure A2-88h. Cumulative occurrence of repairs and breach conditions for MCR North Jetty. Minimum Template Rehab - Immediate (Hold Head).

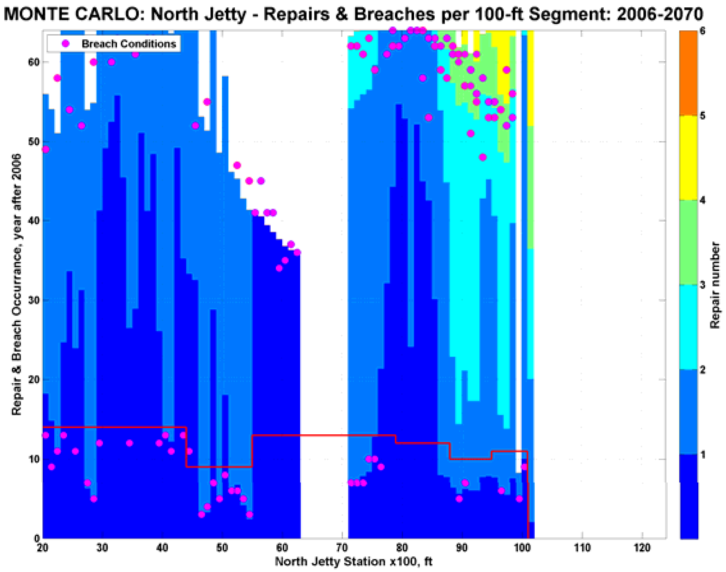

Figure A2-89a. Forecast repair occurrence for MCR North Jetty, shown for each 100 ft jetty segment. Composite 4 Small Rehab - Immediate (Hold Head). RED line marks time of REHAB phase implementation

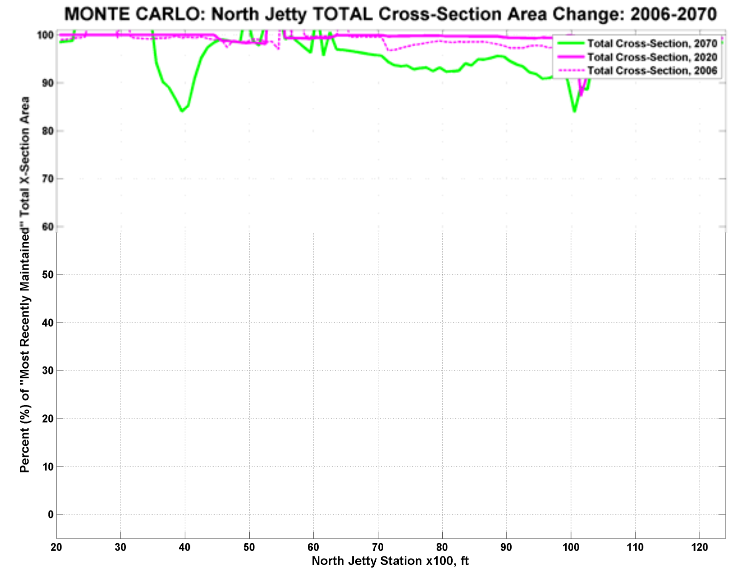

Figure A2-89b. Variation in total cross-section area along MCR North Jetty during forecast period. Composite 4 Small Rehab - Immediate (Hold Head).RED line marks time of REHAB phase implementation

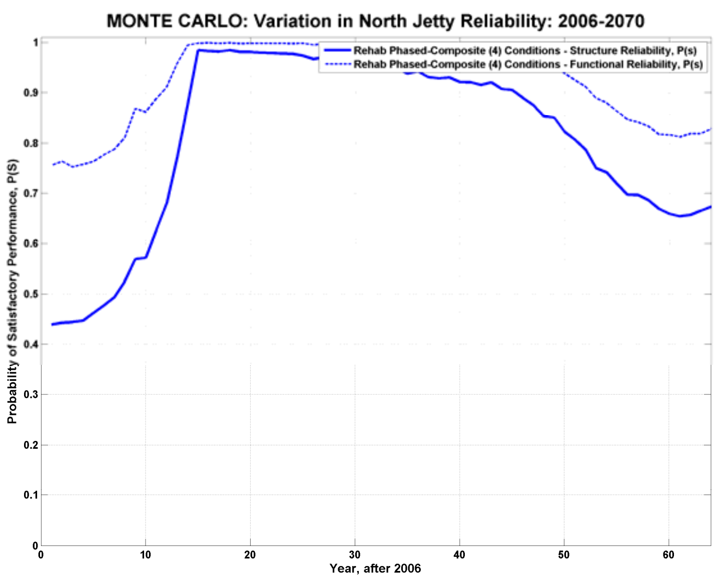

Figure A2-89c. Forecast reliability for MCR North Jetty. Composite 4 Small Rehab - Immediate (Hold Head).

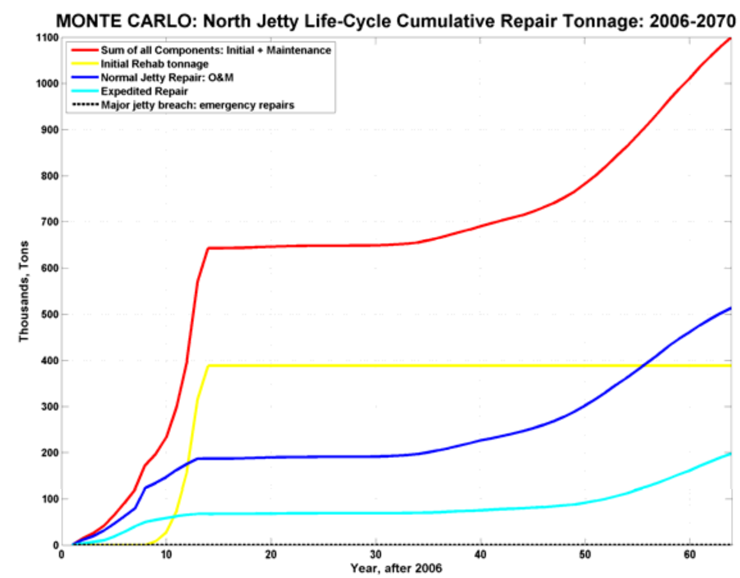

Figure A2-89d. Life-cycle cumulative repair tonnage for MCR North Jetty. Composite 4 Small Rehab - Immediate (Hold Head).

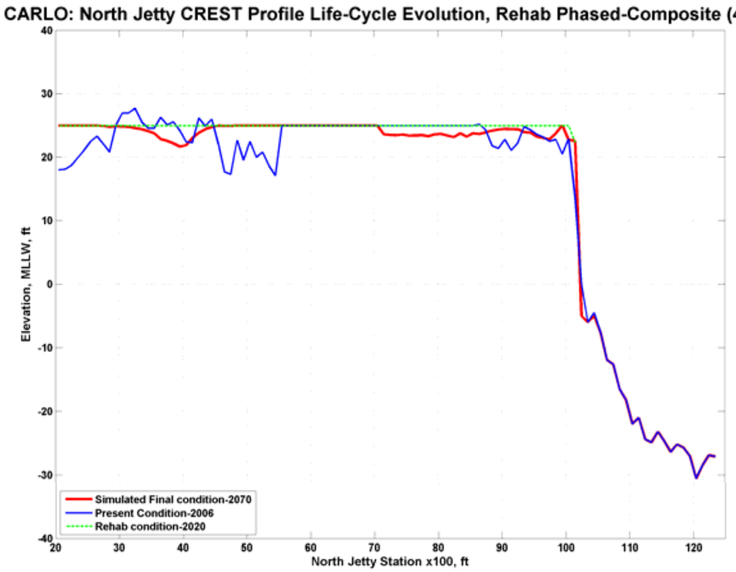

Figure A2-89e. Centerline profile for MCR North Jetty. Composite 4 Small Rehab - Immediate (Hold Head).

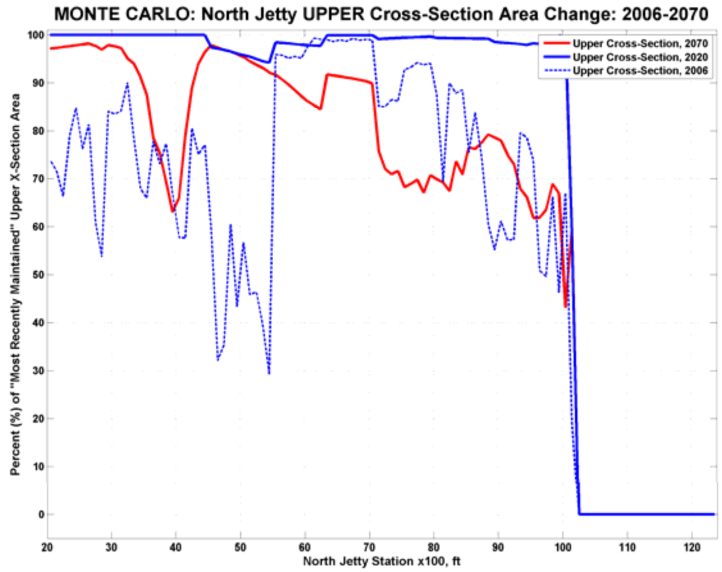

Figure A2-89f. Variation of upper cross-section area for given station of MCR North Jetty. Composite 4 Small Rehab - Immediate (Hold Head).

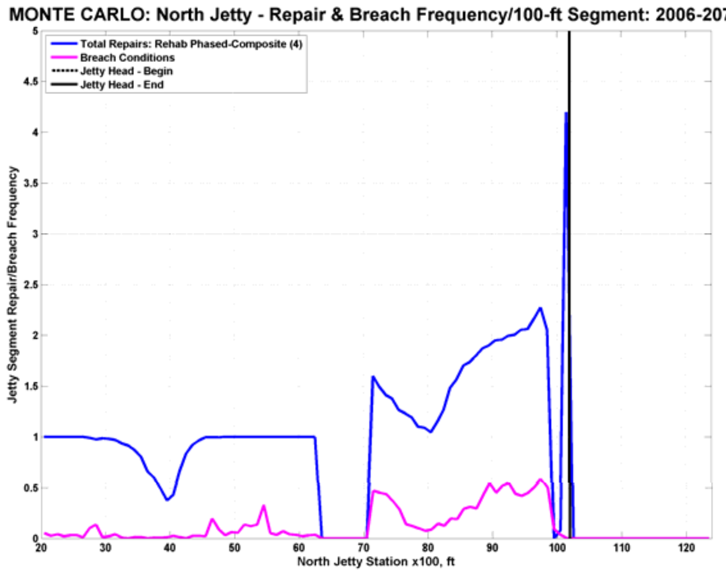

Figure A2-89g. Frequency and location of repairs and breaches for MCR North Jetty. Composite 4 Small Rehab - Immediate (Hold Head).

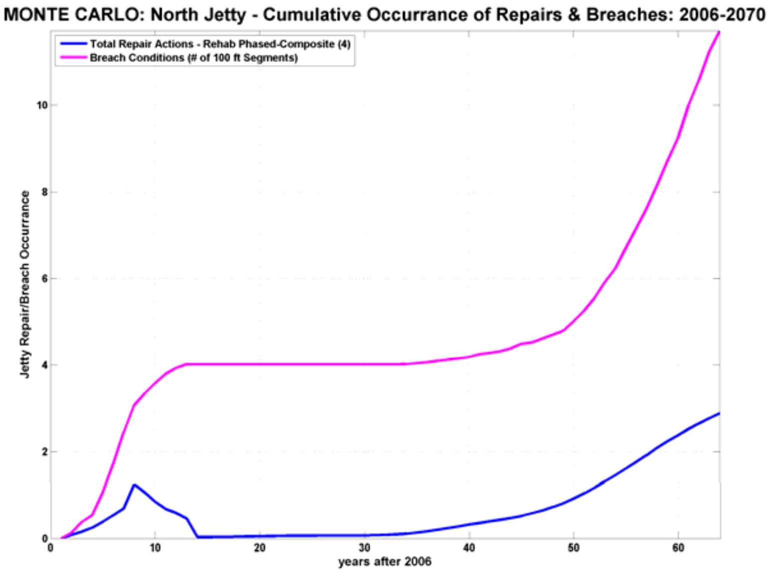

Figure A2-89h. Cumulative occurrence of repairs and breach conditions for MCR North Jetty. Composite 4 Small Rehab - Immediate (Hold Head).

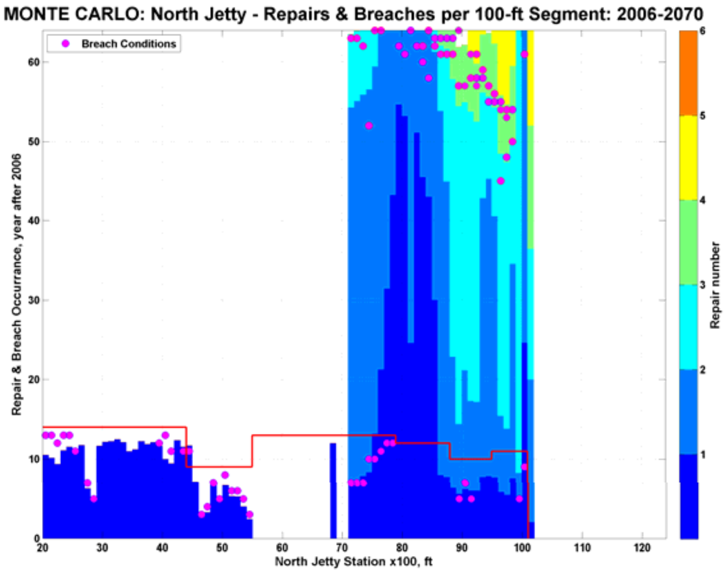

Figure A2-90a. Forecast repair occurrence for MCR North Jetty, shown for each 100 ft jetty segment. Moderate Template Rehab - Immediate (Hold Head). RED line marks time of REHAB phase implementation

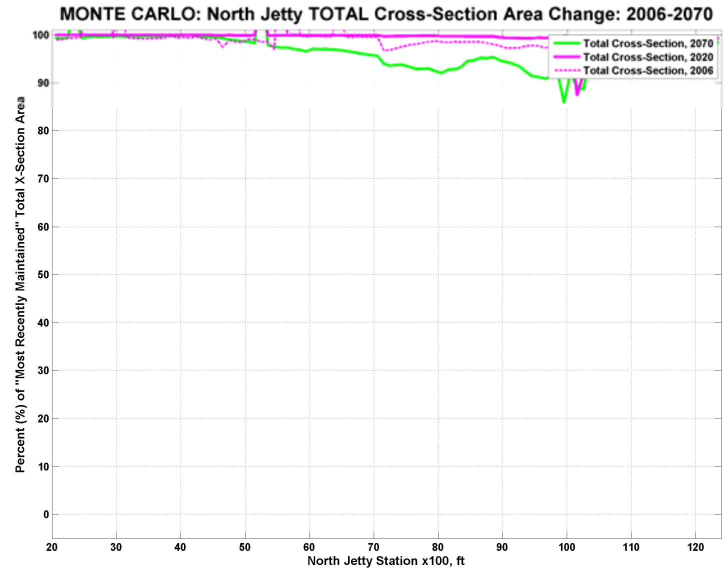

Figure A2-90b. Variation in total cross-section area along MCR North Jetty during forecast period. Moderate Template Rehab - Immediate (Hold Head).RED line marks time of REHAB phase implementation

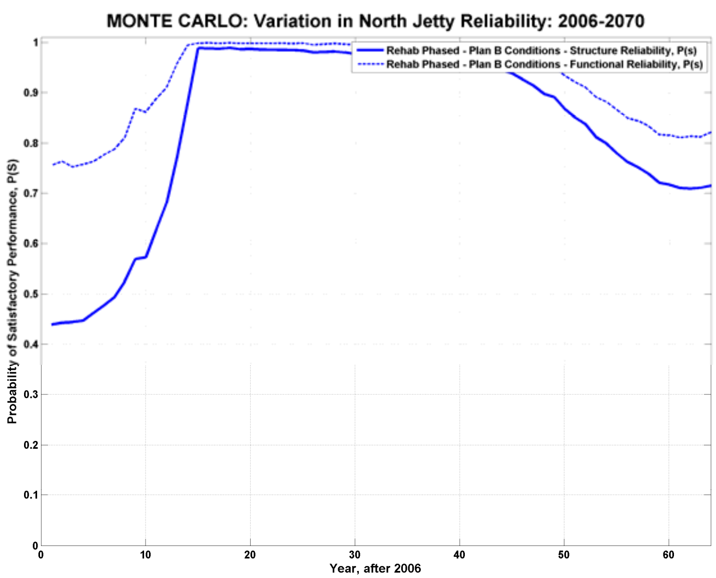

Figure A2-90c. Forecast reliability for MCR North Jetty. Moderate Template Rehab - Immediate (Hold Head).

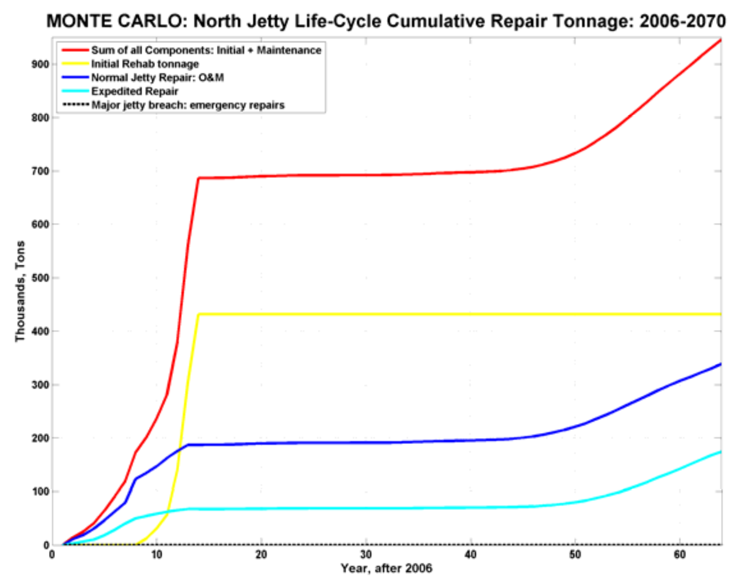

Figure A2-90d. Life-cycle cumulative repair tonnage for MCR North Jetty. Moderate Template Rehab - Immediate (Hold Head).

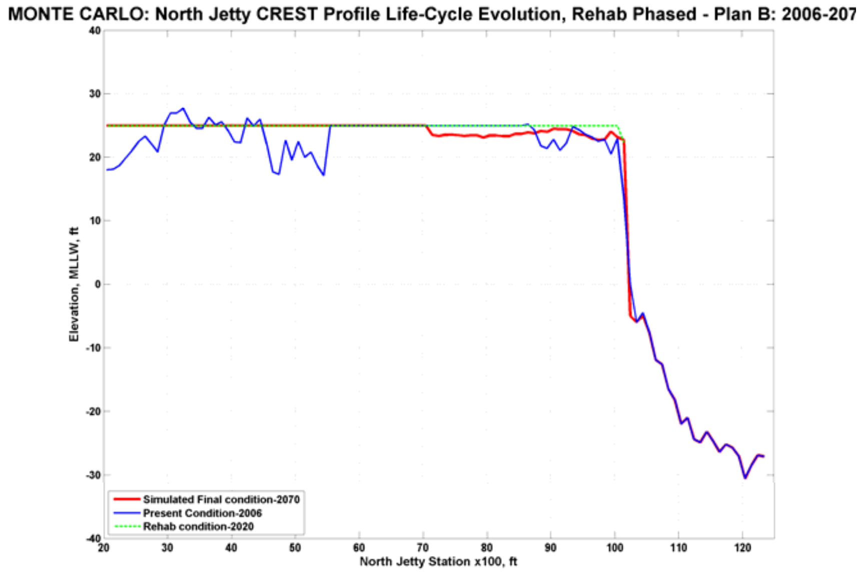

Figure A2-90e. Centerline profile for MCR North Jetty. Moderate Template Rehab - Immediate (Hold Head).

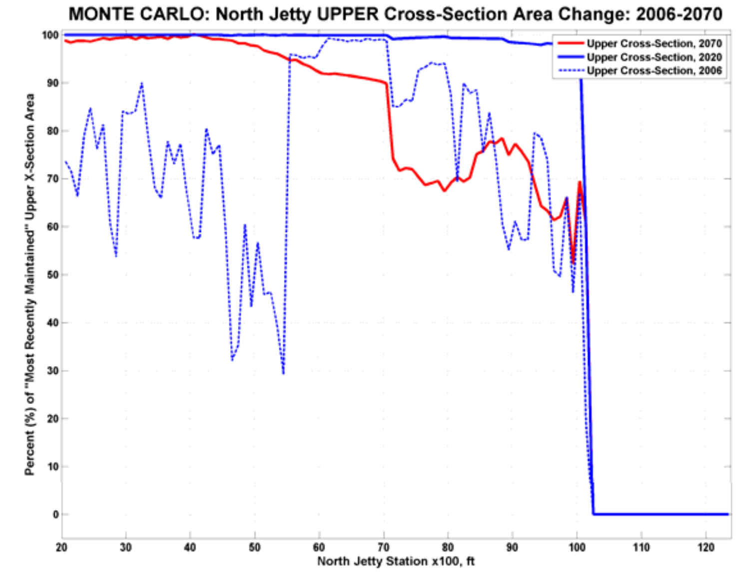

Figure A2-90f. Variation of upper cross-section area for given station of MCR North Jetty. Moderate Template Rehab - Immediate (Hold Head).

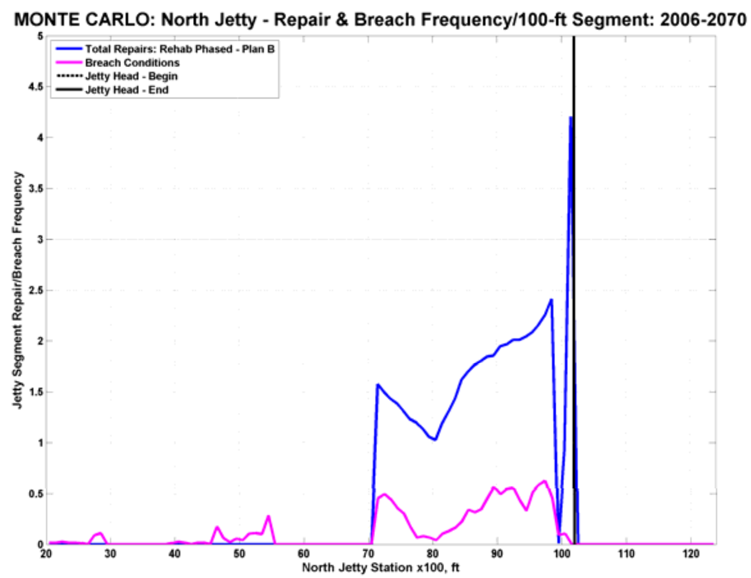

Figure A2-90g. Frequency and location of repairs and breaches for MCR North Jetty. Moderate Template Rehab - Immediate (Hold Head).

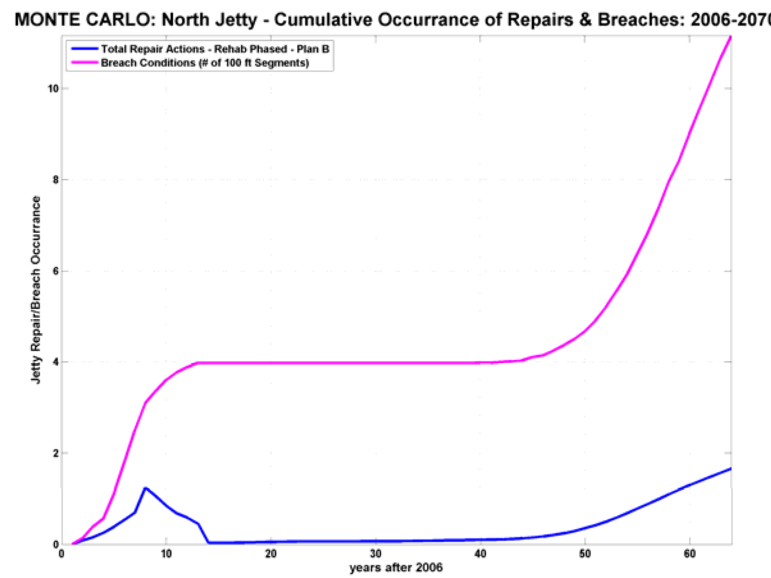

Figure A2-90h. Cumulative occurrence of repairs and breach conditions for MCR North Jetty. Moderate Template Rehab - Immediate (Hold Head).

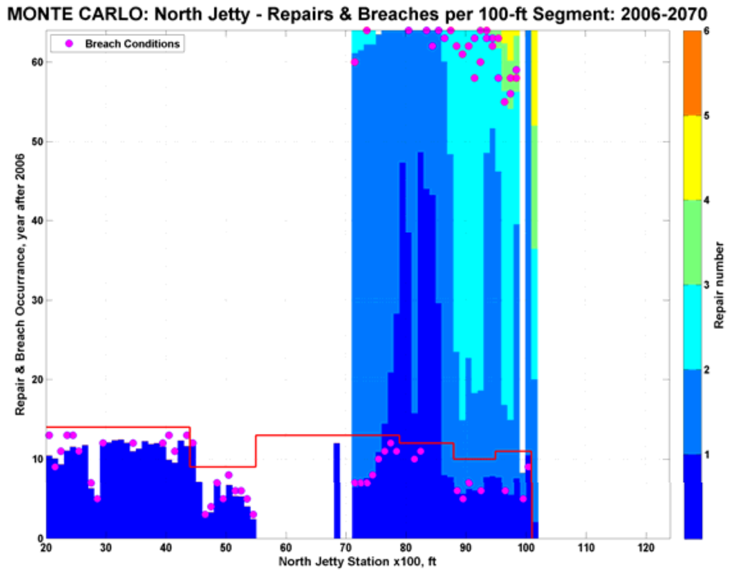

Figure A2-91a. Forecast repair occurrence for MCR North Jetty, shown for each 100 ft jetty segment. Large Template Rehab - Immediate (Hold Head). RED line marks time of REHAB phase implementation

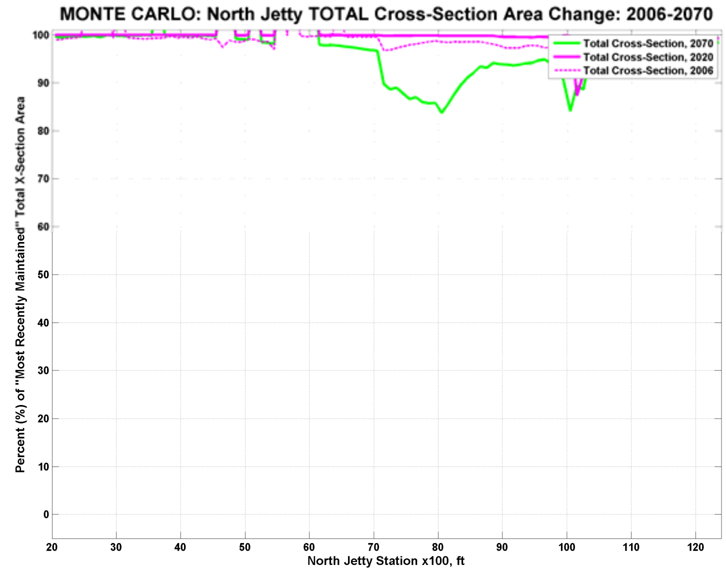

Figure A2-91b. Variation in total cross-section area along MCR North Jetty during forecast period. Large Template Rehab - Immediate (Hold Head).RED line marks time of REHAB phase implementation

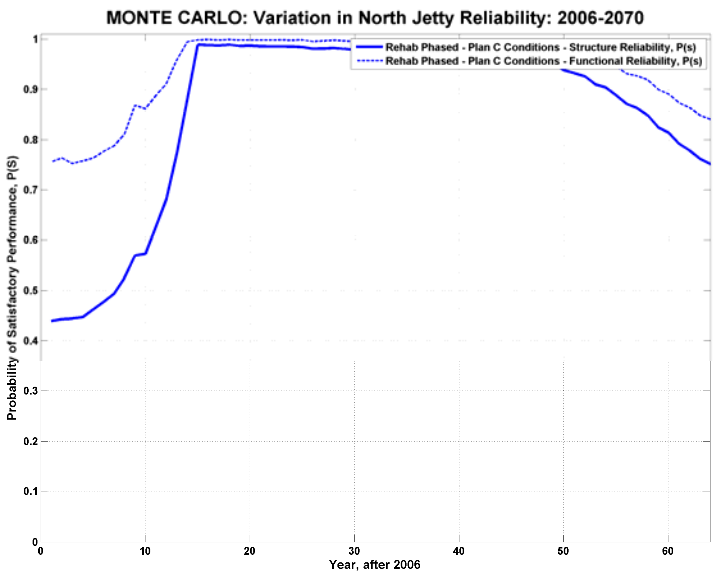

Figure A2-91c. Forecast reliability for MCR North Jetty. Large Template Rehab - Immediate (Hold Head).

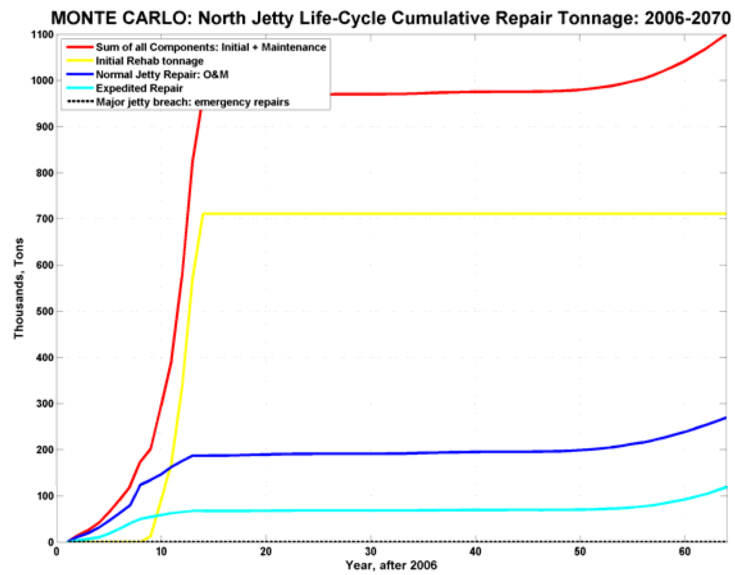

Figure A2-91d. Life-cycle cumulative repair tonnage for MCR North Jetty. Large Template Rehab - Immediate (Hold Head).

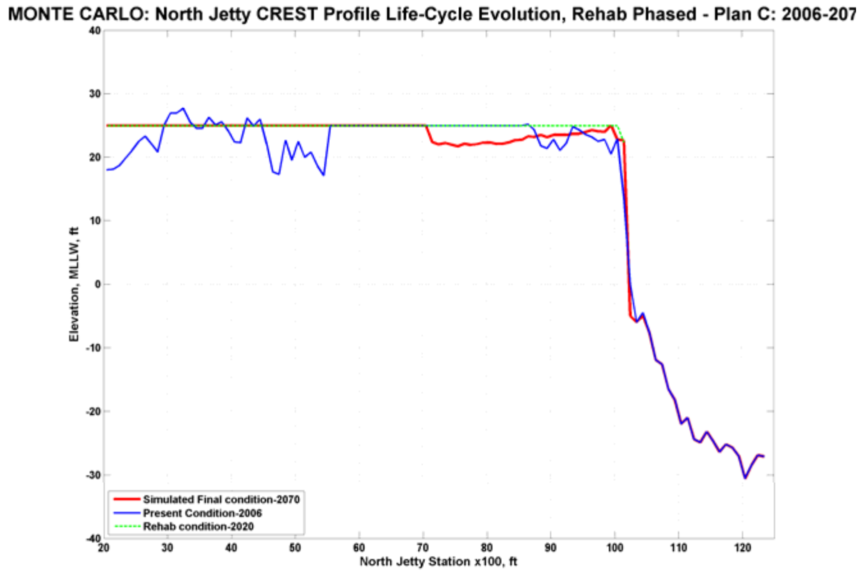

Figure A2-91e. Centerline profile for MCR North Jetty. Large Template Rehab - Immediate (Hold Head).

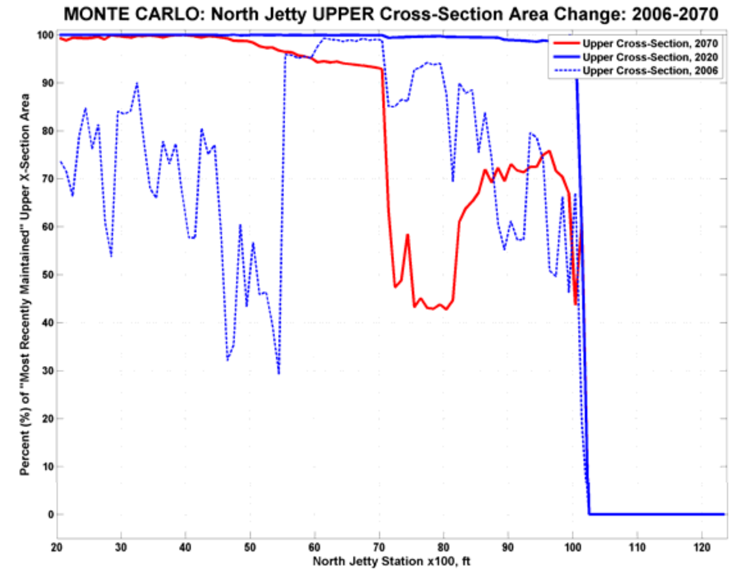

Figure A2-91f. Variation of upper cross-section area for given station of MCR North Jetty. Large Template Rehab - Immediate (Hold Head).

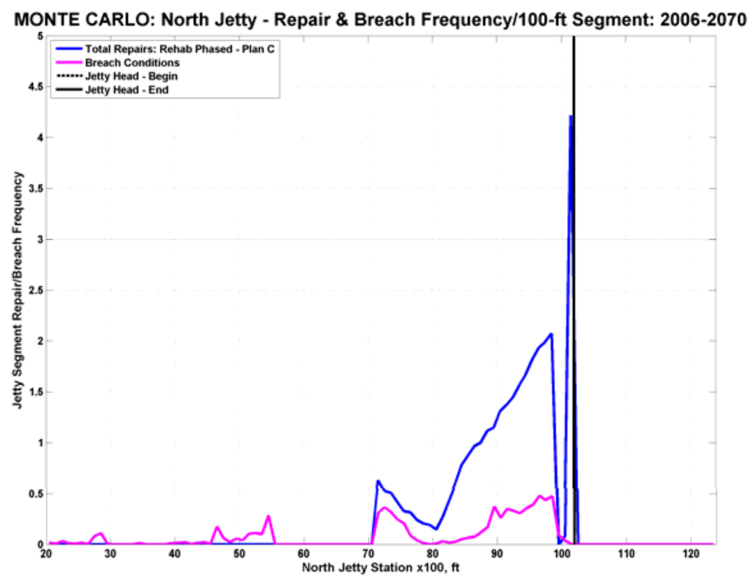

Figure A2-91g. Frequency and location of repairs and breaches for MCR North Jetty. Large Template Rehab - Immediate (Hold Head).

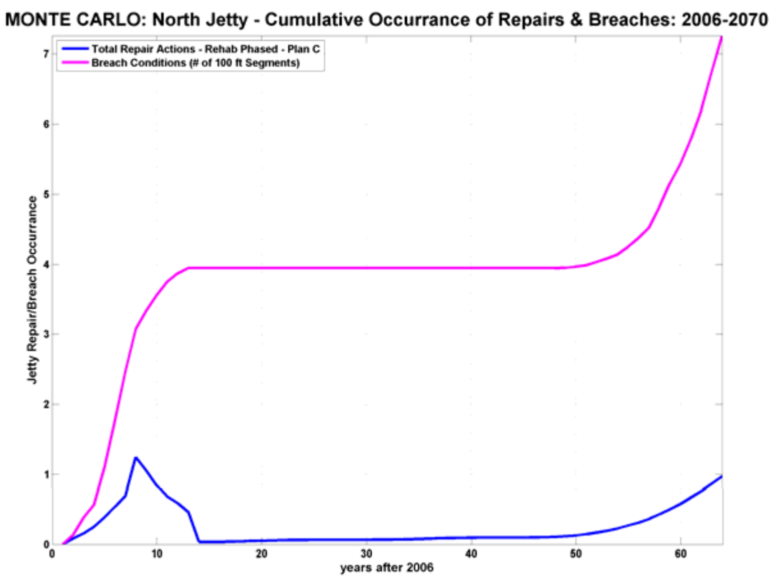

Figure A2-91h. Cumulative occurrence of repairs and breach conditions for MCR North Jetty. Large Template Rehab - Immediate (Hold Head).

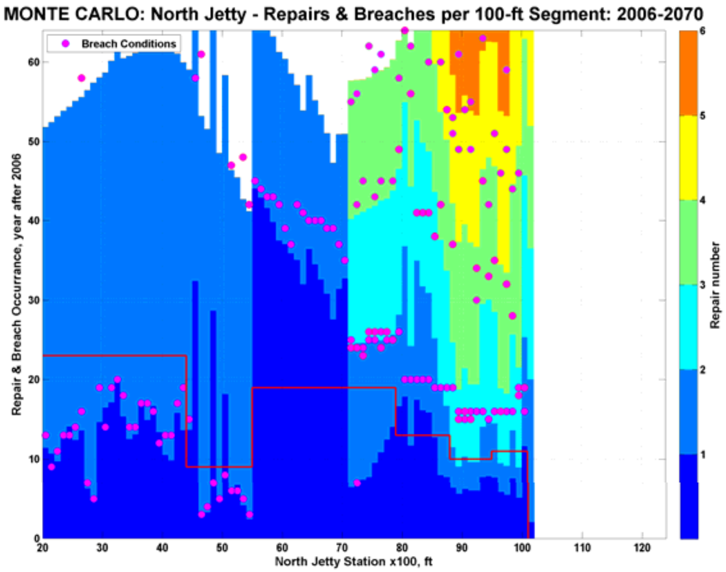

Figure A2-92a. Forecast repair occurrence for MCR North Jetty, shown for each 100 ft jetty segment. Minimum Template Rehab - Scheduled (Hold Head). RED line marks time of REHAB phase implementation

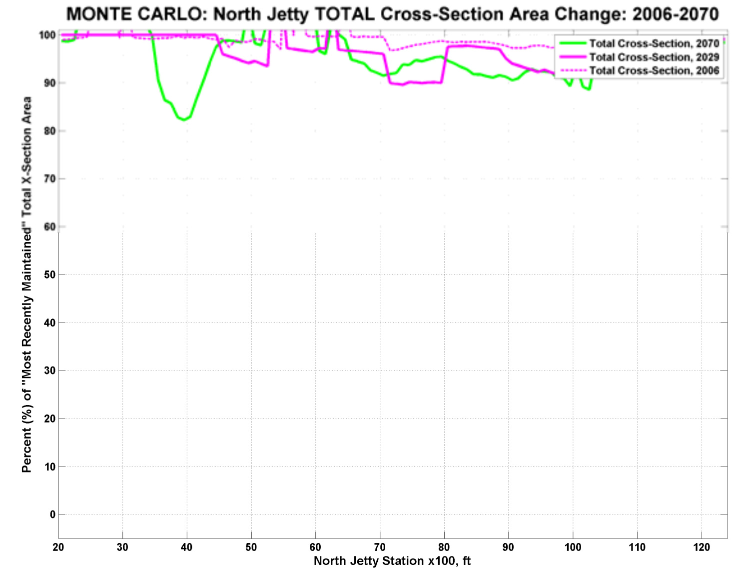

Figure A2-92b. Variation in total cross-section area along MCR North Jetty during forecast period. Minimum Template Rehab - Scheduled (Hold Head).RED line marks time of REHAB phase implementation

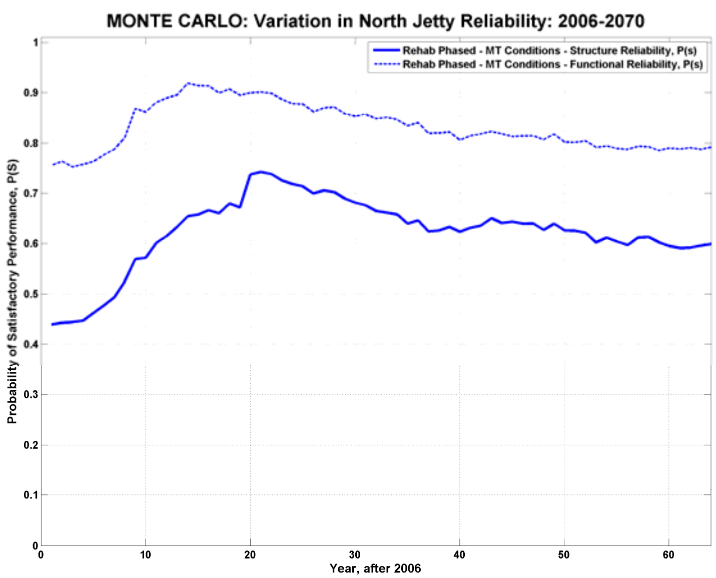

Figure A2-92c. Forecast reliability for MCR North Jetty. Minimum Template Rehab - Scheduled (Hold Head).

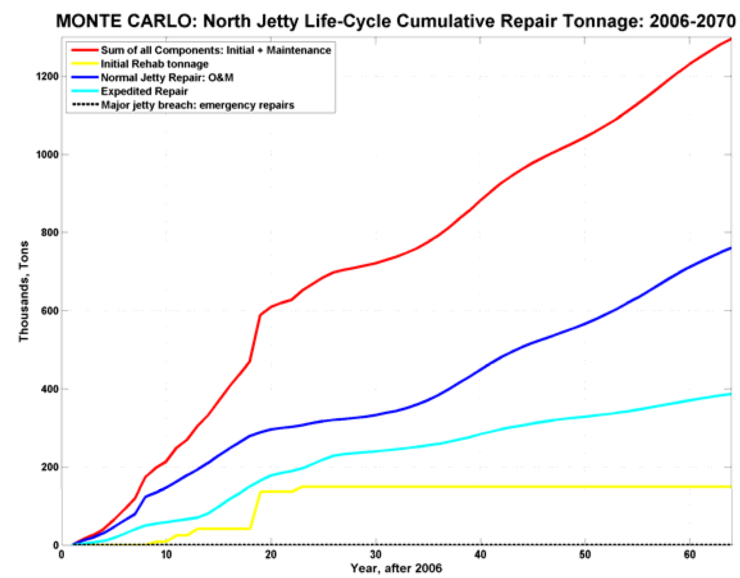

Figure A2-92d. Life-cycle cumulative repair tonnage for MCR North Jetty. Minimum Template Rehab - Scheduled (Hold Head).

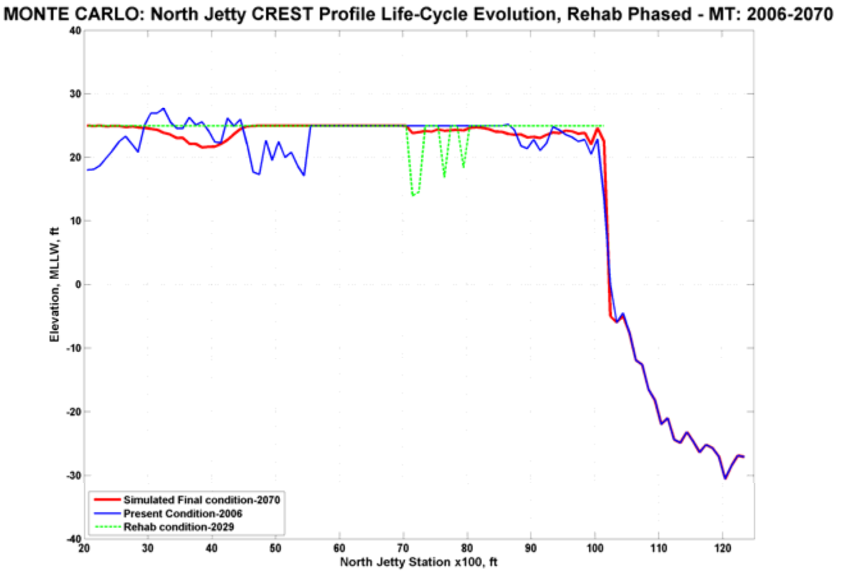

Figure A2-92e. Centerline profile for MCR North Jetty. Minimum Template Rehab - Scheduled (Hold Head).

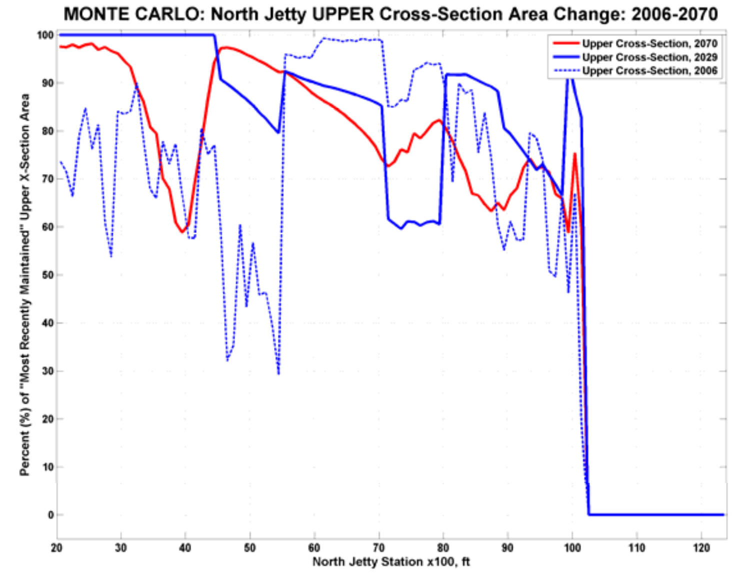

Figure A2-92f. Variation of upper cross-section area for given station of MCR North Jetty. Minimum Template Rehab - Scheduled (Hold Head).

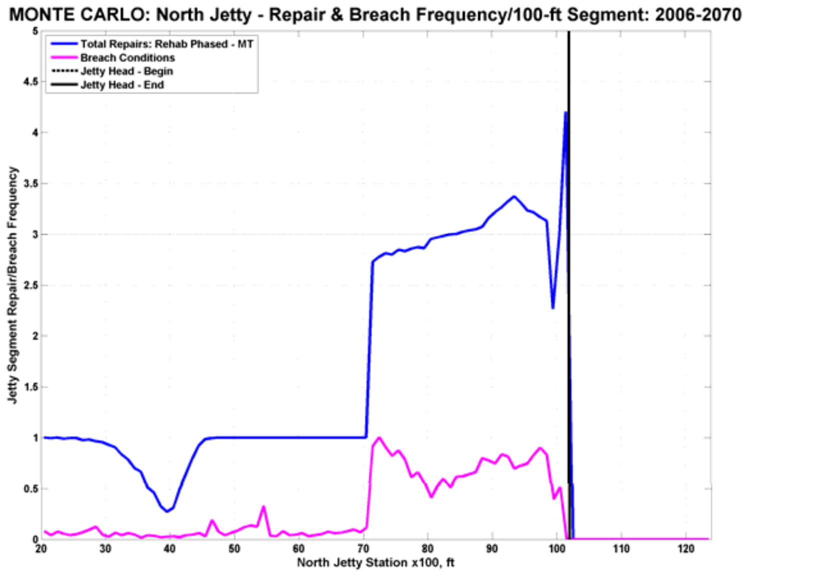

Figure A2-92g. Frequency and location of repairs and breaches for MCR North Jetty. Minimum Template Rehab - Scheduled (Hold Head).

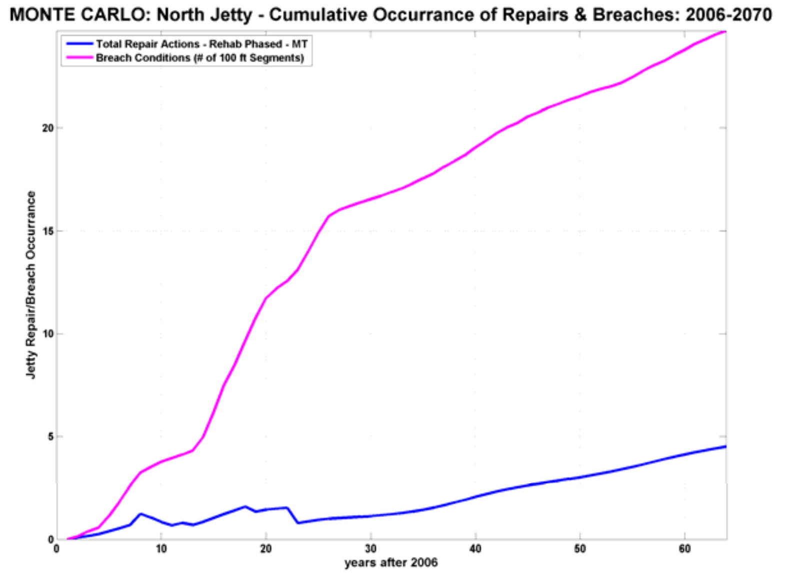

Figure A2-92h. Cumulative occurrence of repairs and breach conditions for MCR North Jetty. Minimum Template Rehab - Scheduled (Hold Head).

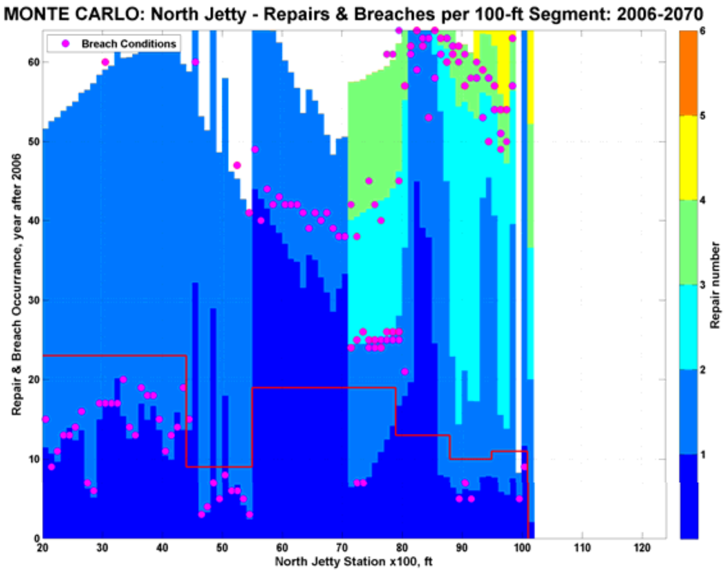

Figure A2-93a. Forecast repair occurrence for MCR North Jetty, shown for each 100 ft jetty segment. Composite 3 Small Rehab - Scheduled (Hold Head). RED line marks time of REHAB phase implementation

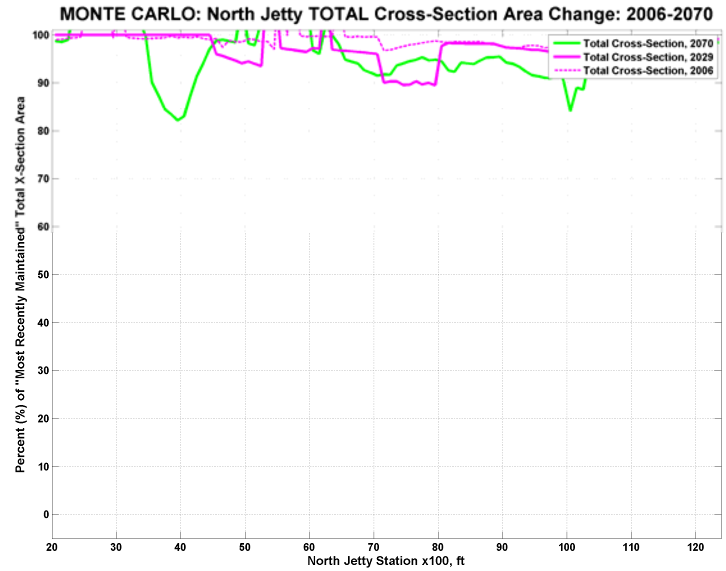

Figure A2-93b. Variation in total cross-section area along MCR North Jetty during forecast period. Composite 3 Small Rehab - Scheduled (Hold Head).RED line marks time of REHAB phase implementation

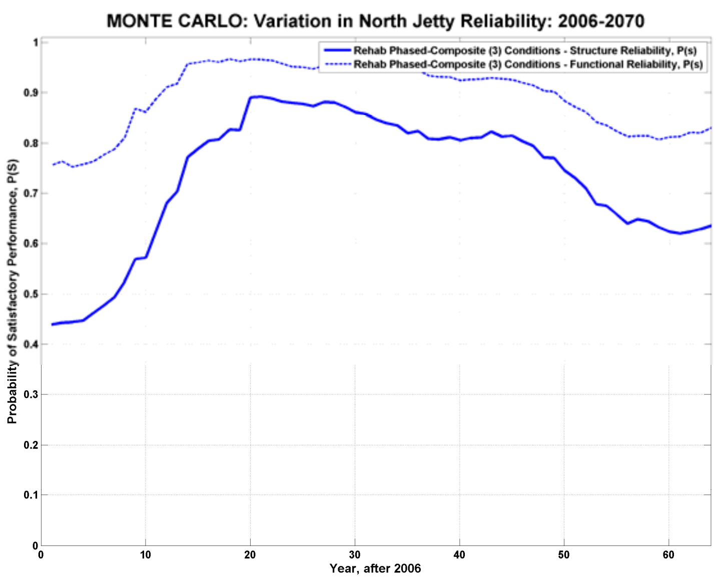

Figure A2-93c. Forecast reliability for MCR North Jetty. Composite 3 Small Rehab - Scheduled (Hold Head).

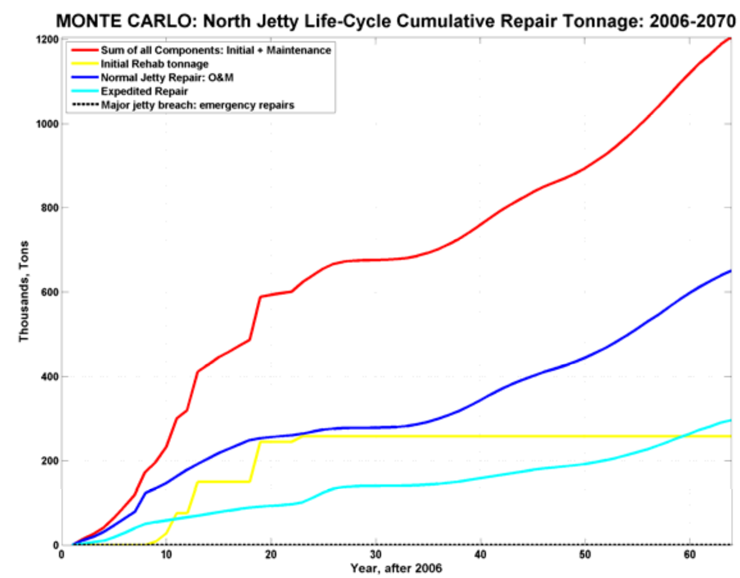

Figure A2-93d. Life-cycle cumulative repair tonnage for MCR North Jetty. Composite 3 Small Rehab - Scheduled (Hold Head).

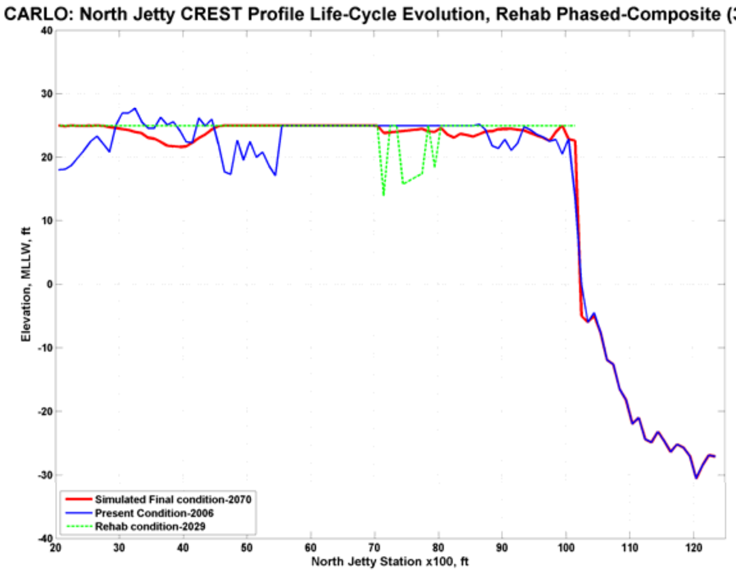

Figure A2-93e. Centerline profile for MCR North Jetty. Composite 3 Small Rehab - Scheduled (Hold Head).

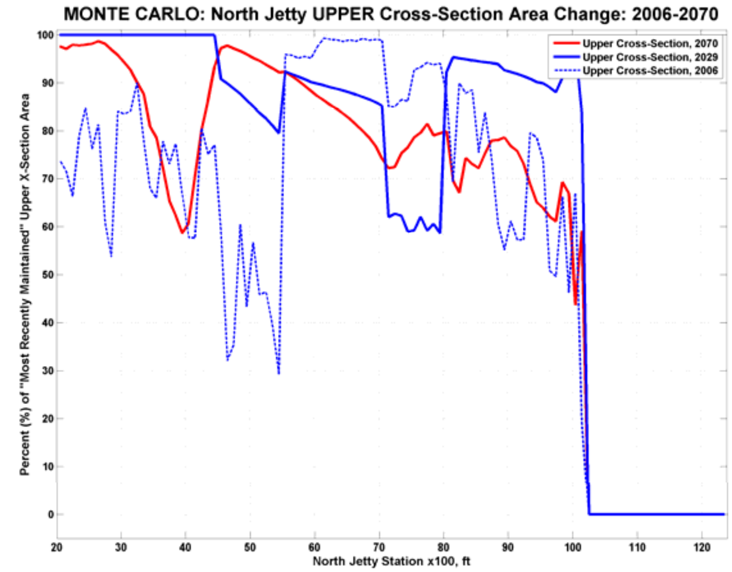

Figure A2-93f. Variation of upper cross-section area for given station of MCR North Jetty. Composite 3 Small Rehab - Scheduled (Hold Head).

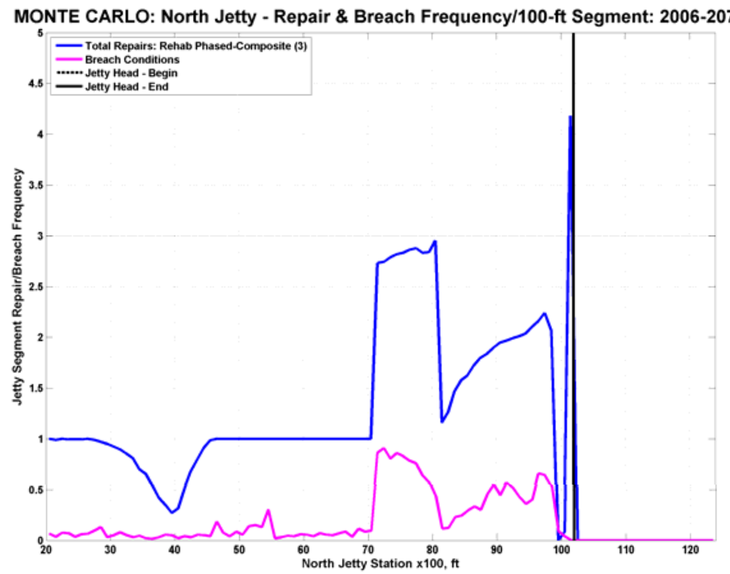

Figure A2-93g. Frequency and location of repairs and breaches for MCR North Jetty. Composite 3 Small Rehab - Scheduled (Hold Head).

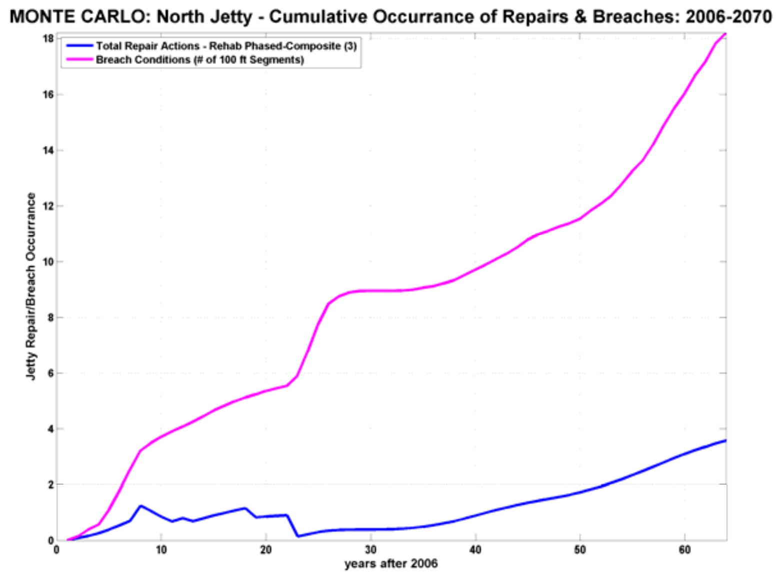

Figure A2-93h. Cumulative occurrence of repairs and breach conditions for MCR North Jetty. Composite 3 Small Rehab - Scheduled (Hold Head).

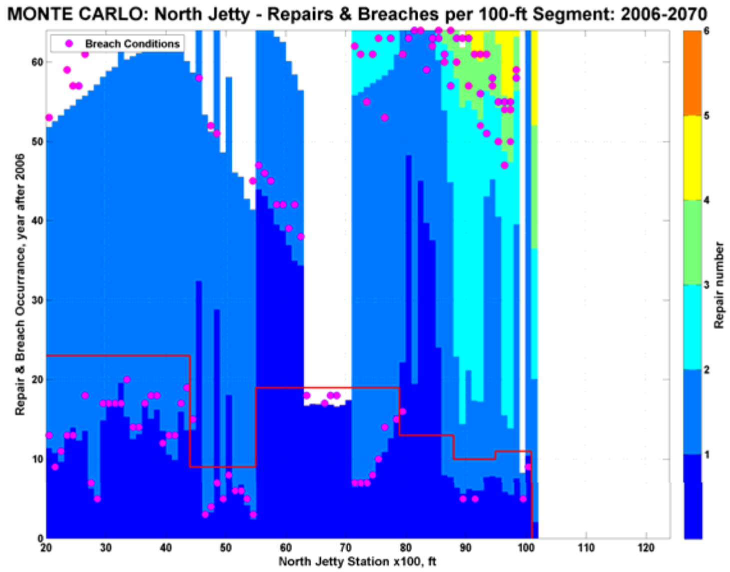

Figure A2-94a. Forecast repair occurrence for MCR North Jetty, shown for each 100 ft jetty segment. Composite 4 Small Modified Rehab - Scheduled (Hold Head). RED line marks time of REHAB phase implementation

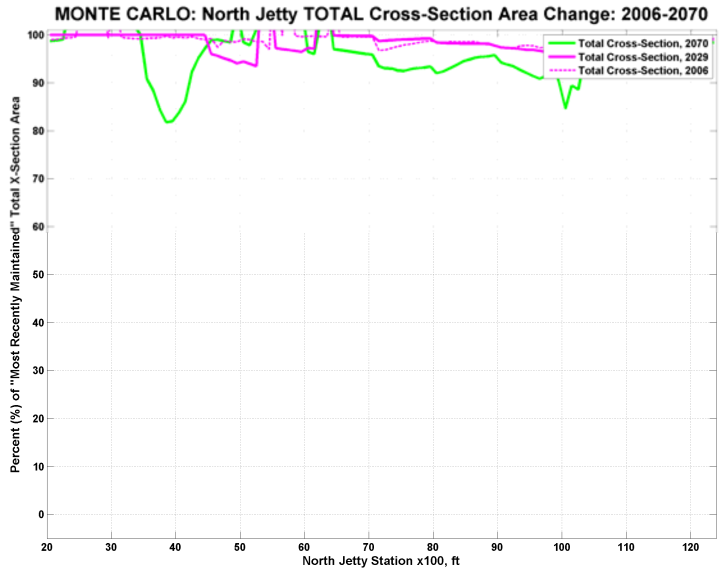

Figure A2-94b. Variation in total cross-section area along MCR North Jetty during forecast period. Composite 4 Small Modified Rehab - Scheduled (Hold Head).RED line marks time of REHAB phase implementation

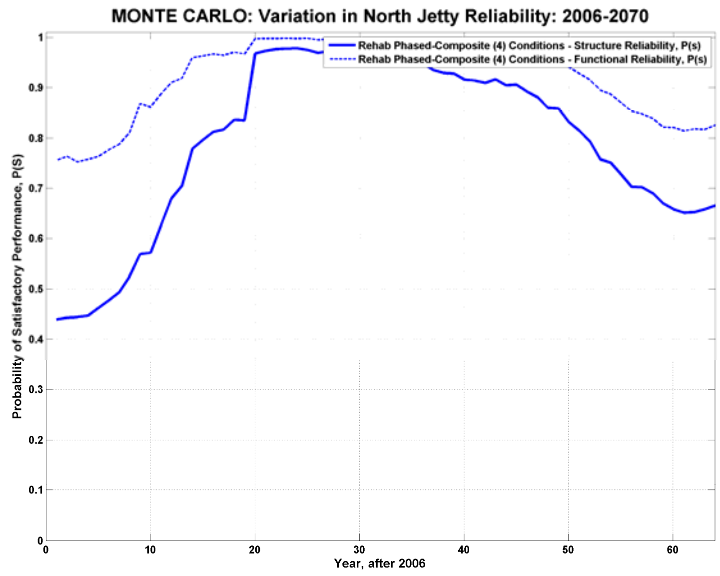

Figure A2-94c. Forecast reliability for MCR North Jetty. Composite 4 Small Modified Rehab - Scheduled (Hold Head).

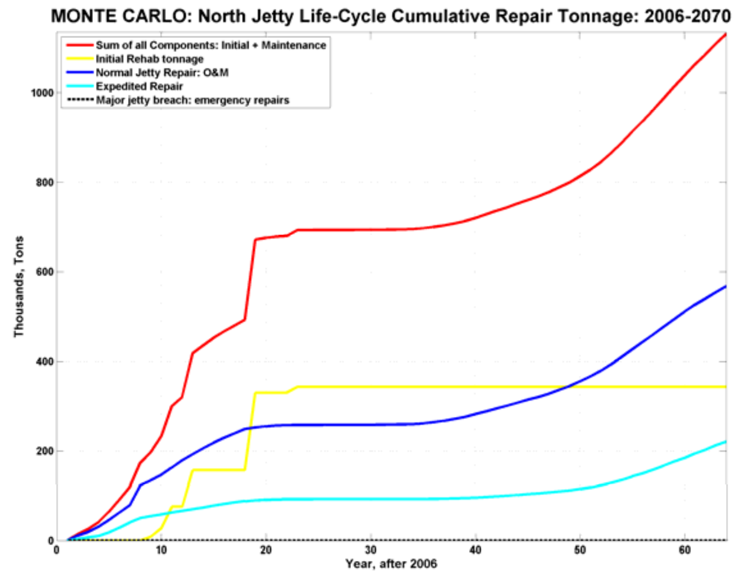

Figure A2-94d. Life-cycle cumulative repair tonnage for MCR North Jetty. Composite 4 Small Modified Rehab - Scheduled (Hold Head).

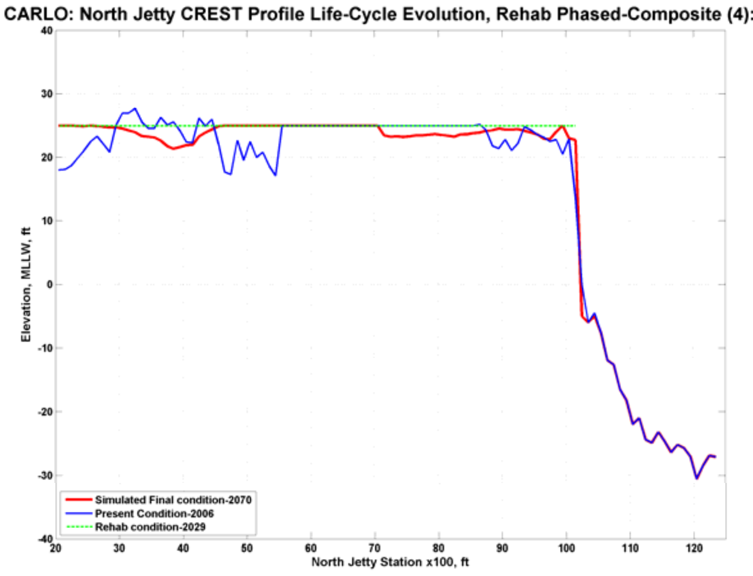

Figure A2-94e. Centerline profile for MCR North Jetty. Composite 4 Small Modified Rehab - Scheduled (Hold Head).

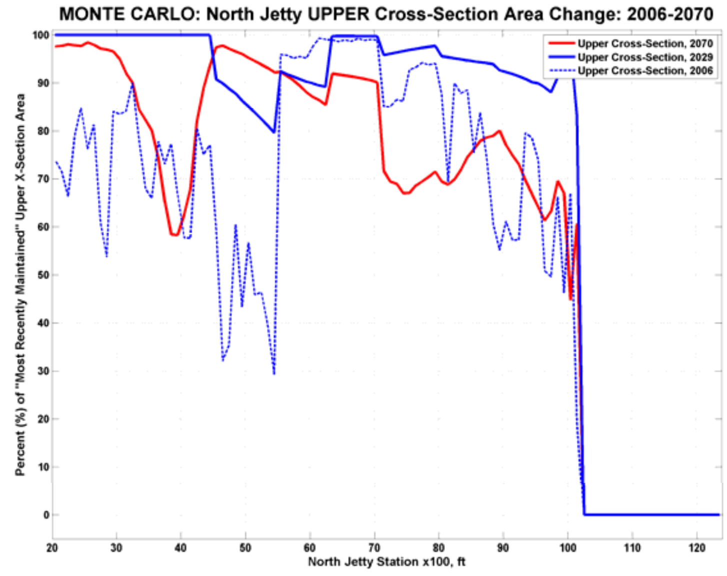

Figure A2-94f. Variation of upper cross-section area for given station of MCR North Jetty. Composite 4 Small Modified Rehab - Scheduled (Hold Head).

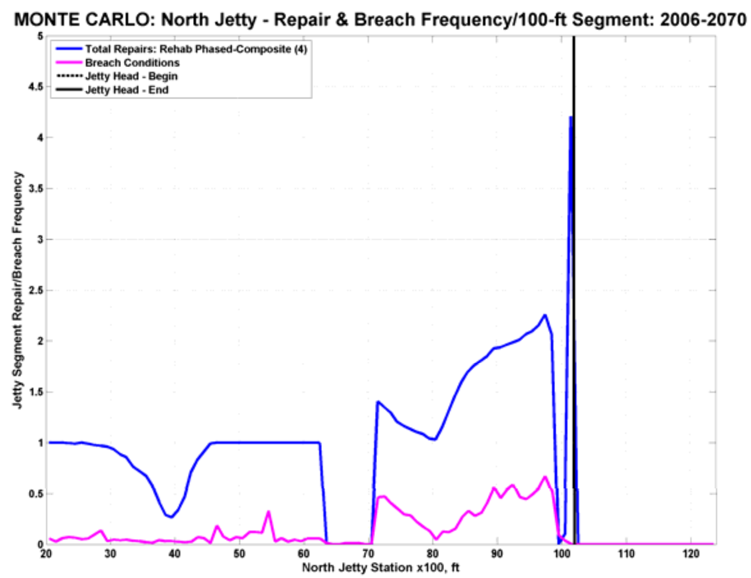

Figure A2-94g. Frequency and location of repairs and breaches for MCR North Jetty. Composite 4 Small Modified Rehab - Scheduled (Hold Head).

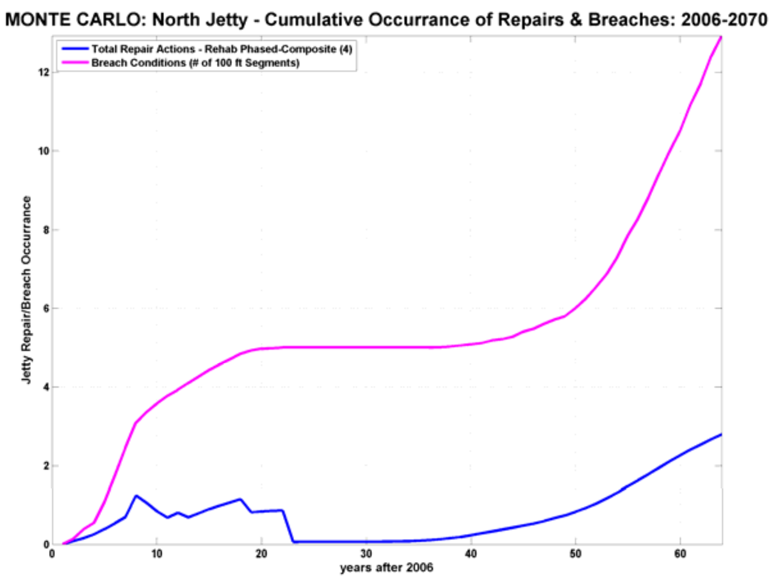

Figure A2-94h. Cumulative occurrence of repairs and breach conditions for MCR North Jetty. Composite 4 Small Modified Rehab - Scheduled (Hold Head).

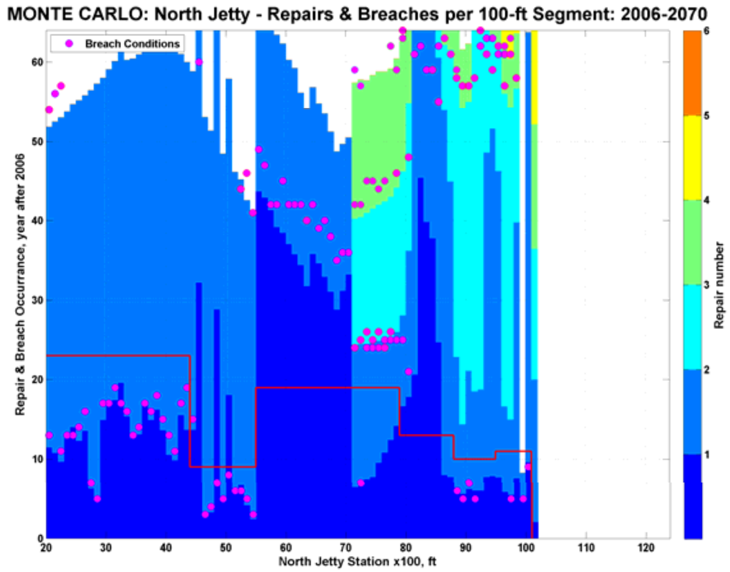

Figure A2-95a. Forecast repair occurrence for MCR North Jetty, shown for each 100 ft jetty segment. Composite 2 Medium Rehab - Scheduled (Hold Head). RED line marks time of REHAB phase implementation

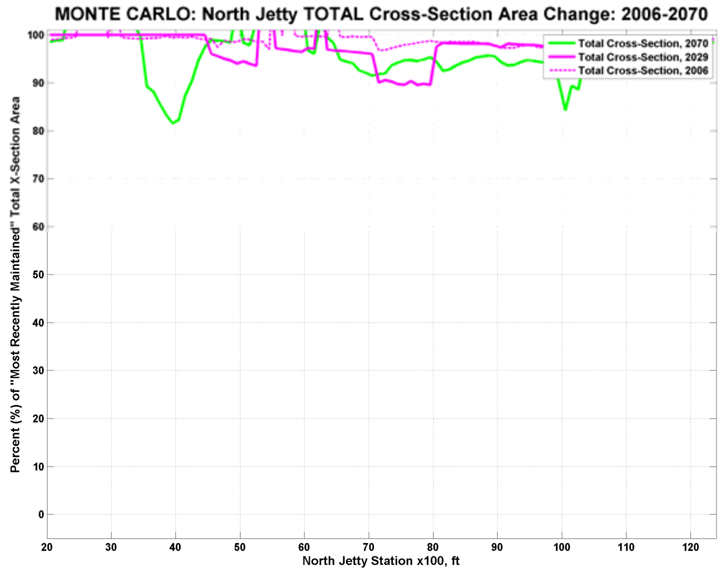

Figure A2-95b. Variation in total cross-section area along MCR North Jetty during forecast period. Composite 2 Medium Rehab - Scheduled (Hold Head).RED line marks time of REHAB phase implementation

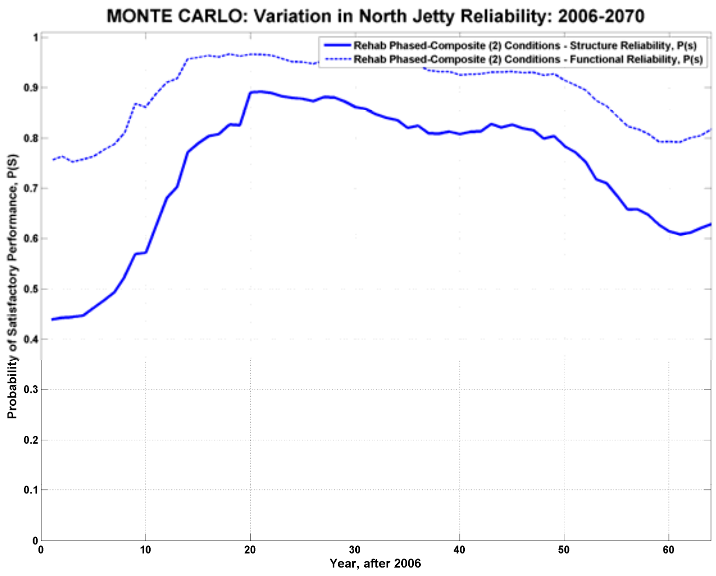

Figure A2-95c. Forecast reliability for MCR North Jetty. Composite 2 Medium Rehab - Scheduled (Hold Head).

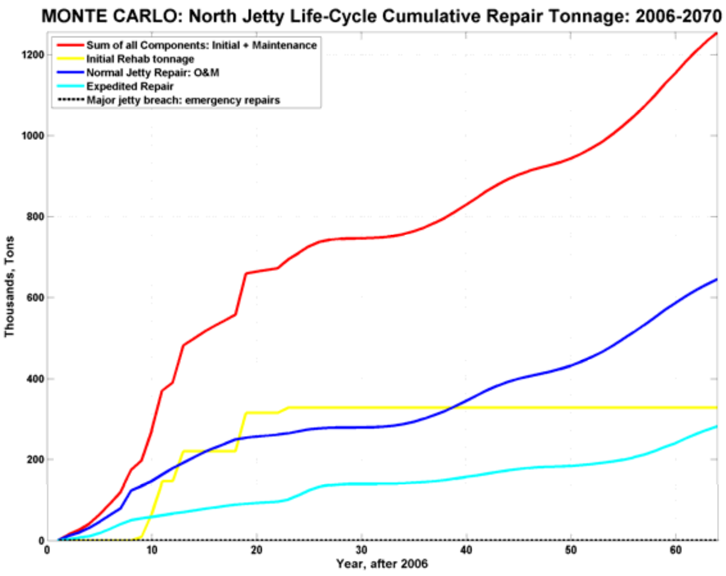

Figure A2-95d. Life-cycle cumulative repair tonnage for MCR North Jetty. Composite 2 Medium Rehab - Scheduled (Hold Head).

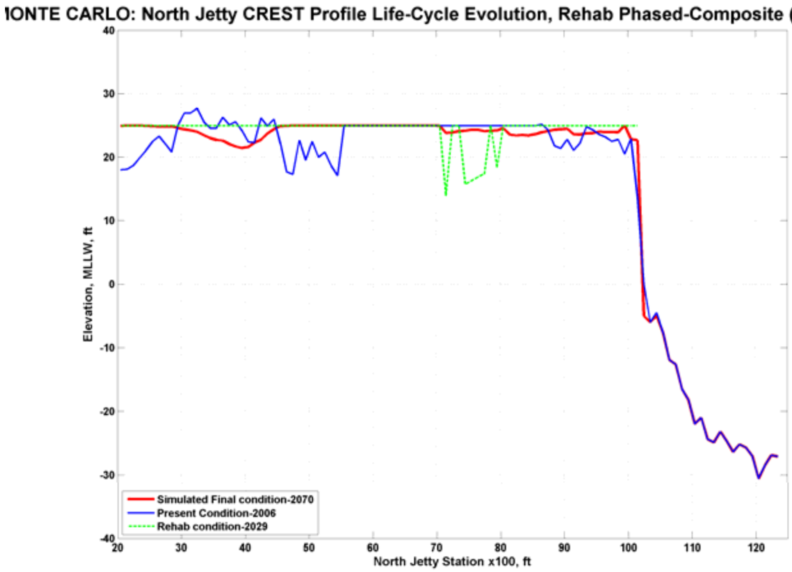

Figure A2-95e. Centerline profile for MCR North Jetty. Composite 2 Medium Rehab - Scheduled (Hold Head).

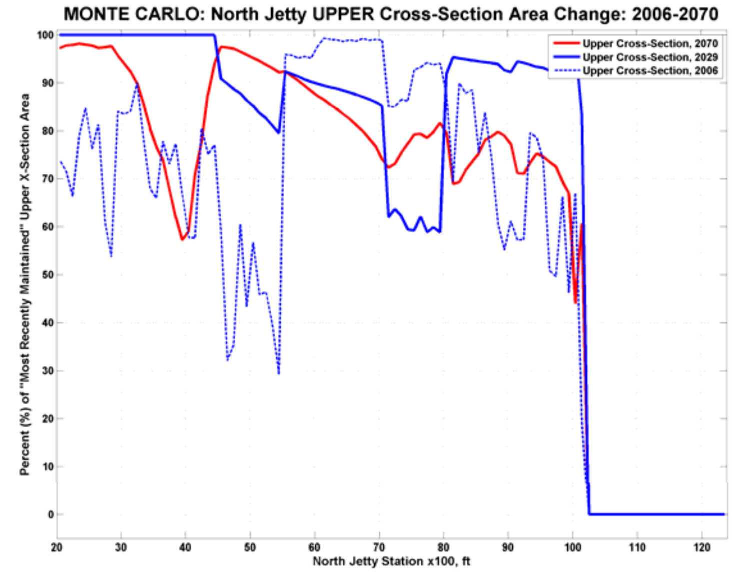

Figure A2-95f. Variation of upper cross-section area for given station of MCR North Jetty. Composite 2 Medium Rehab - Scheduled (Hold Head).

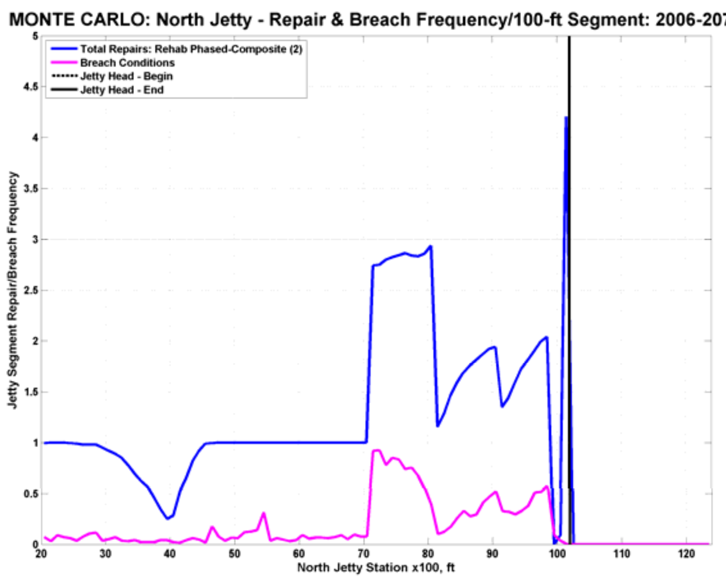

Figure A2-95g. Frequency and location of repairs and breaches for MCR North Jetty. Composite 2 Medium Rehab - Scheduled (Hold Head).

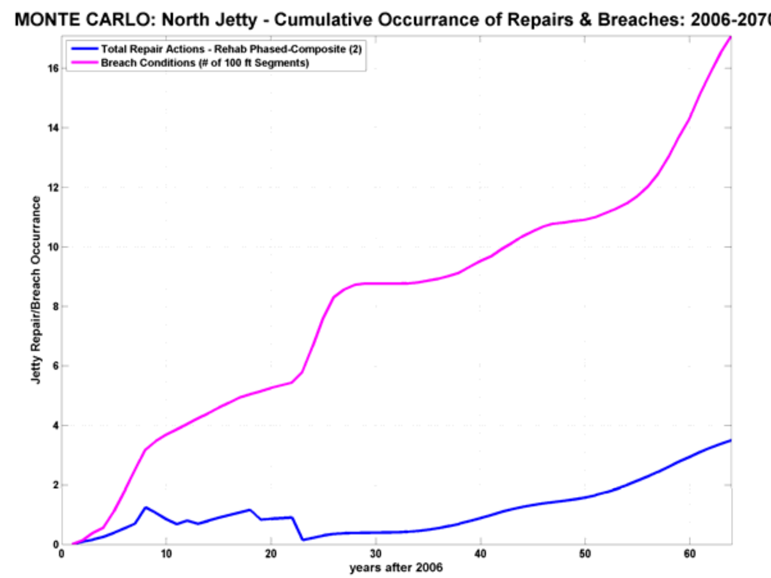

Figure A2-95h. Cumulative occurrence of repairs and breach conditions for MCR North Jetty. Composite 2 Medium Rehab - Scheduled (Hold Head).

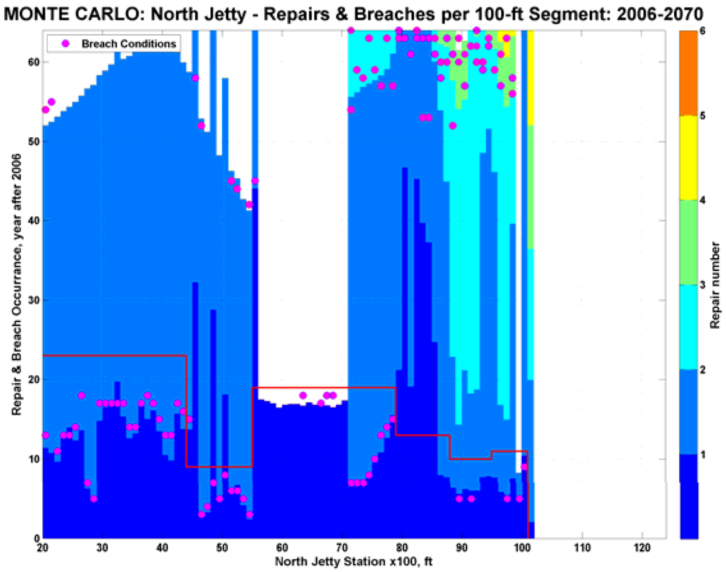

Figure A2-96a. Forecast repair occurrence for MCR North Jetty, shown for each 100 ft jetty segment. Composite 1 Large Rehab - Scheduled (Hold Head). RED line marks time of REHAB phase implementation

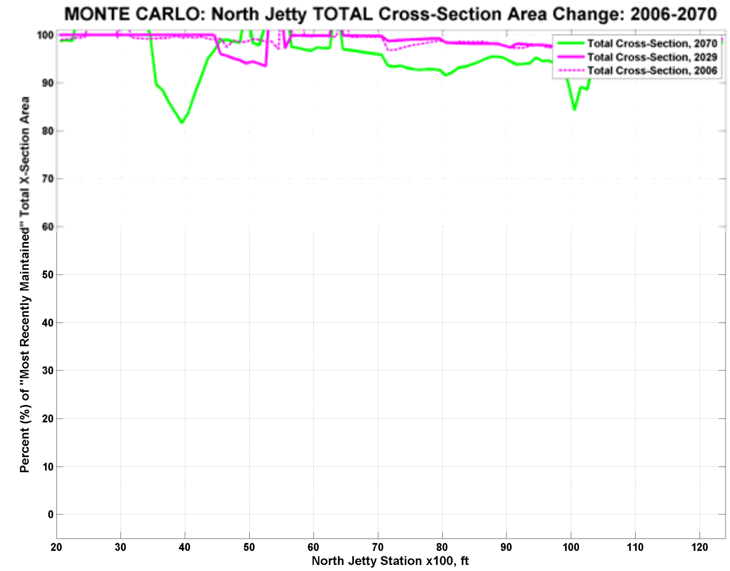

Figure A2-96b. Variation in total cross-section area along MCR North Jetty during forecast period. Composite 1 Large Rehab - Scheduled (Hold Head).RED line marks time of REHAB phase implementation

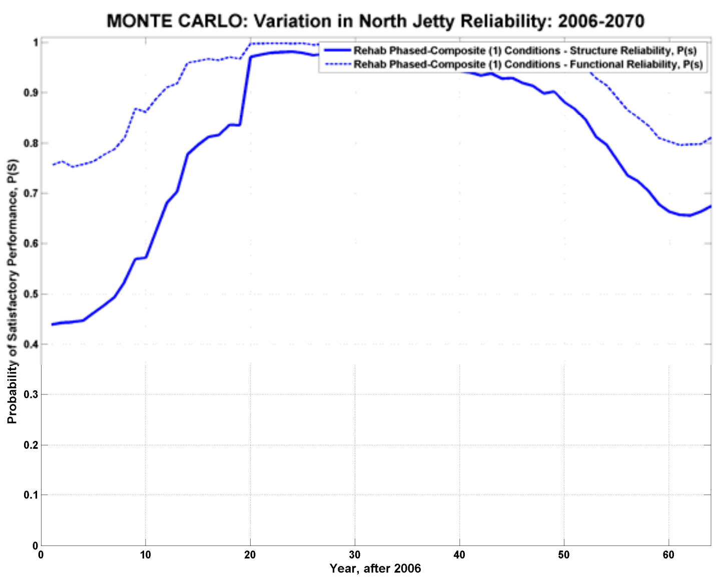

Figure A2-96c. Forecast reliability for MCR North Jetty. Composite 1 Large Rehab - Scheduled (Hold Head).

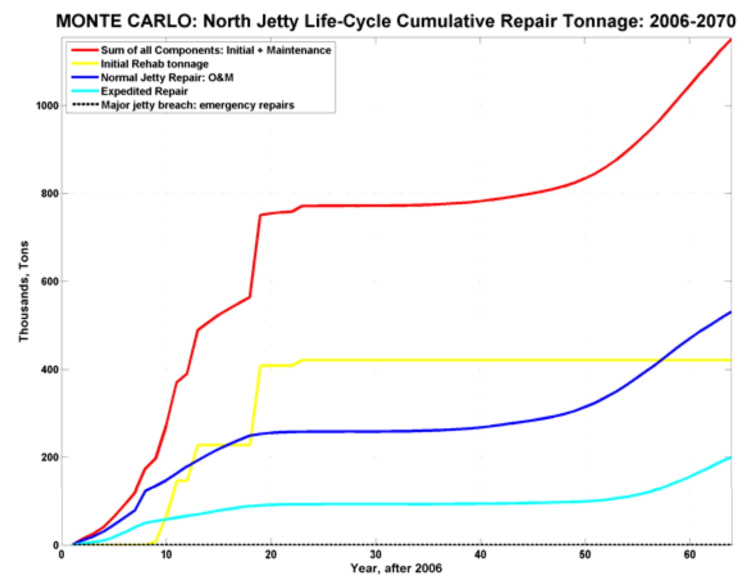

Figure A2-96d. Life-cycle cumulative repair tonnage for MCR North Jetty. Composite 1 Large Rehab - Scheduled (Hold Head).

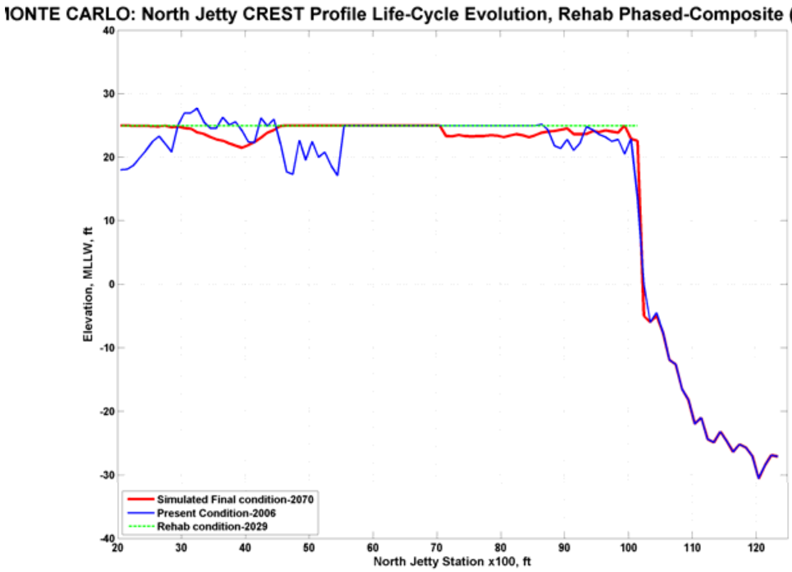

Figure A2-96e. Centerline profile for MCR North Jetty. Composite 1 Large Rehab - Scheduled (Hold Head).

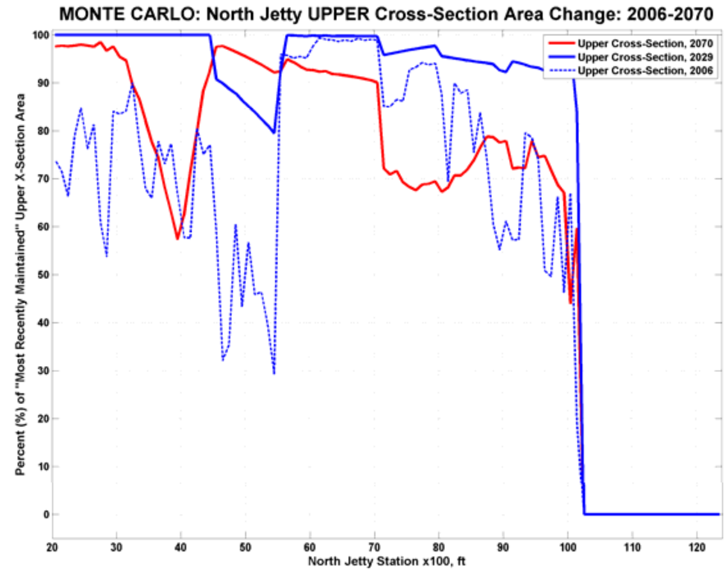

Figure A2-96f. Variation of upper cross-section area for given station of MCR North Jetty. Composite 1 Large Rehab - Scheduled (Hold Head).

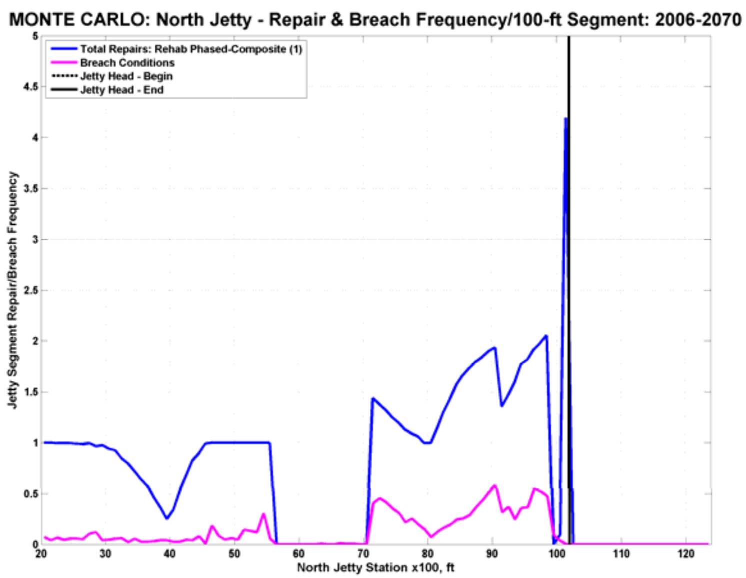

Figure A2-96g. Frequency and location of repairs and breaches for MCR North Jetty. Composite 1 Large Rehab - Scheduled (Hold Head).

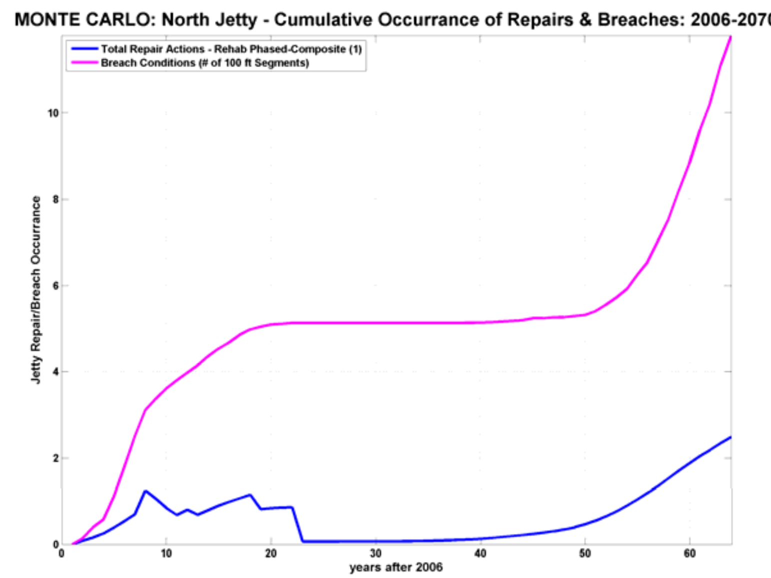

Figure A2-96h. Cumulative occurrence of repairs and breach conditions for MCR North Jetty. Composite 1 Large Rehab - Scheduled (Hold Head).

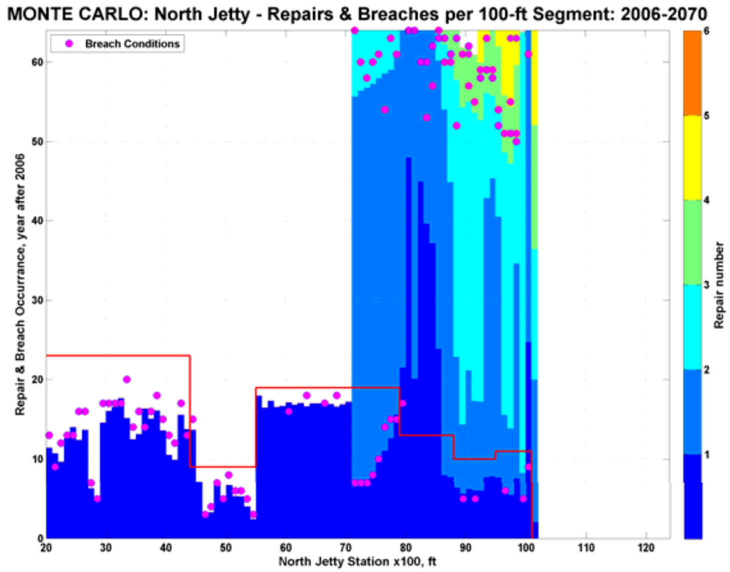

Figure A2-97a. Forecast repair occurrence for MCR North Jetty, shown for each 100 ft jetty segment. Moderate Template Rehab - Scheduled (Hold Head). RED line marks time of REHAB phase implementation

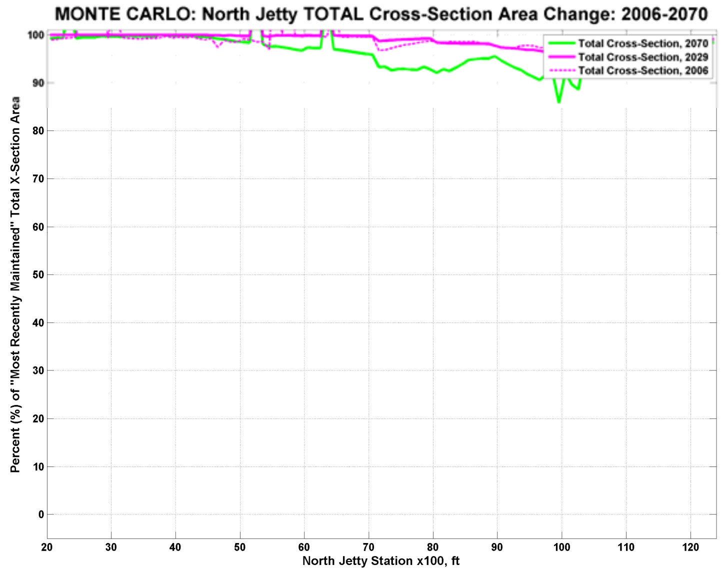

Figure A2-97b. Variation in total cross-section area along MCR North Jetty during forecast period. Moderate Template Rehab - Scheduled (Hold Head).RED line marks time of REHAB phase implementation

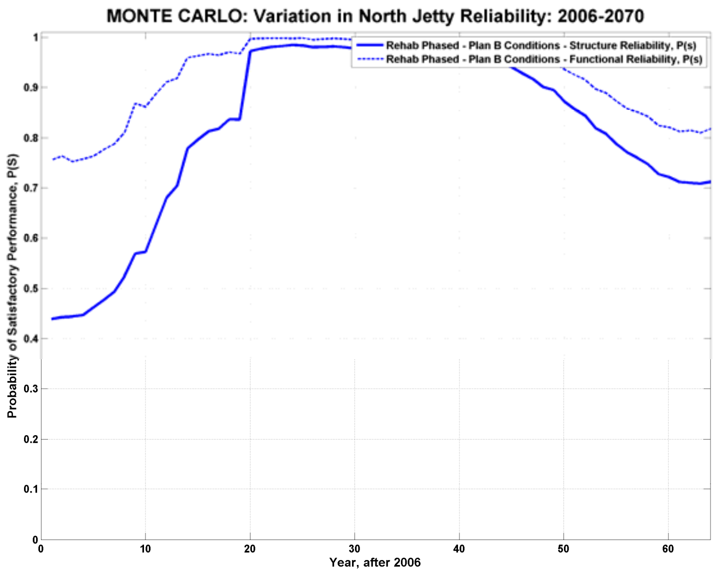

Figure A2-97c. Forecast reliability for MCR North Jetty. Moderate Template Rehab - Scheduled (Hold Head).

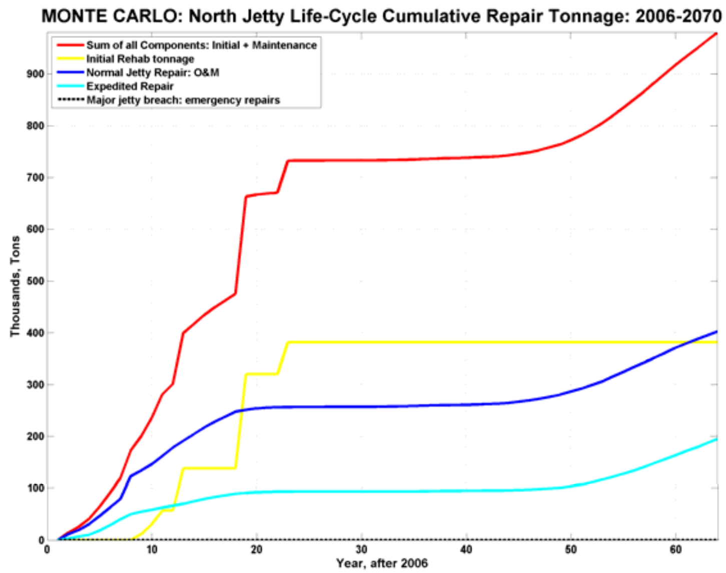

Figure A2-97d. Life-cycle cumulative repair tonnage for MCR North Jetty. Moderate Template Rehab - Scheduled (Hold Head).

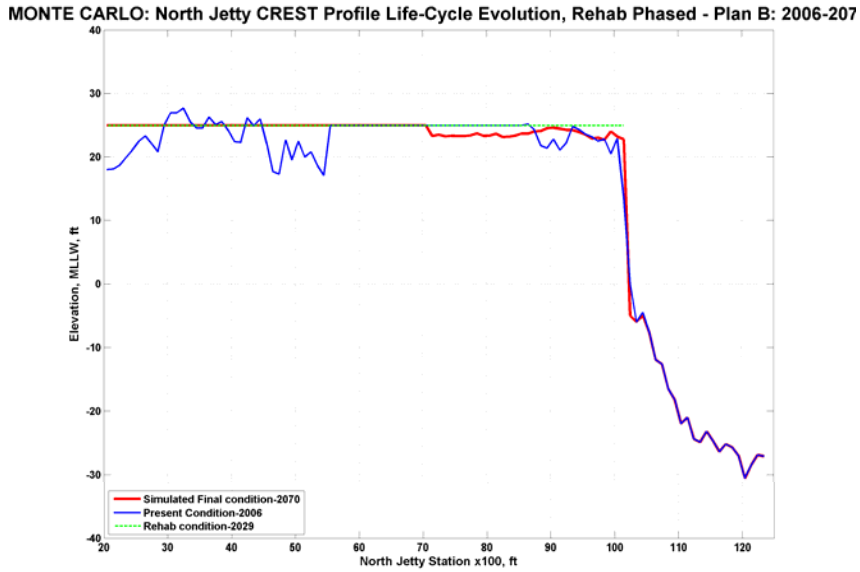

Figure A2-97e. Centerline profile for MCR North Jetty. Moderate Template Rehab - Scheduled (Hold Head).

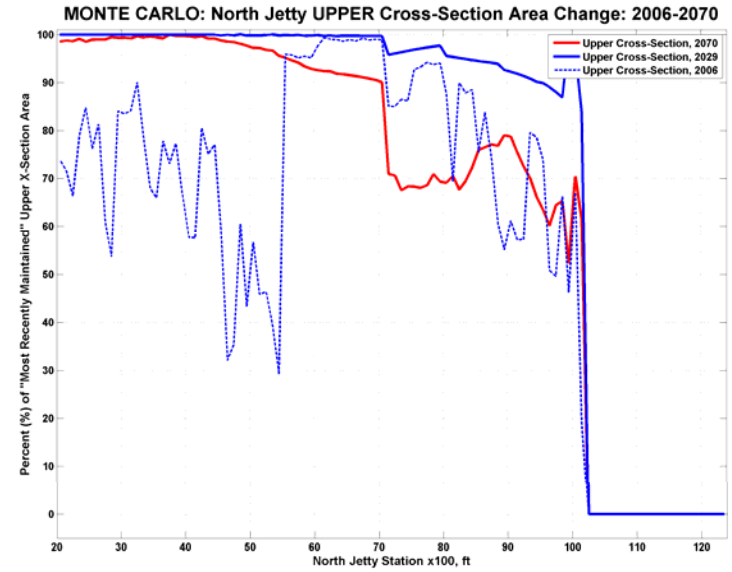

Figure A2-97f. Variation of upper cross-section area for given station of MCR North Jetty. Moderate Template Rehab - Scheduled (Hold Head).

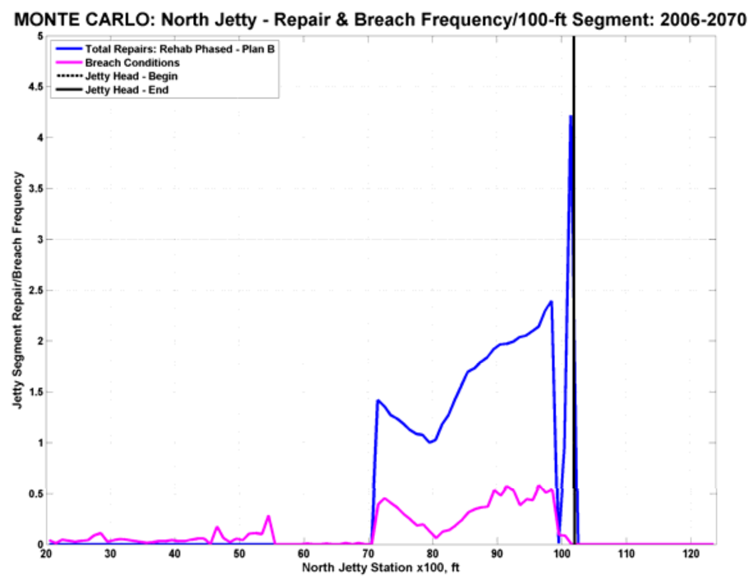

Figure A2-97g. Frequency and location of repairs and breaches for MCR North Jetty. Moderate Template Rehab - Scheduled (Hold Head).

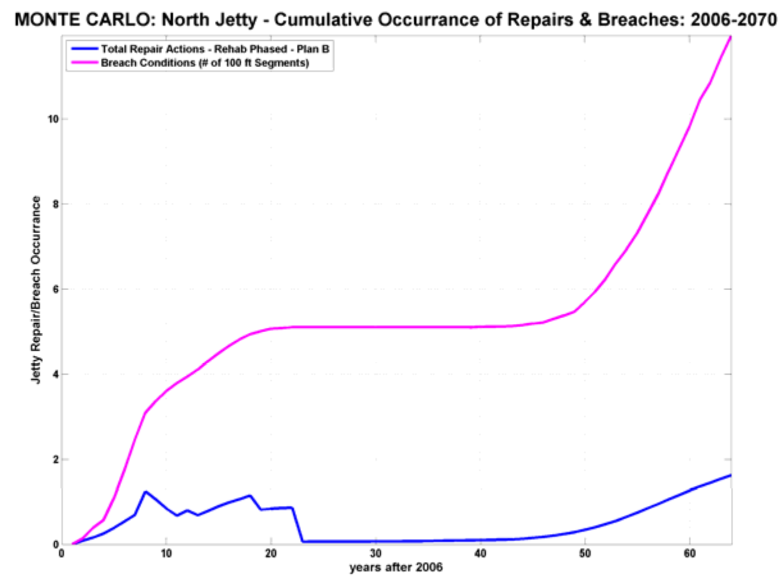

Figure A2-97h. Cumulative occurrence of repairs and breach conditions for MCR North Jetty. Moderate Template Rehab - Scheduled (Hold Head).

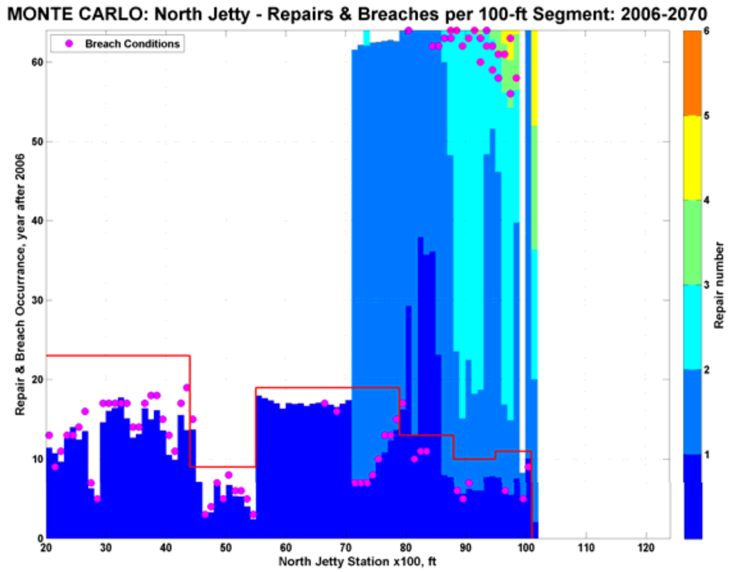

Figure A2-98a. Forecast repair occurrence for MCR North Jetty, shown for each 100 ft jetty segment. Large Template Rehab - Scheduled (Hold Head). RED line marks time of REHAB phase implementation

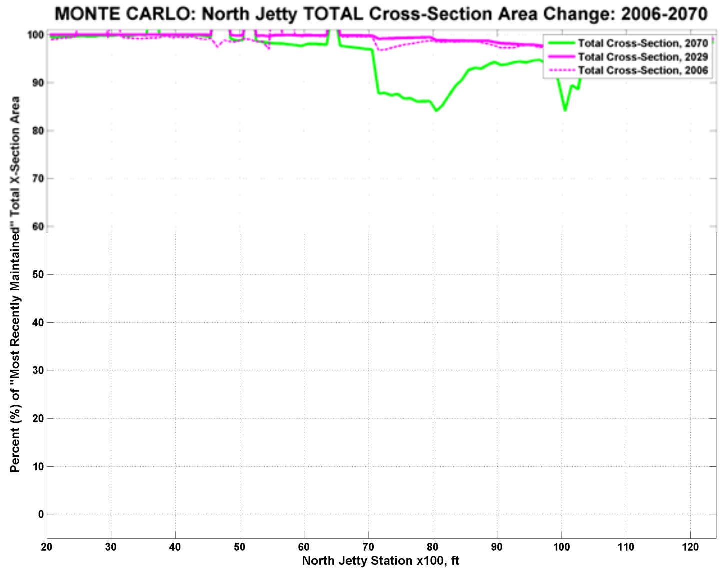

Figure A2-98b. Variation in total cross-section area along MCR North Jetty during forecast period. Large Template Rehab - Scheduled (Hold Head).RED line marks time of REHAB phase implementation

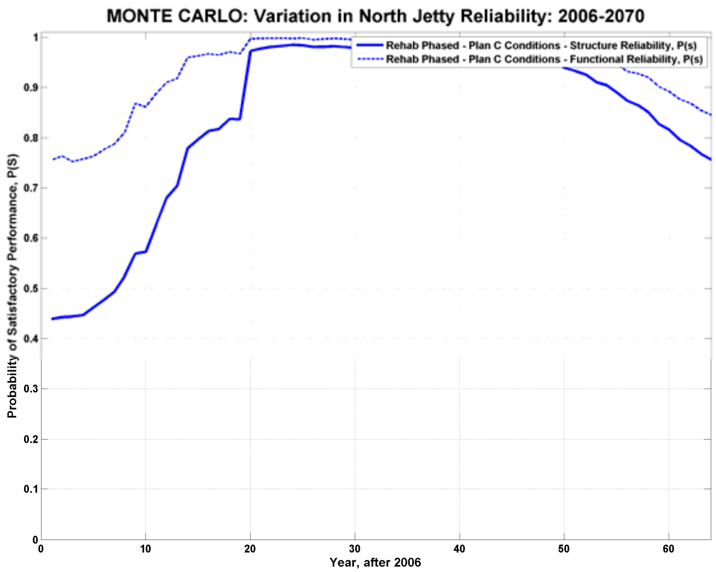

Figure A2-98c. Forecast reliability for MCR North Jetty. Large Template Rehab - Scheduled (Hold Head).

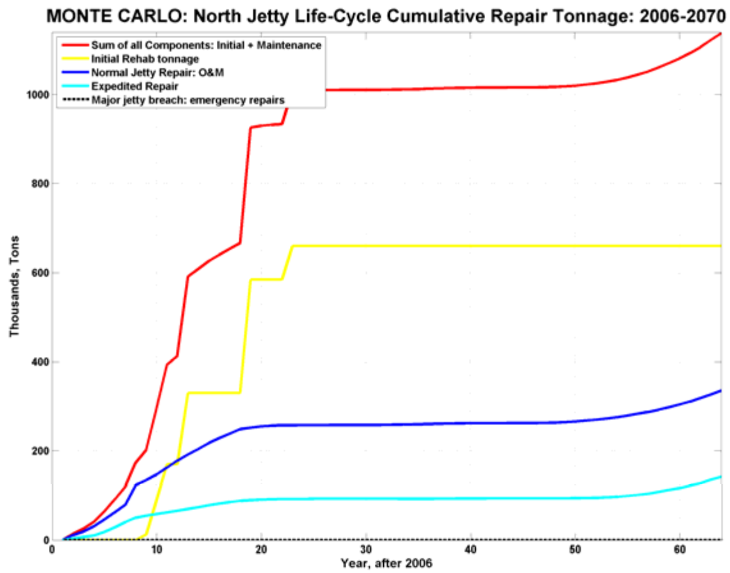

Figure A2-98d. Life-cycle cumulative repair tonnage for MCR North Jetty. Large Template Rehab - Scheduled (Hold Head).

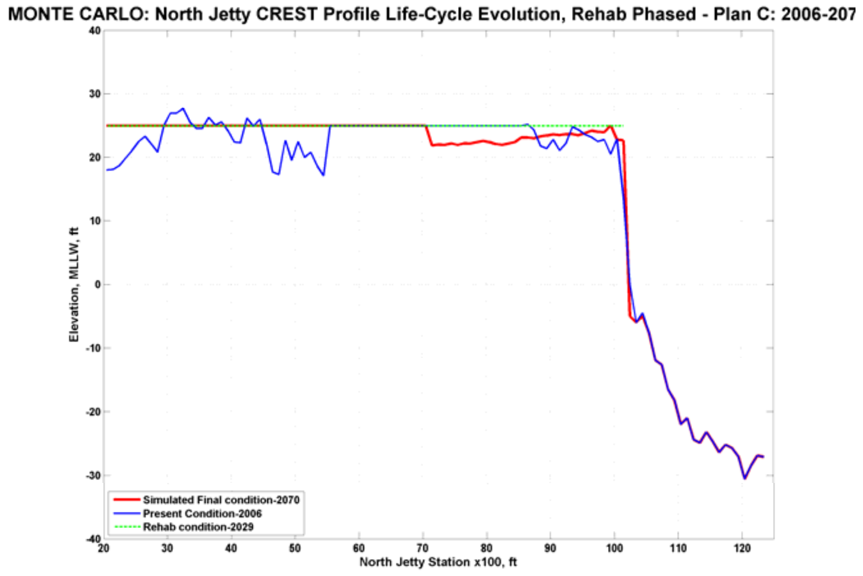

Figure A2-98e. Centerline profile for MCR North Jetty. Large Template Rehab - Scheduled (Hold Head).

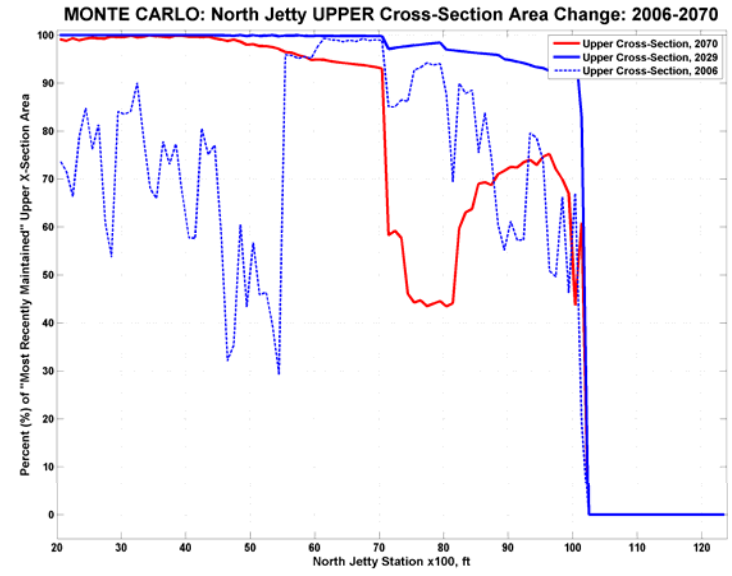

Figure A2-98f. Variation of upper cross-section area for given station of MCR North Jetty. Large Template Rehab - Scheduled (Hold Head).

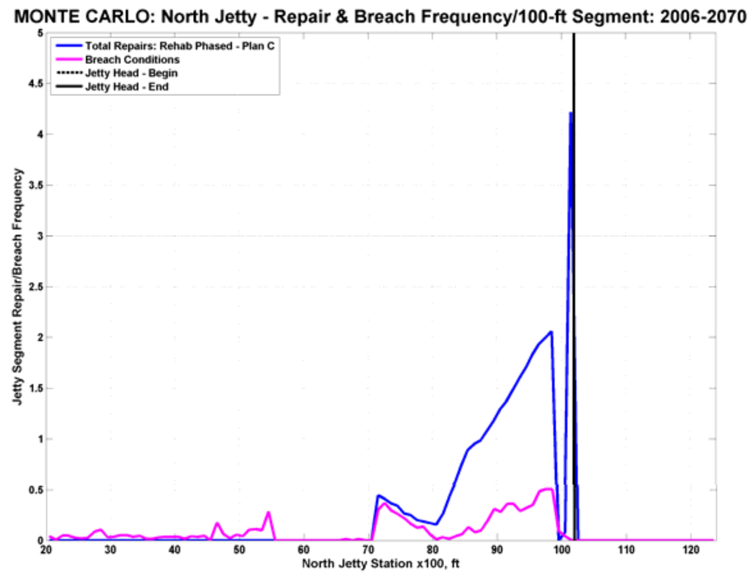

Figure A2-98g. Frequency and location of repairs and breaches for MCR North Jetty. Large Template Rehab - Scheduled (Hold Head).

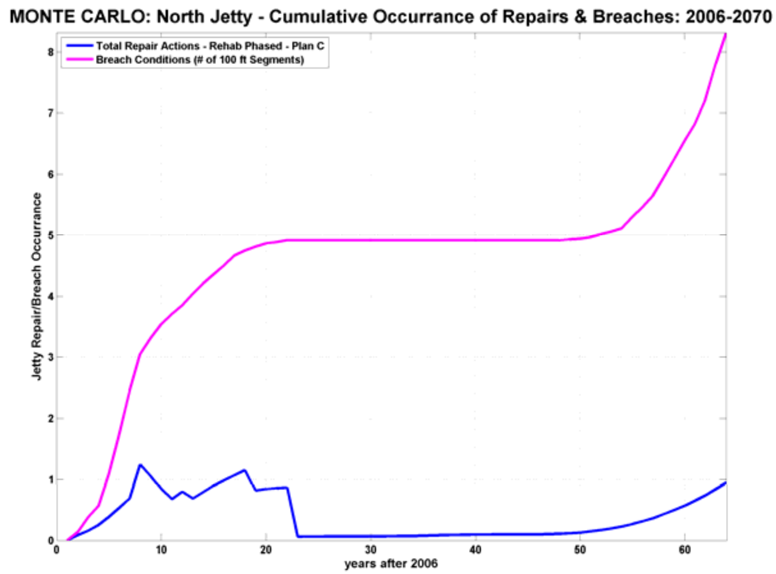

Figure A2-98h. Cumulative occurrence of repairs and breach conditions for MCR North Jetty. Large Template Rehab - Scheduled (Hold Head).

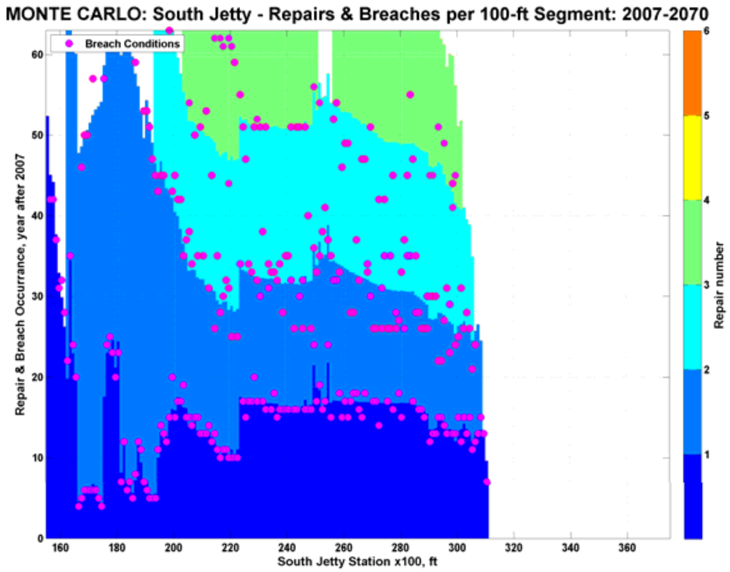

Figure A2-99a. Forecast repair occurrence for MCR South Jetty, shown for each 100 ft jetty segment. Fix-as-Fail Repair.

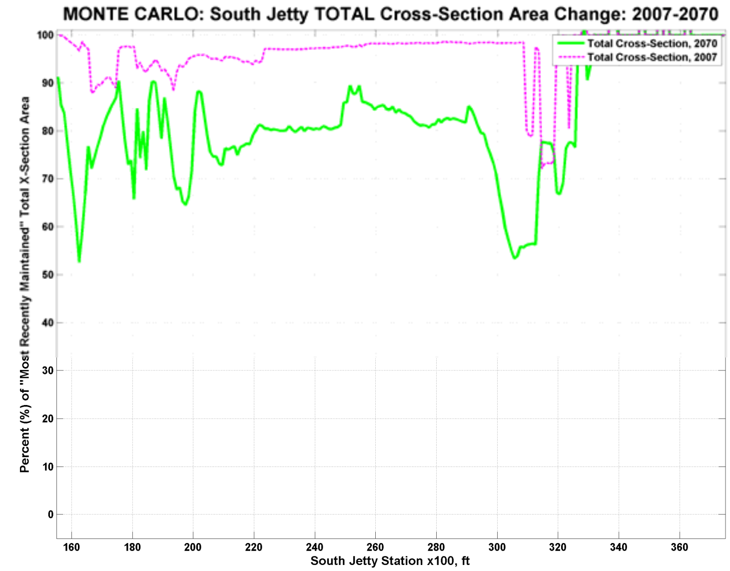

Figure A2-99b. Variation in total cross-section area along MCR South Jetty during forecast period. Fix-as-Fail Repair.

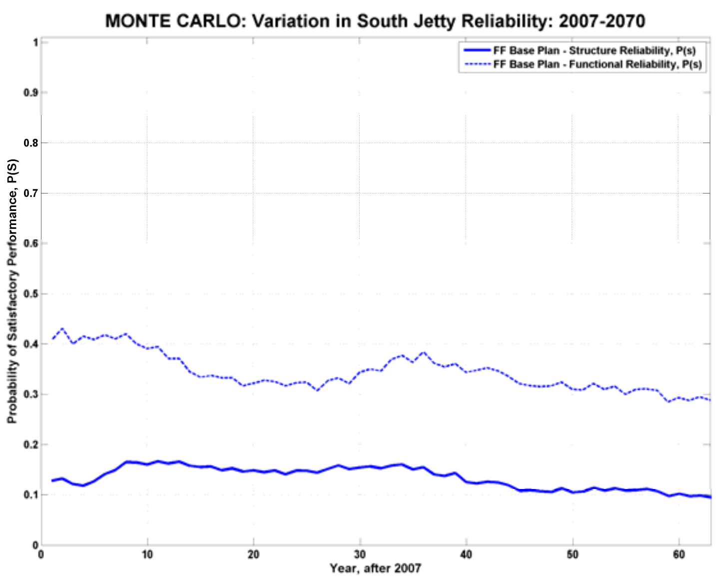

Figure A2-99c. Forecast reliability for MCR South Jetty. Fix-as-Fail Repair.

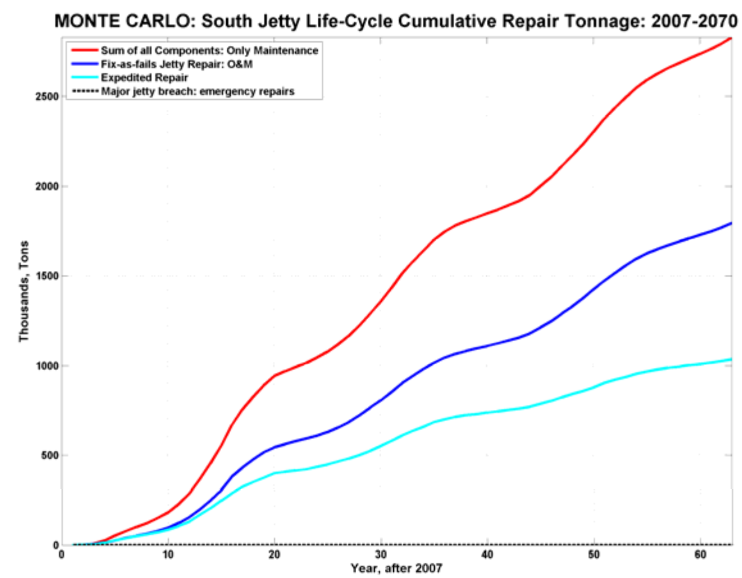

Figure A2-99d. Life-cycle cumulative repair tonnage for MCR South Jetty. Fix-as-Fail Repair.

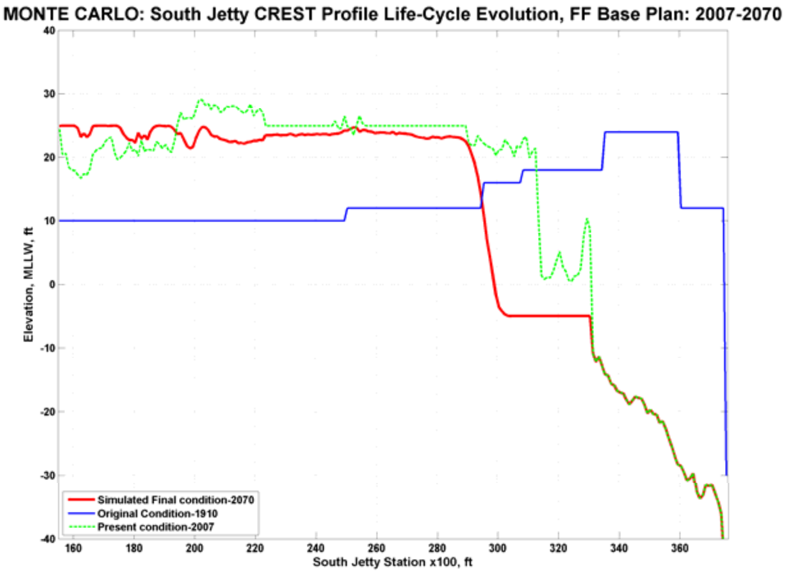

Figure A2-99e. Centerline profile for MCR South Jetty. Fix-as-Fail Repair.

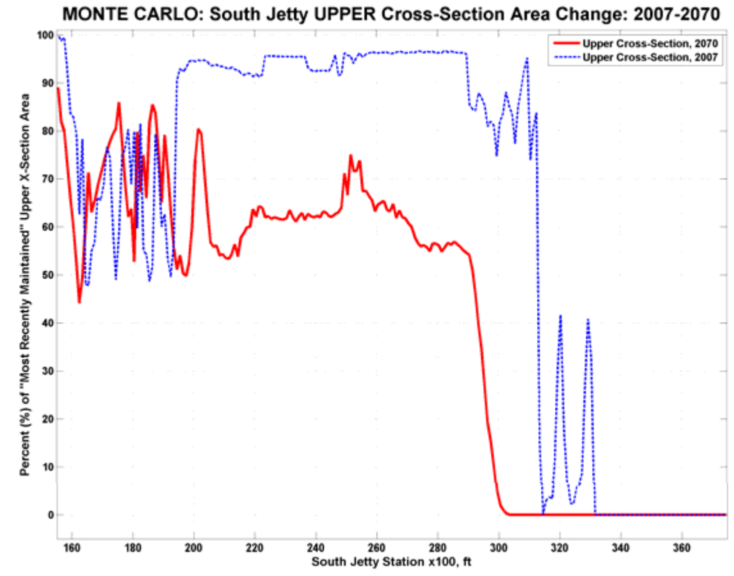

Figure A2-99f. Variation of upper cross-section area for given station of MCR South Jetty. Fix-as-Fail Repair.

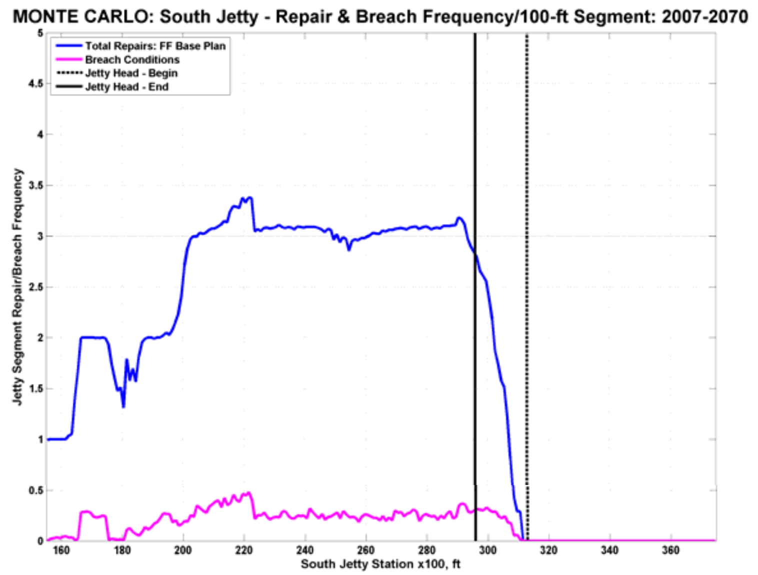

Figure A2-99g. Frequency and location of repairs and breaches for MCR South Jetty. Fix-as-Fail Repair.

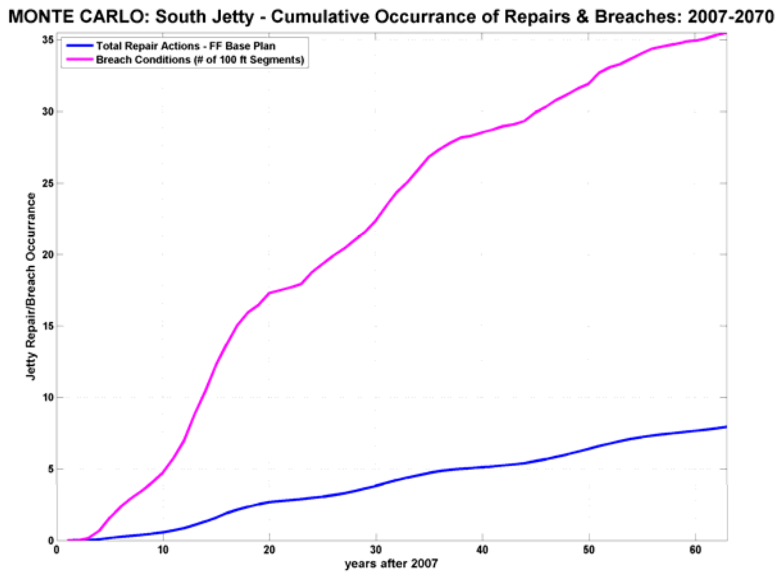

Figure A2-99h. Cumulative occurrence of repairs and breach conditions for MCR South Jetty. Fix-as-Fail Repair.

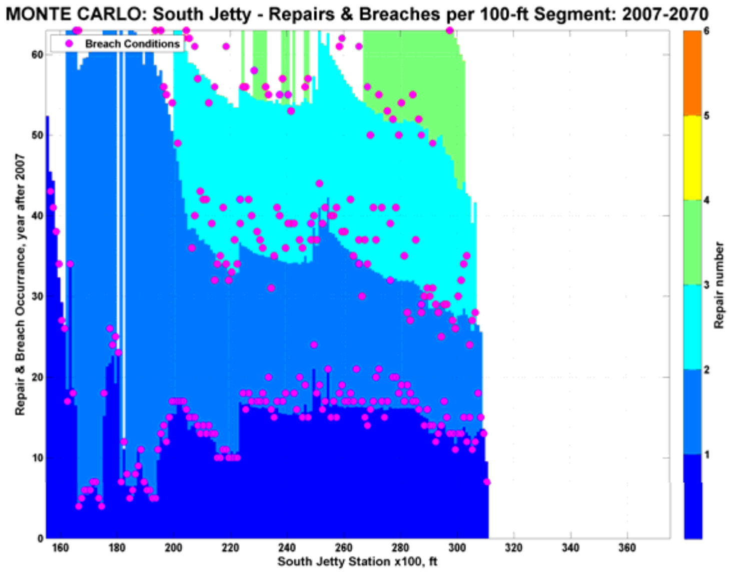

Figure A2-100a. Forecast repair occurrence for MCR South Jetty, shown for each 100 ft jetty segment. Base Condition.

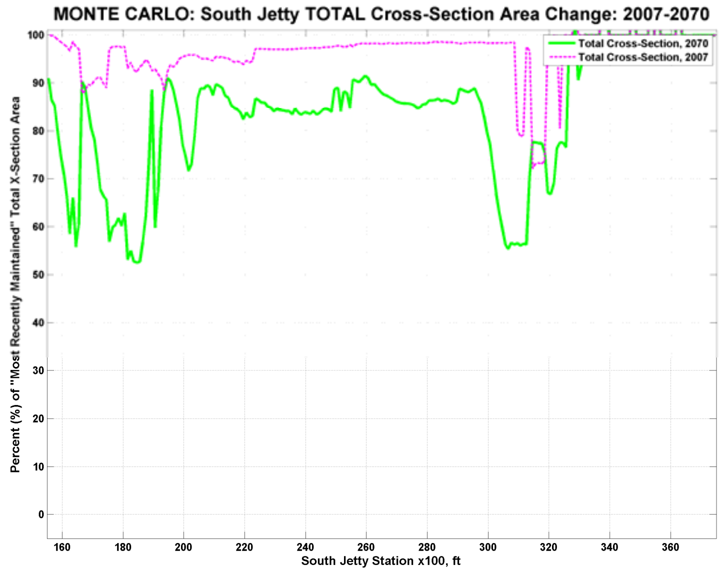

Figure A2-100b. Variation in total cross-section area along MCR South Jetty during forecast period. Base Condition.

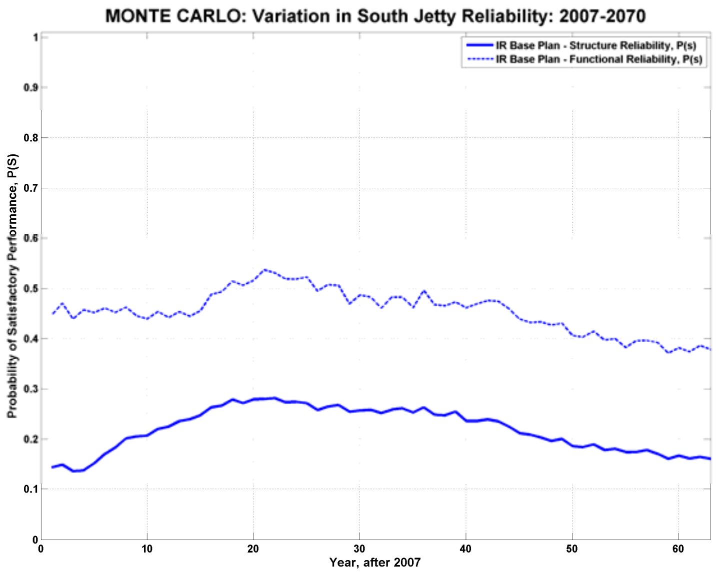

Figure A2-100c. Forecast reliability for MCR South Jetty. Base Condition.

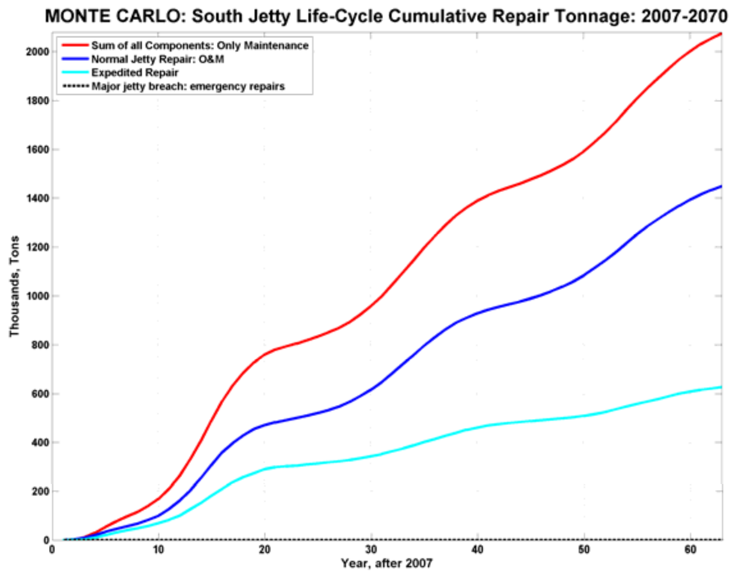

Figure A2-100d. Life-cycle cumulative repair tonnage for MCR South Jetty. Base Condition.

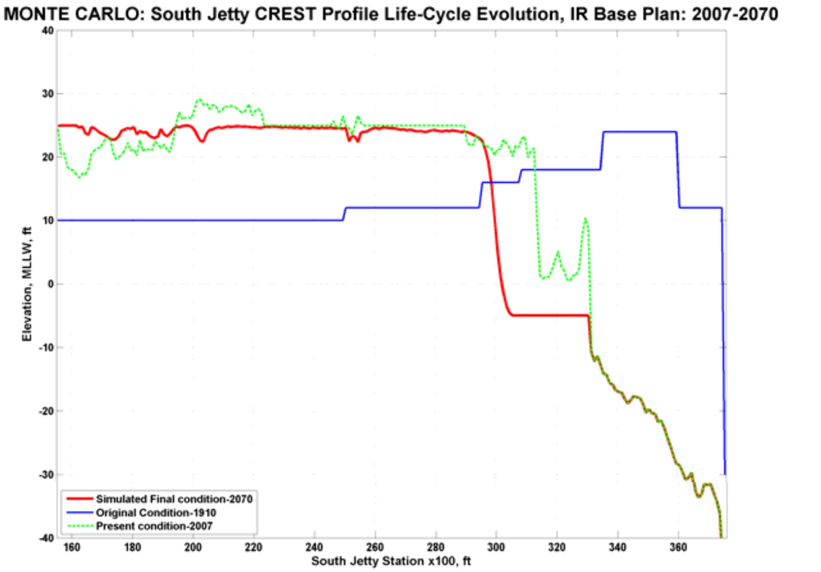

Figure A2-100e. Centerline profile for MCR South Jetty. Base Condition.

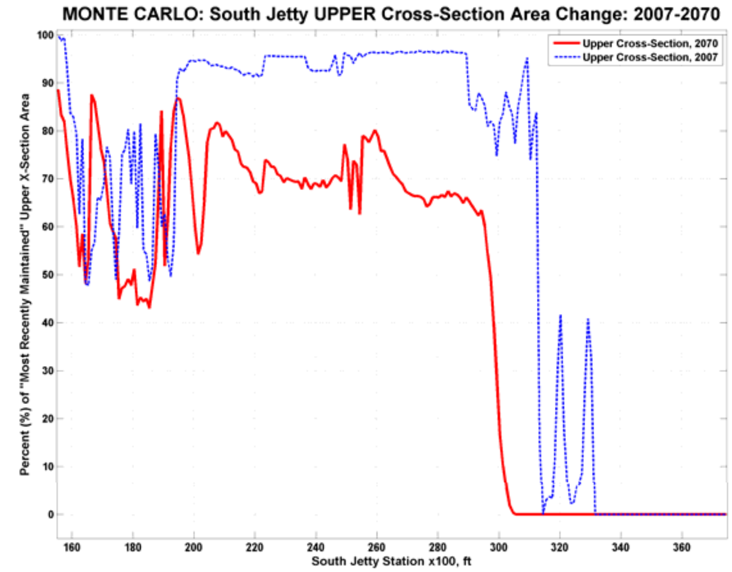

Figure A2-100f. Variation of upper cross-section area for given station of MCR South Jetty. Base Condition.

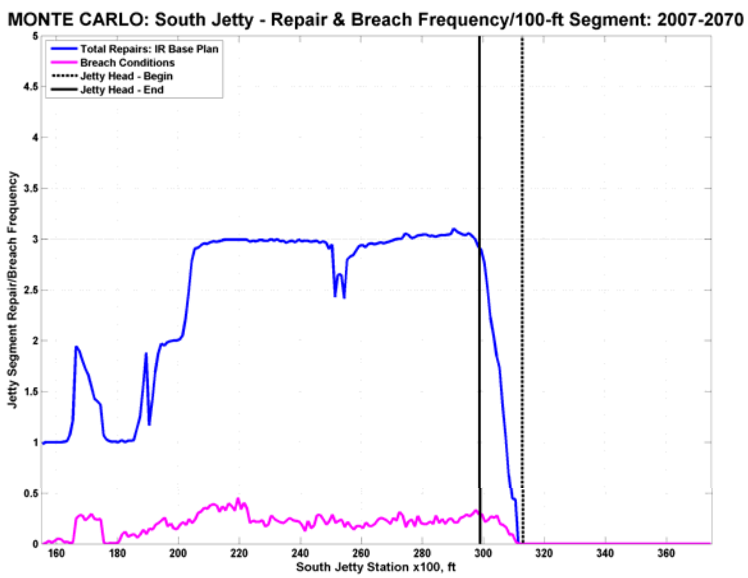

Figure A2-100g. Frequency and location of repairs and breaches for MCR South Jetty. Base Condition.

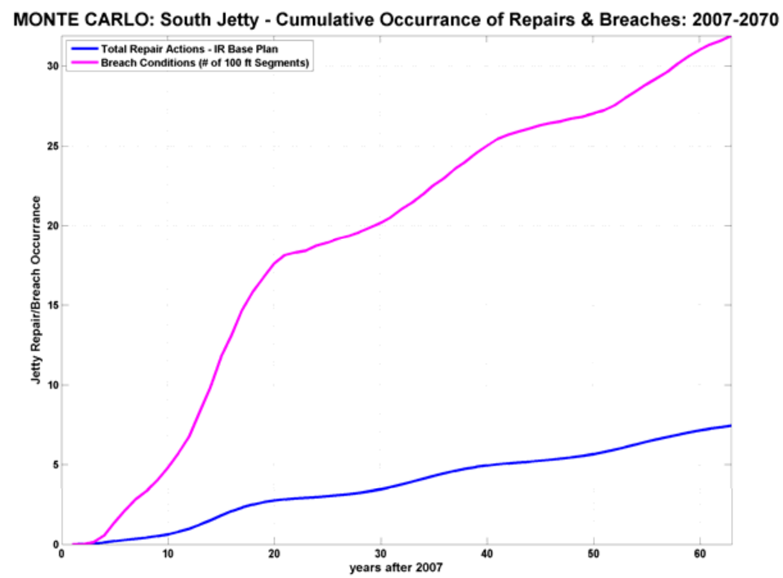

Figure A2-100h. Cumulative occurrence of repairs and breach conditions for MCR South Jetty. Base Condition.

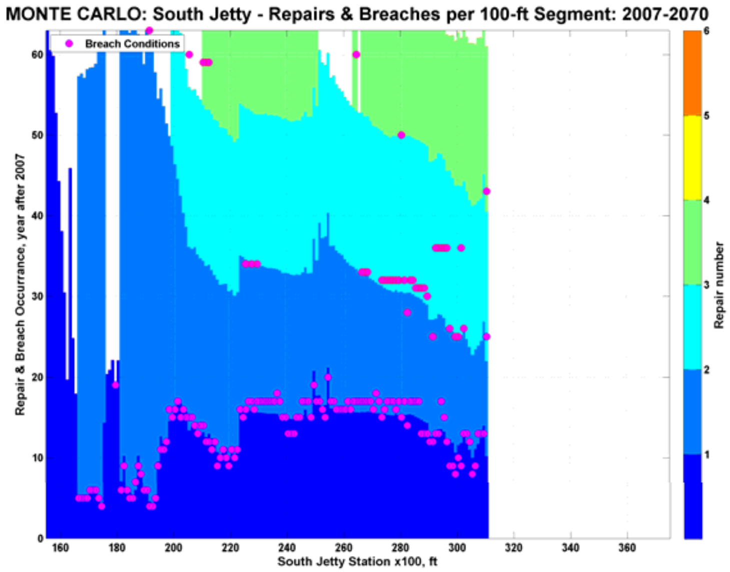

Figure A2-101a. Forecast repair occurrence for MCR South Jetty, shown for each 100 ft jetty segment. Scheduled Repair w/ Engineering Features.

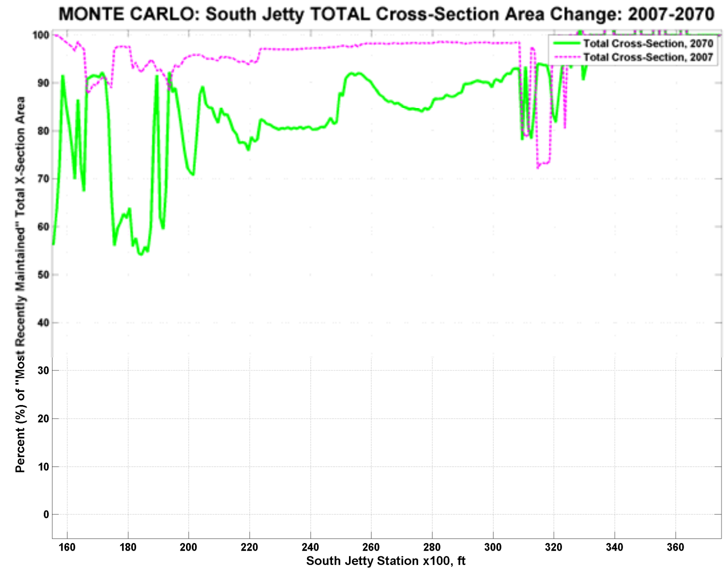

Figure A2-101b. Variation in total cross-section area along MCR South Jetty during forecast period. Scheduled Repair w/ Engineering Features.

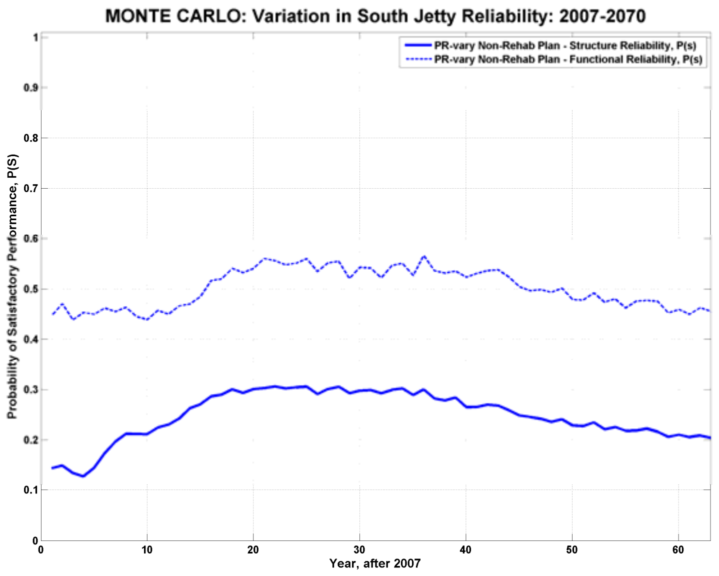

Figure A2-101c. Forecast reliability for MCR South Jetty. Scheduled Repair w/ Engineering Features.

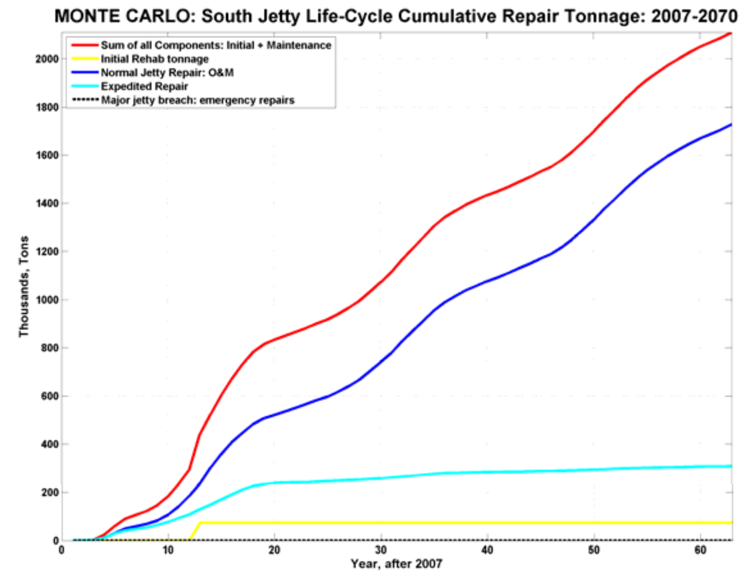

Figure A2-101d. Life-cycle cumulative repair tonnage for MCR South Jetty. Scheduled Repair w/ Engineering Features.

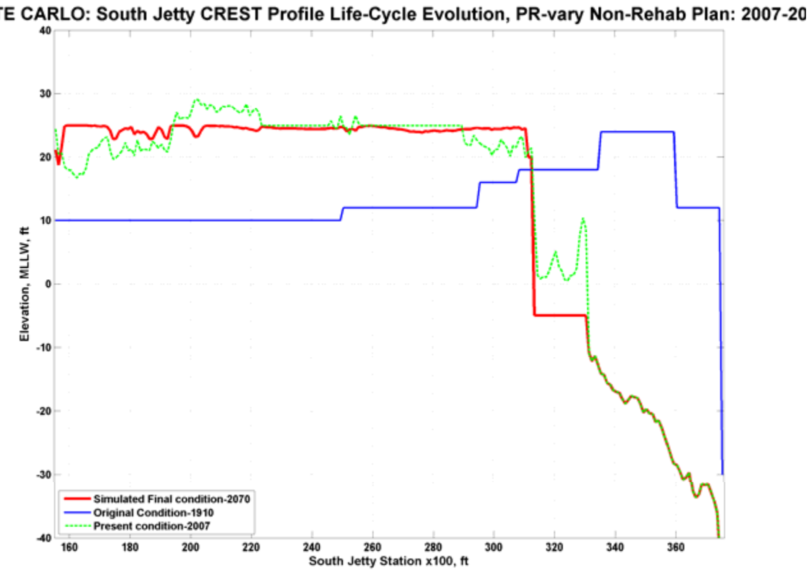

Figure A2-101e. Centerline profile for MCR South Jetty. Scheduled Repair w/ Engineering Features.

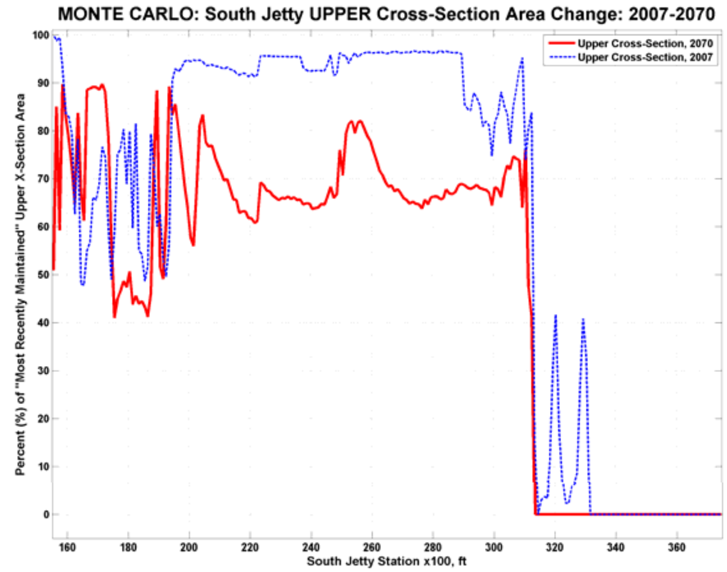

Figure A2-101f. Variation of upper cross-section area for given station of MCR South Jetty. Scheduled Repair w/ Engineering Features.

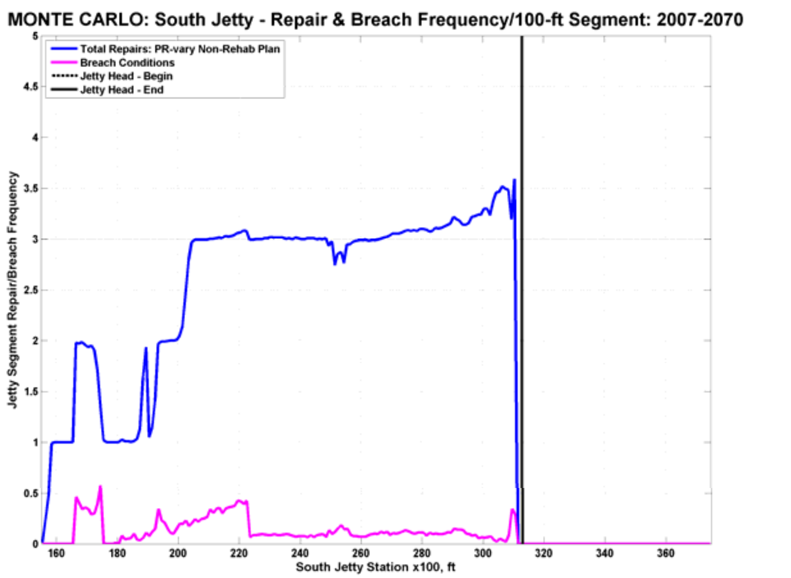

Figure A2-101g. Frequency and location of repairs and breaches for MCR South Jetty. Scheduled Repair w/ Engineering Features.

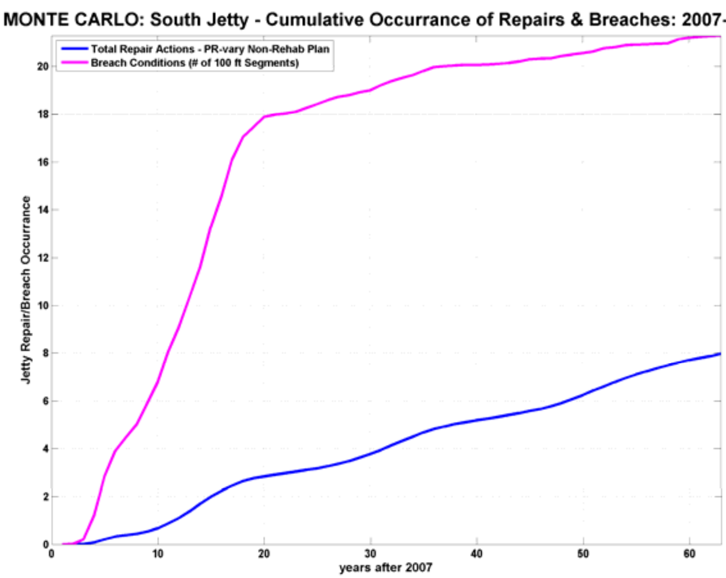

Figure A2-101h. Cumulative occurrence of repairs and breach conditions for MCR South Jetty. Scheduled Repair w/ Engineering Features.

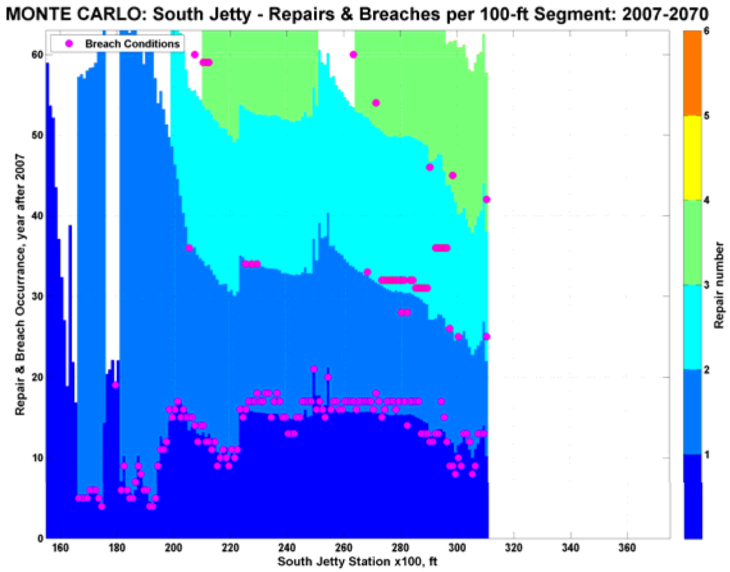

Figure A2-102a. Forecast repair occurrence for MCR South Jetty, shown for each 100 ft jetty segment. Scheduled Repair w/ Head Capping.

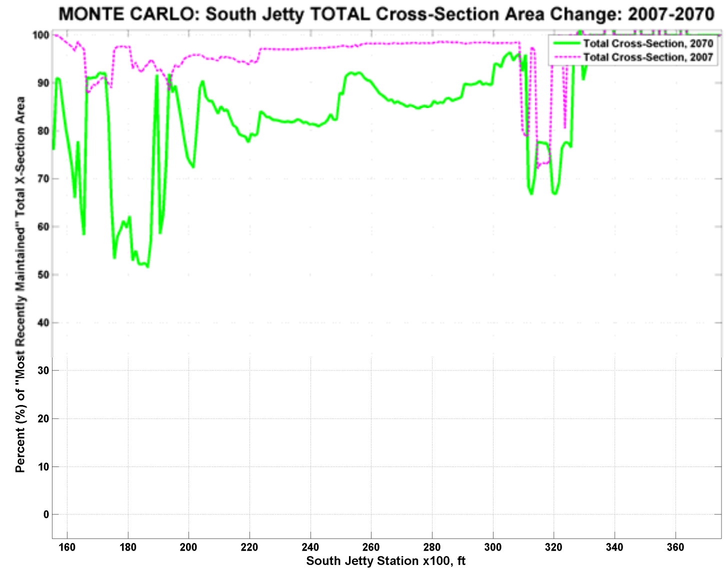

Figure A2-102b. Variation in total cross-section area along MCR South Jetty during forecast period. Scheduled Repair w/ Head Capping.

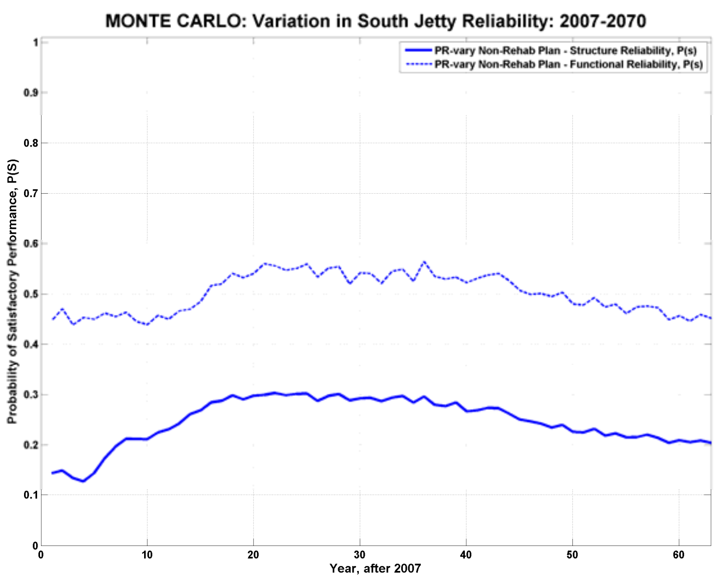

Figure A2-102c. Forecast reliability for MCR South Jetty. Scheduled Repair w/ Head Capping.

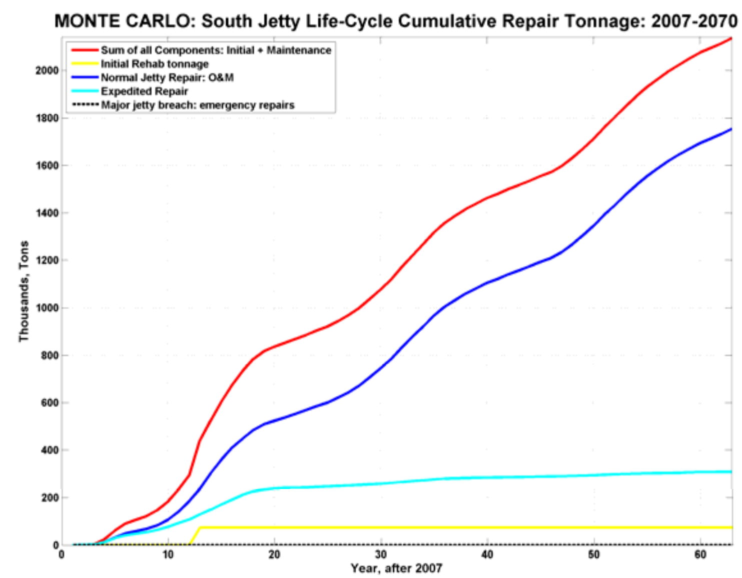

Figure A2-102d. Life-cycle cumulative repair tonnage for MCR South Jetty. Scheduled Repair w/ Head Capping.

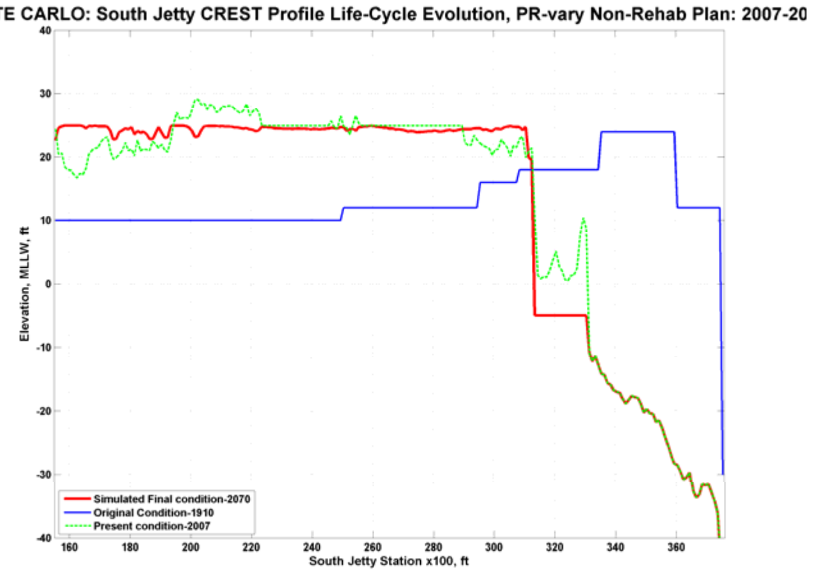

Figure A2-102e. Centerline profile for MCR South Jetty. Scheduled Repair w/ Head Capping.

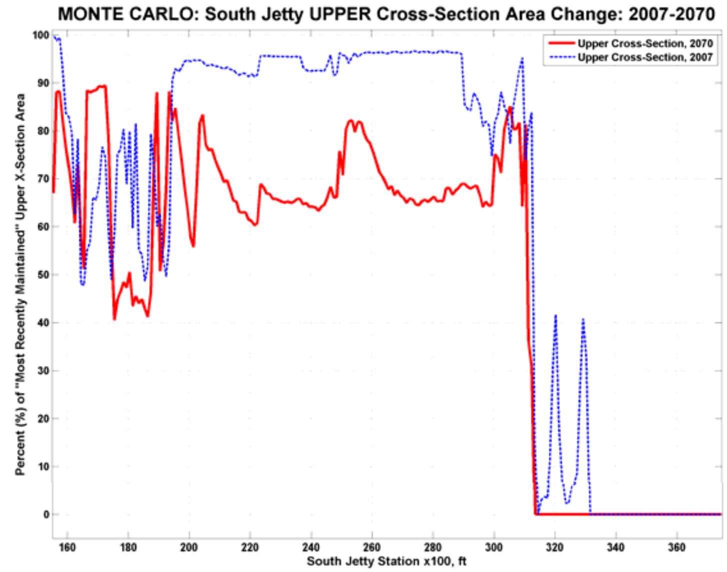

Figure A2-102f. Variation of upper cross-section area for given station of MCR South Jetty. Scheduled Repair w/ Head Capping.

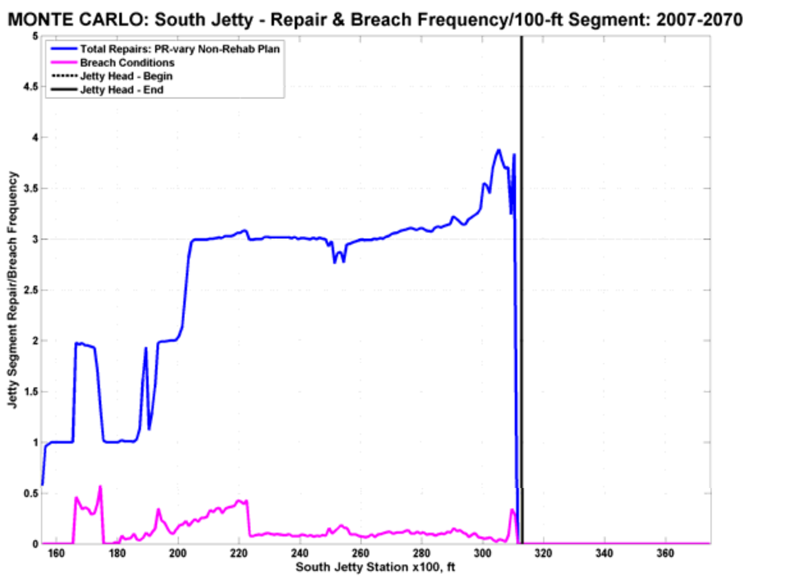

Figure A2-102g. Frequency and location of repairs and breaches for MCR South Jetty. Scheduled Repair w/ Head Capping.

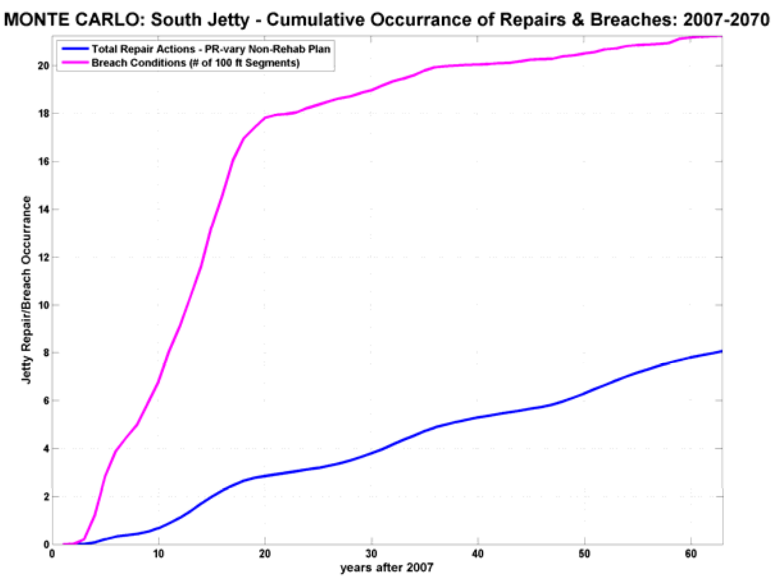

Figure A2-102h. Cumulative occurrence of repairs and breach conditions for MCR South Jetty. Scheduled Repair w/ Head Capping.

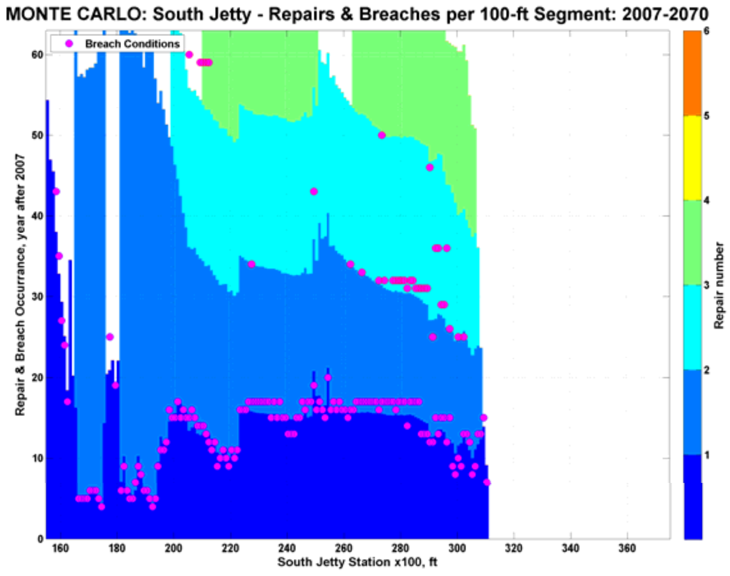

Figure A2-103a. Forecast repair occurrence for MCR South Jetty, shown for each 100 ft jetty segment. Scheduled Repair.

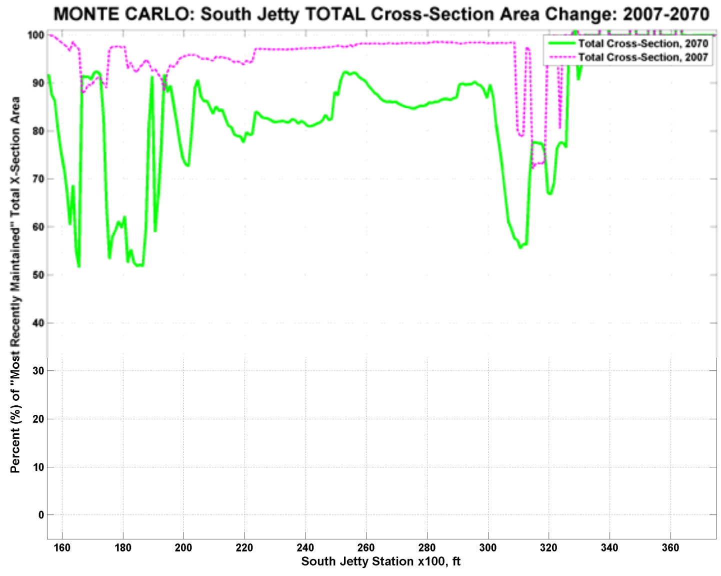

Figure A2-103b. Variation in total cross-section area along MCR South Jetty during forecast period. Scheduled Repair.

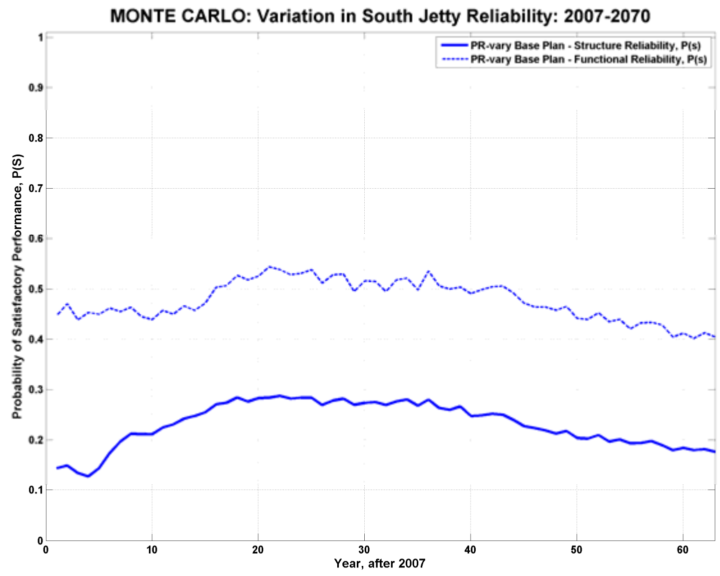

Figure A2-103c. Forecast reliability for MCR South Jetty. Scheduled Repair.

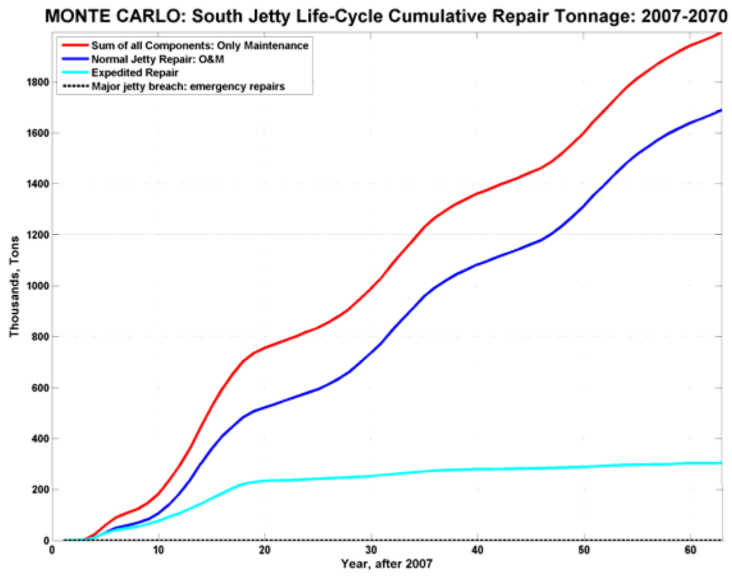

Figure A2-103d. Life-cycle cumulative repair tonnage for MCR South Jetty. Scheduled Repair.

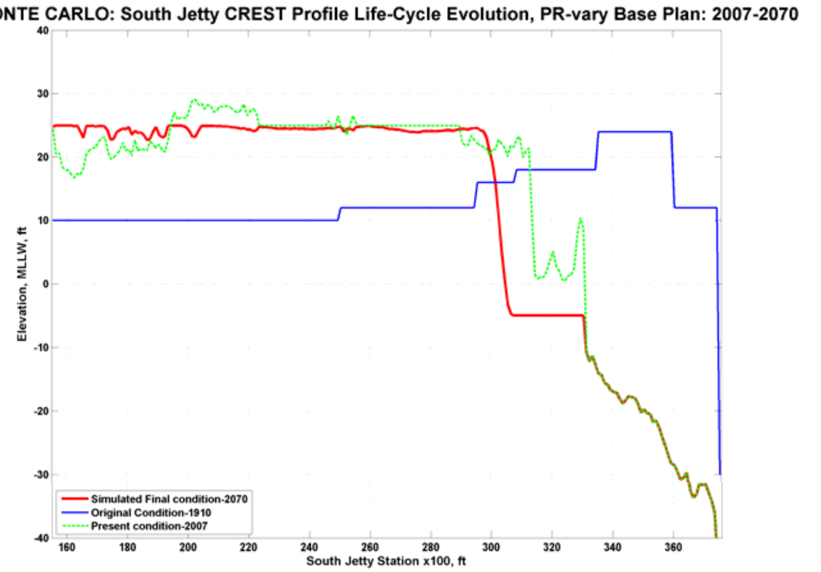

Figure A2-103e. Centerline profile for MCR South Jetty. Scheduled Repair.

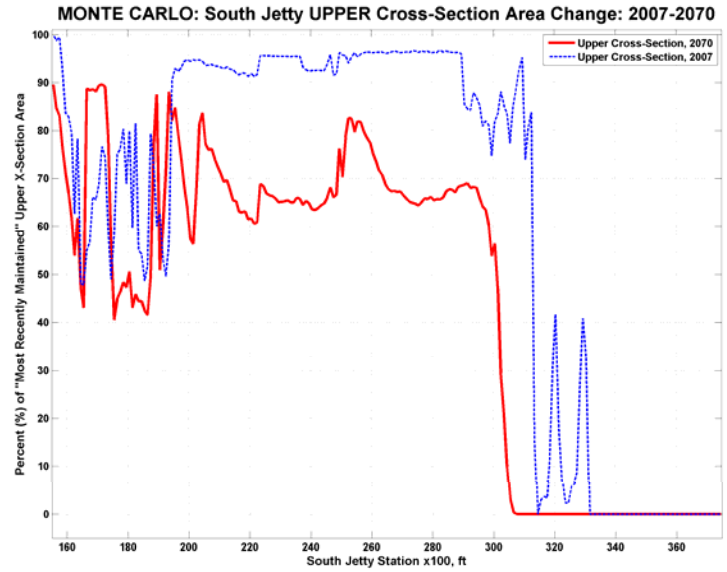

Figure A2-103f. Variation of upper cross-section area for given station of MCR South Jetty. Scheduled Repair.

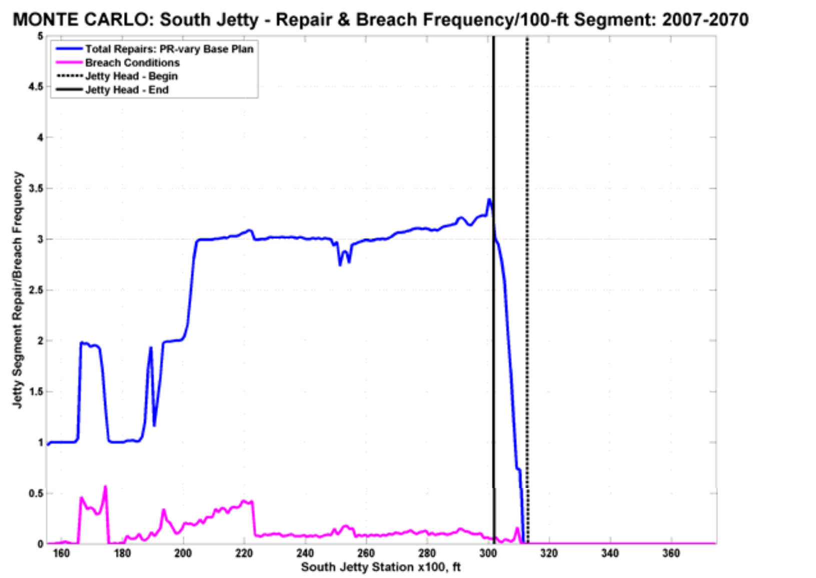

Figure A2-103g. Frequency and location of repairs and breaches for MCR South Jetty. Scheduled Repair.

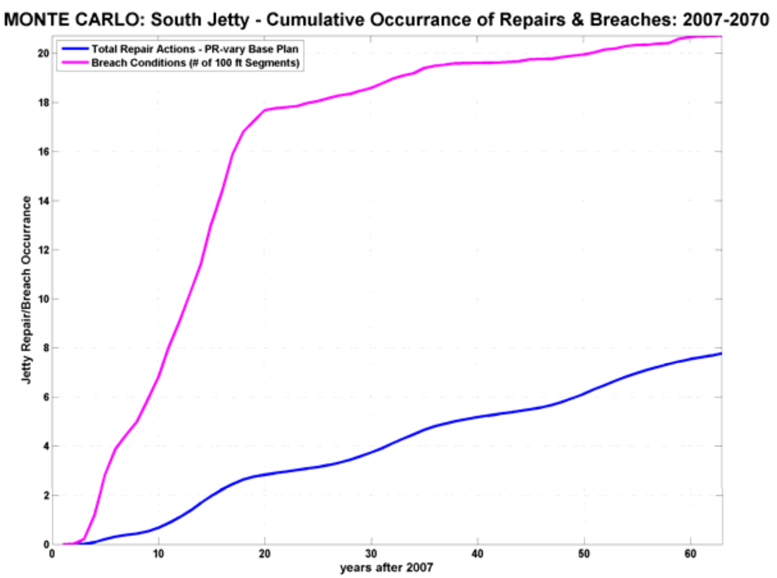

Figure A2-103h. Cumulative occurrence of repairs and breach conditions for MCR South Jetty. Scheduled Repair.

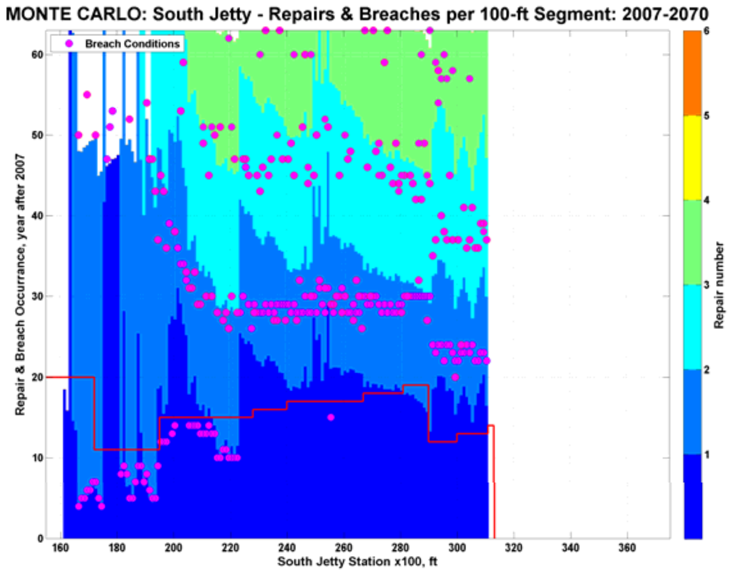

Figure A2-104a. Forecast repair occurrence for MCR South Jetty, shown for each 100 ft jetty segment. Minimum Template Rehab - Immediate. RED line marks time of REHAB phase implementation

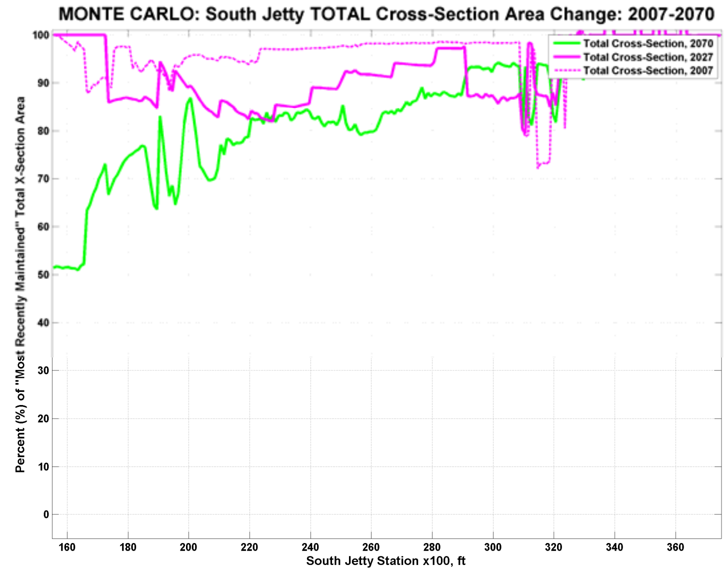

Figure A2-104b. Variation in total cross-section area along MCR South Jetty during forecast period. Minimum Template Rehab - Immediate.RED line marks time of REHAB phase implementation

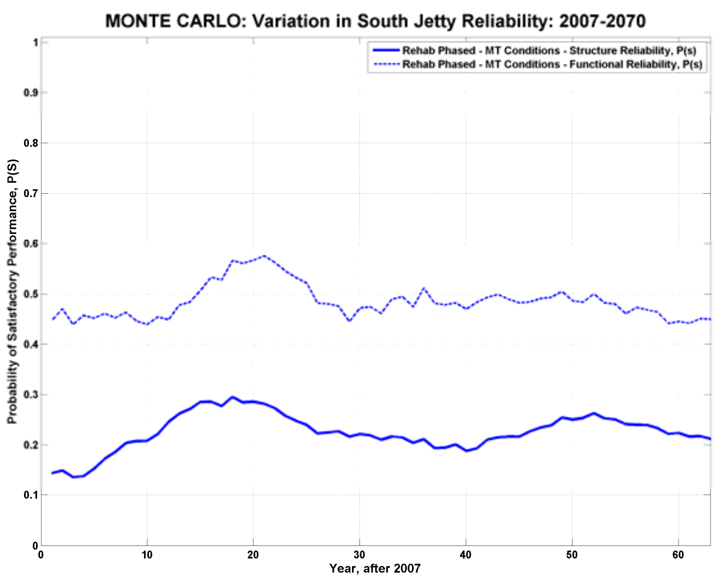

Figure A2-104c. Forecast reliability for MCR South Jetty. Minimum Template Rehab - Immediate.

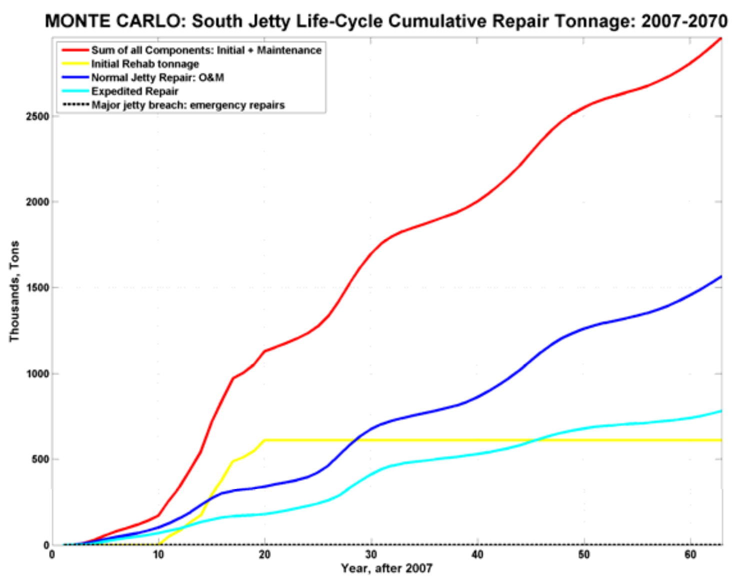

Figure A2-104d. Life-cycle cumulative repair tonnage for MCR South Jetty. Minimum Template Rehab - Immediate.

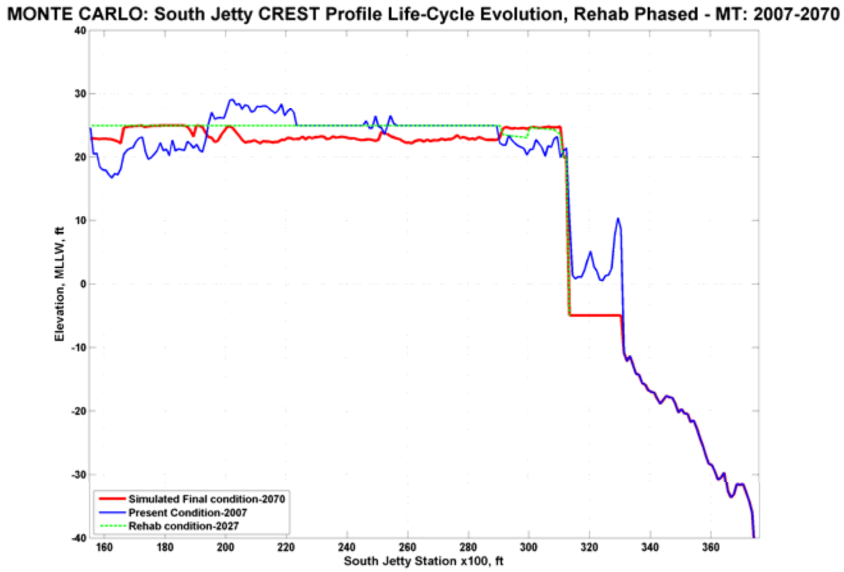

Figure A2-104e. Centerline profile for MCR South Jetty. Minimum Template Rehab - Immediate.

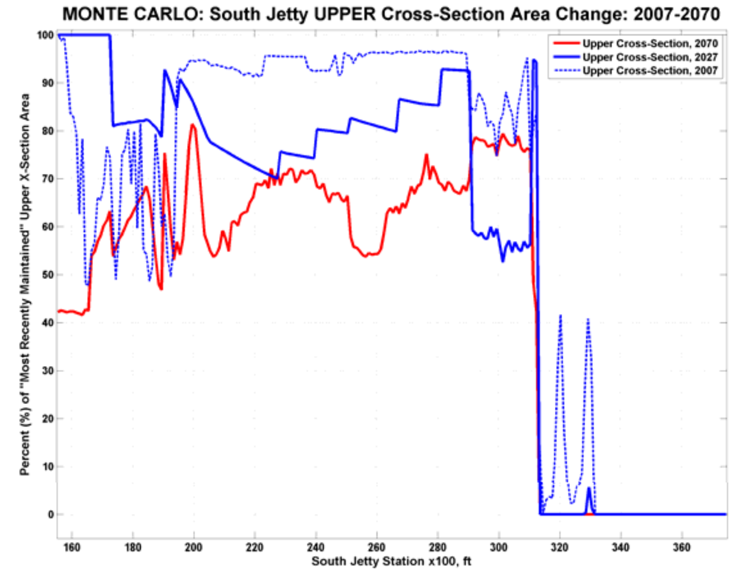

Figure A2-104f. Variation of upper cross-section area for given station of MCR South Jetty. Minimum Template Rehab - Immediate.

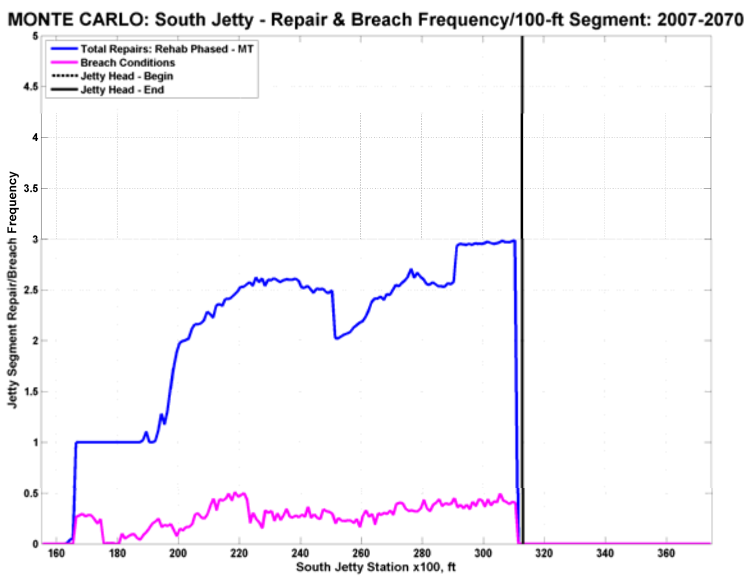

Figure A2-104g. Frequency and location of repairs and breaches for MCR South Jetty. Minimum Template Rehab - Immediate.

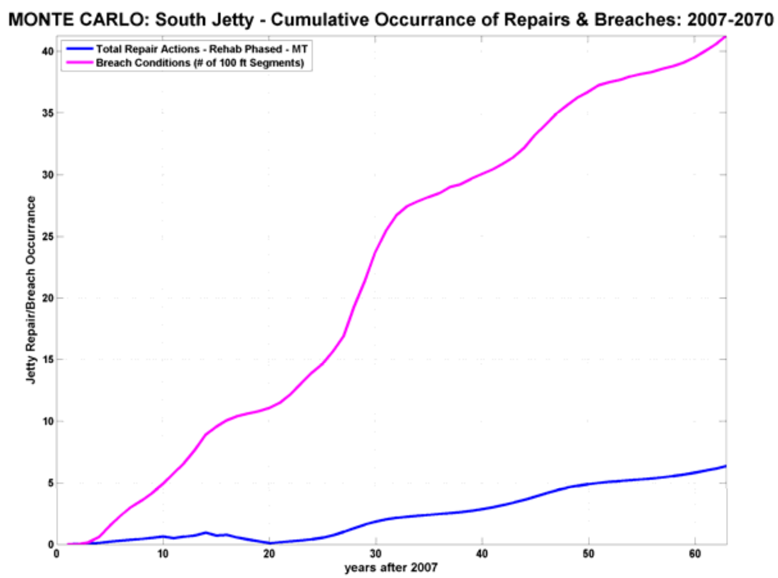

Figure A2-104h. Cumulative occurrence of repairs and breach conditions for MCR South Jetty. Minimum Template Rehab - Immediate.

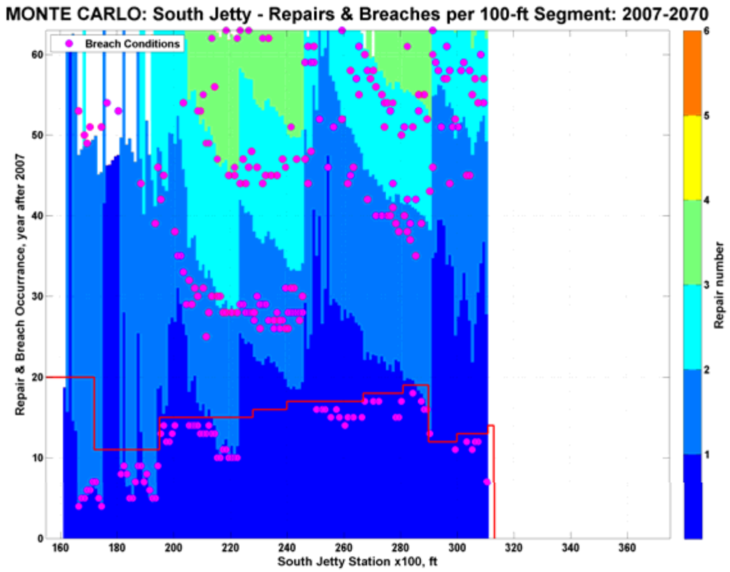

Figure A2-105a. Forecast repair occurrence for MCR South Jetty, shown for each 100 ft jetty segment. Composite 3 Small Rehab - Immediate. RED line marks time of REHAB phase implementation

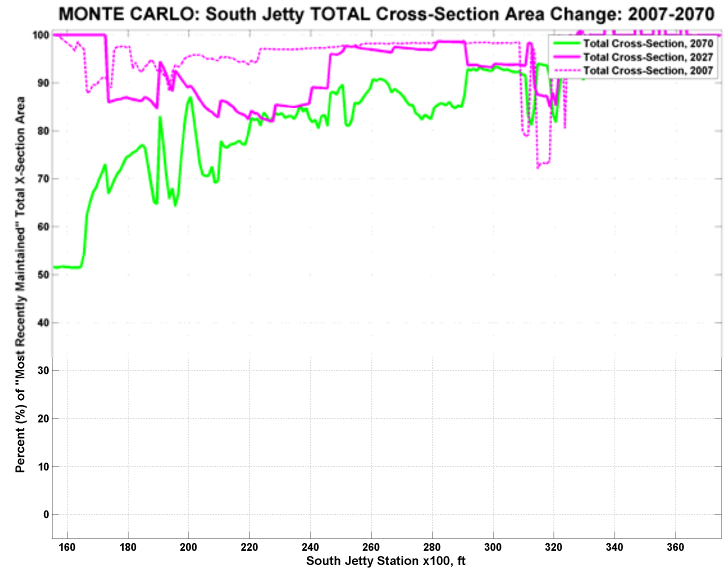

Figure A2-105b. Variation in total cross-section area along MCR South Jetty during forecast period. Composite 3 Small Rehab - Immediate.RED line marks time of REHAB phase implementation

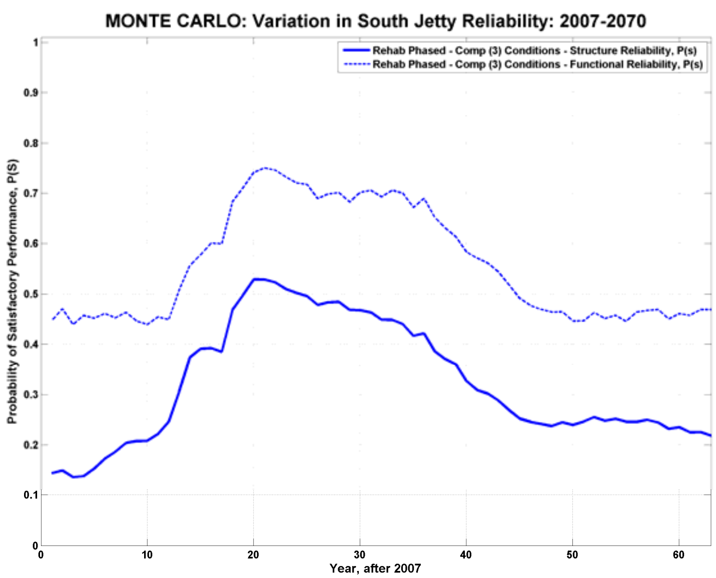

Figure A2-105c. Forecast reliability for MCR South Jetty. Composite 3 Small Rehab - Immediate.

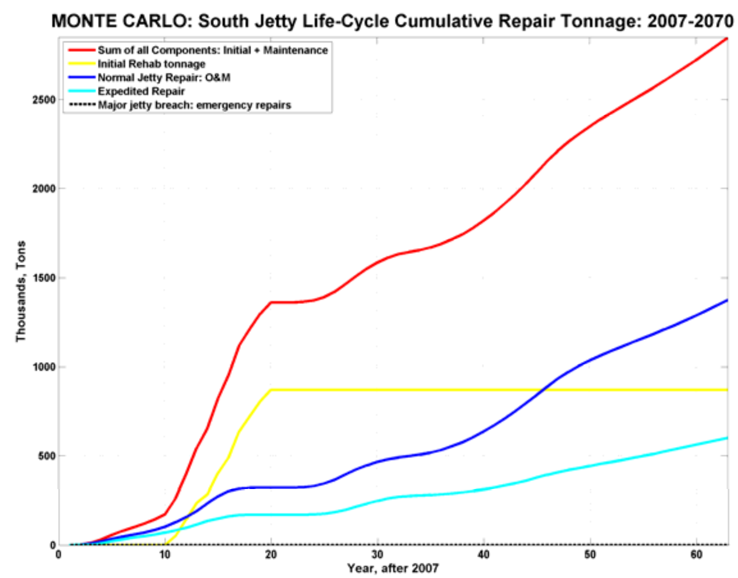

Figure A2-105d. Life-cycle cumulative repair tonnage for MCR South Jetty. Composite 3 Small Rehab - Immediate.

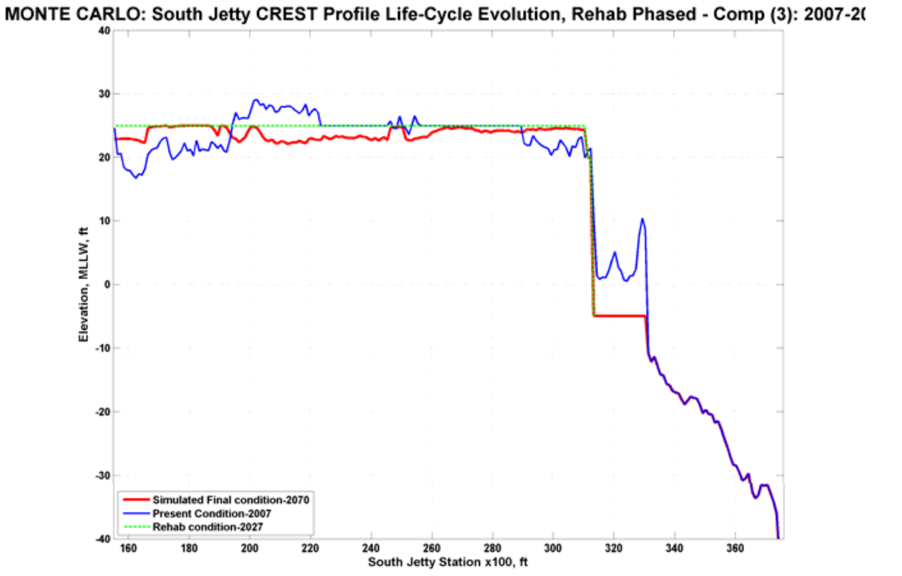

Figure A2-105e. Centerline profile for MCR South Jetty. Composite 3 Small Rehab - Immediate.

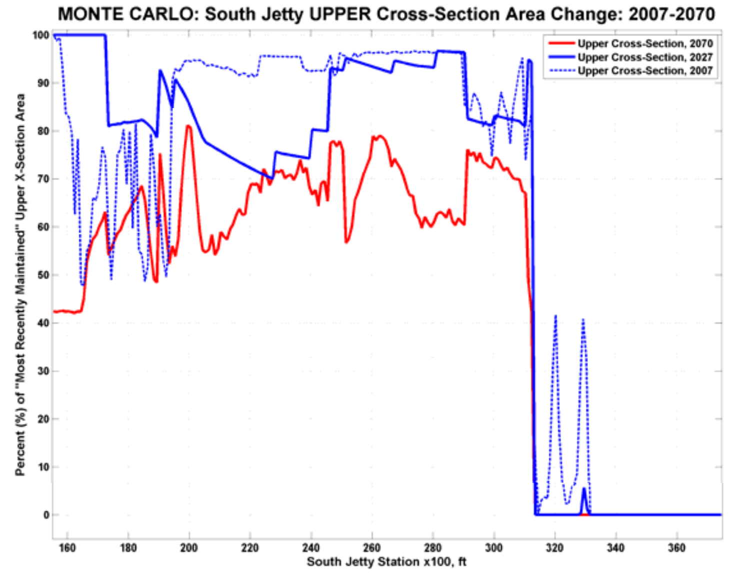

Figure A2-105f. Variation of upper cross-section area for given station of MCR South Jetty. Composite 3 Small Rehab - Immediate.

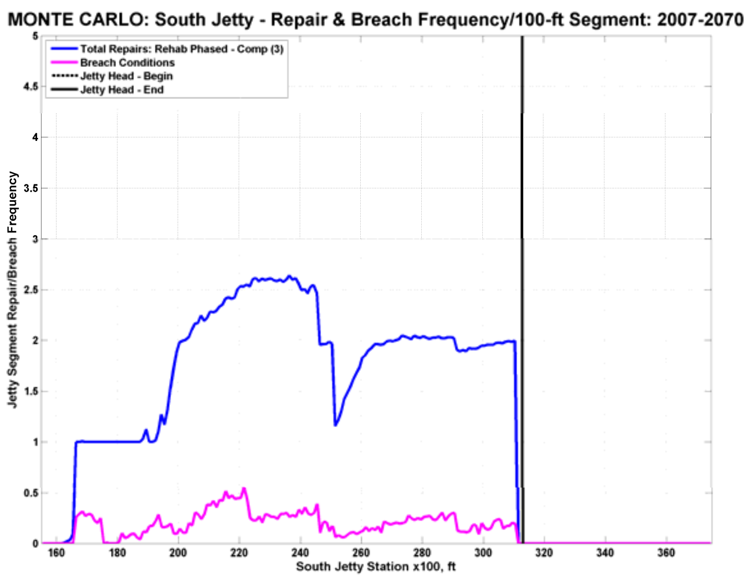

Figure A2-105g. Frequency and location of repairs and breaches for MCR South Jetty. Composite 3 Small Rehab - Immediate.

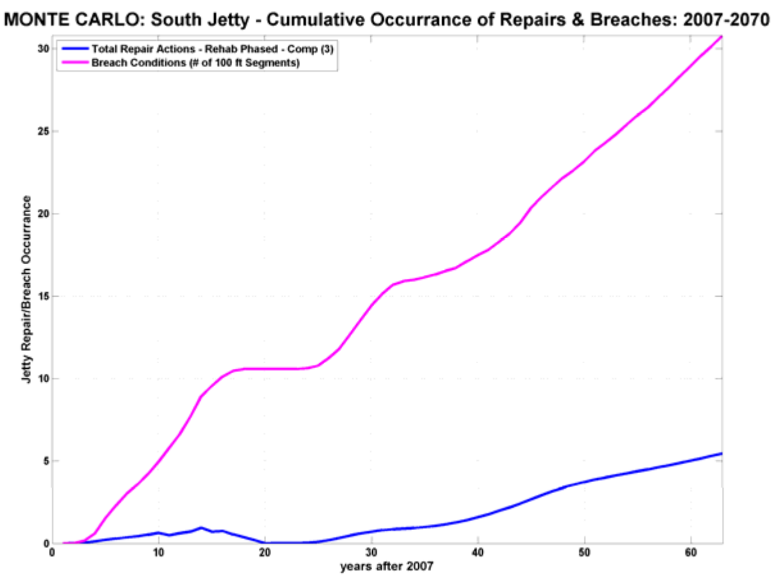

Figure A2-105h. Cumulative occurrence of repairs and breach conditions for MCR South Jetty. Composite 3 Small Rehab - Immediate.

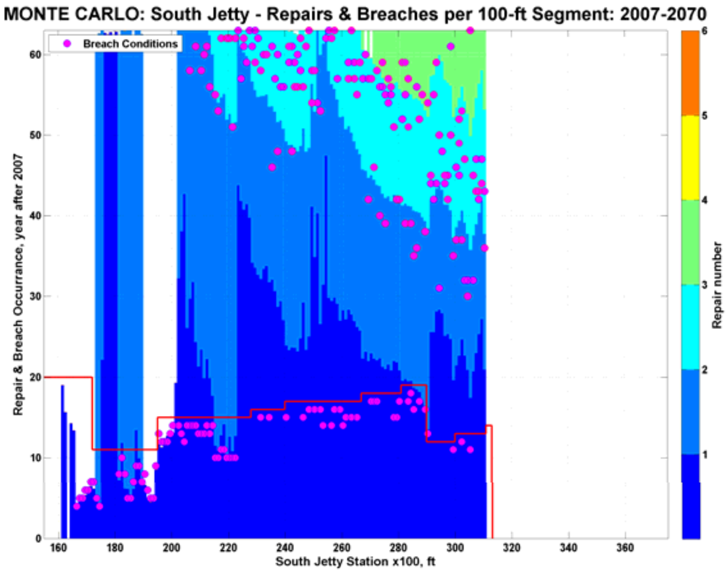

Figure A2-106a. Forecast repair occurrence for MCR South Jetty, shown for each 100 ft jetty segment. Small Template Rehab - Immediate. RED line marks time of REHAB phase implementation

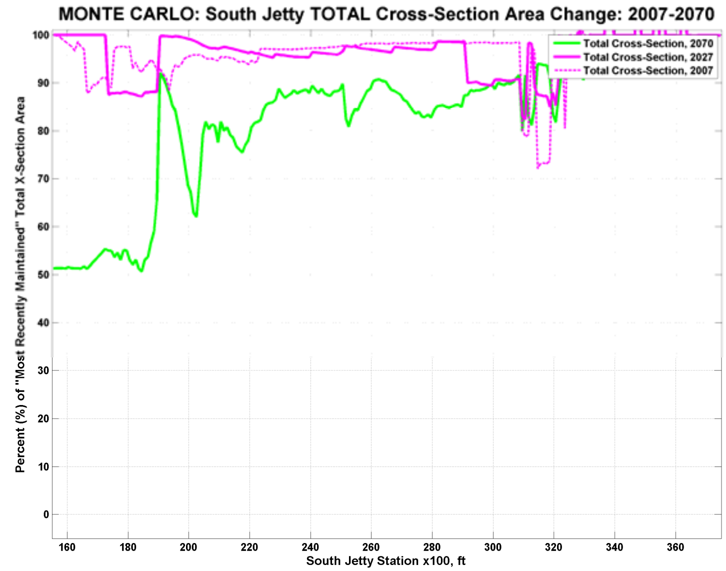

Figure A2-106b. Variation in total cross-section area along MCR South Jetty during forecast period. Small Template Rehab - Immediate.RED line marks time of REHAB phase implementation

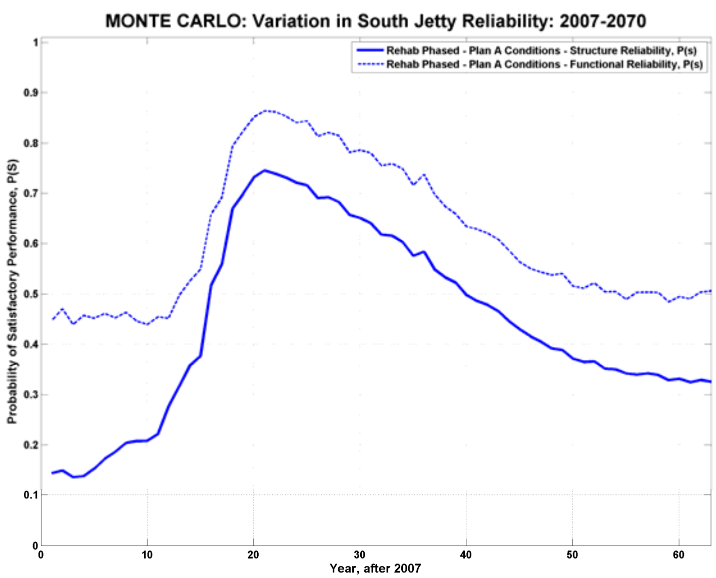

Figure A2-106c. Forecast reliability for MCR South Jetty. Small Template Rehab - Immediate.

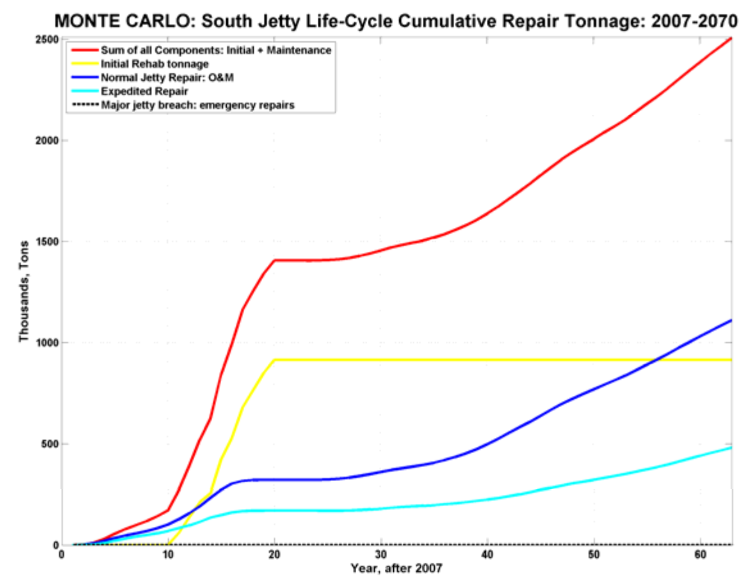

Figure A2-106d. Life-cycle cumulative repair tonnage for MCR South Jetty. Small Template Rehab - Immediate.

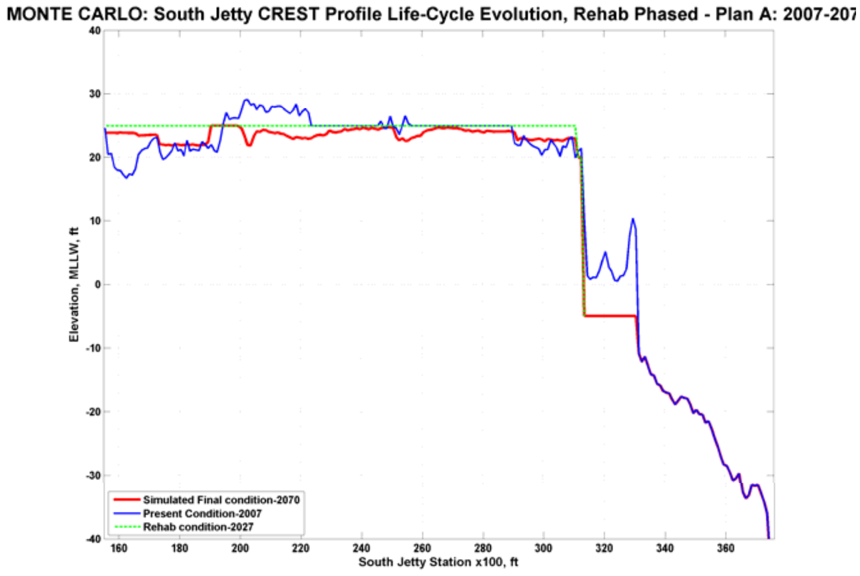

Figure A2-106e. Centerline profile for MCR South Jetty. Small Template Rehab - Immediate.

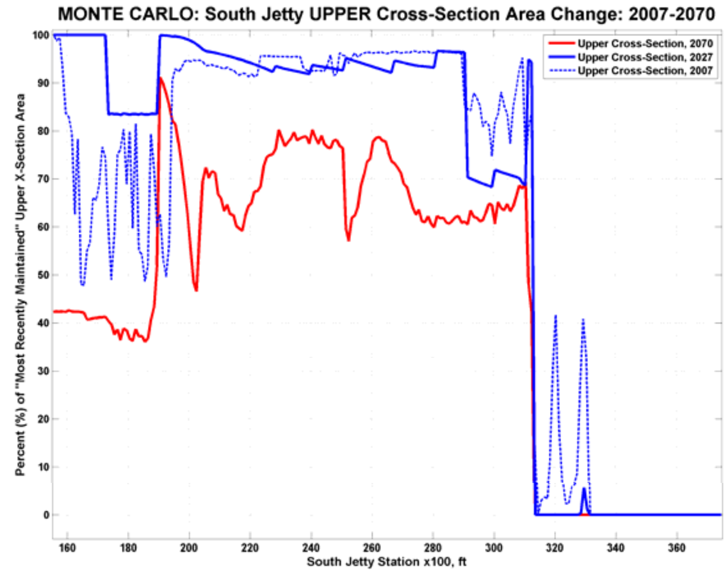

Figure A2-106f. Variation of upper cross-section area for given station of MCR South Jetty. Small Template Rehab - Immediate.

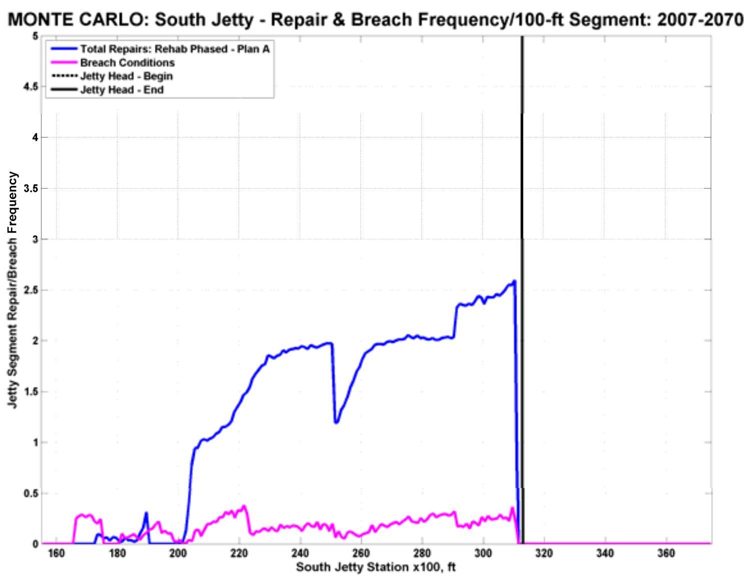

Figure A2-106g. Frequency and location of repairs and breaches for MCR South Jetty. Small Template Rehab - Immediate.

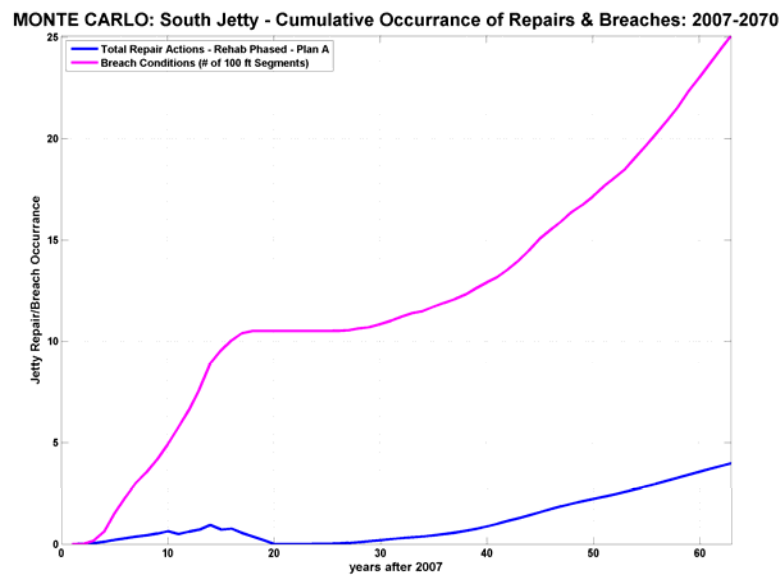

Figure A2-106h. Cumulative occurrence of repairs and breach conditions for MCR South Jetty. Small Template Rehab - Immediate.

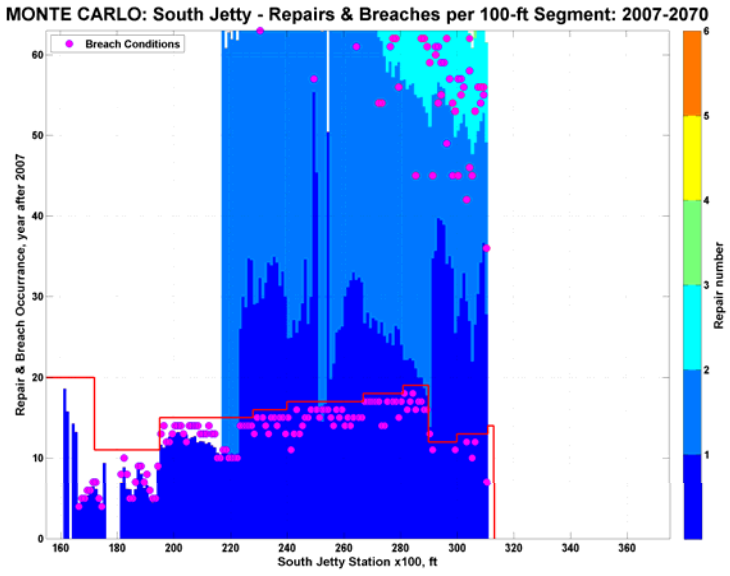

Figure A2-107a. Forecast repair occurrence for MCR South Jetty, shown for each 100 ft jetty segment. Moderate Template Rehab - Immediate. RED line marks time of REHAB phase implementation

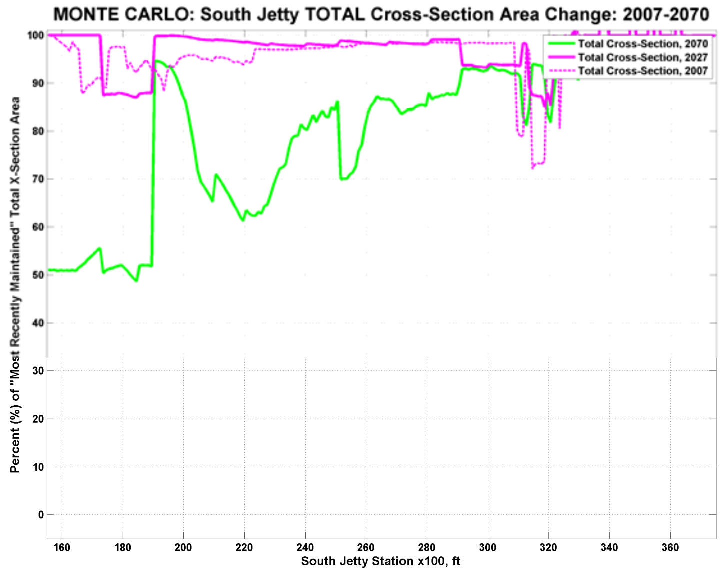

Figure A2-107b. Variation in total cross-section area along MCR South Jetty during forecast period. Moderate Template Rehab - Immediate.RED line marks time of REHAB phase implementation

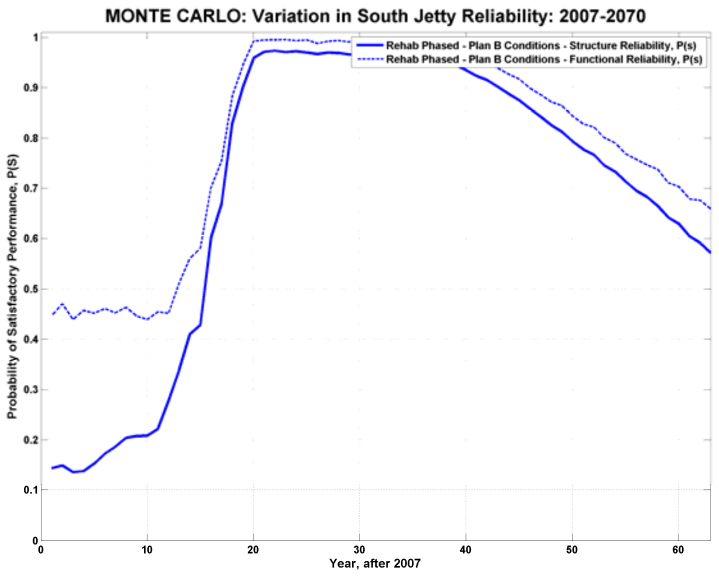

Figure A2-107c. Forecast reliability for MCR South Jetty. Moderate Template Rehab - Immediate.

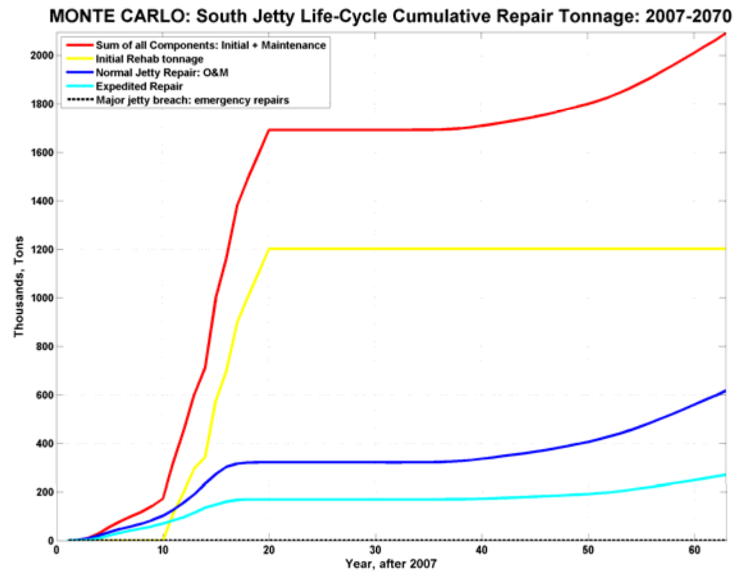

Figure A2-107d. Life-cycle cumulative repair tonnage for MCR South Jetty. Moderate Template Rehab - Immediate.

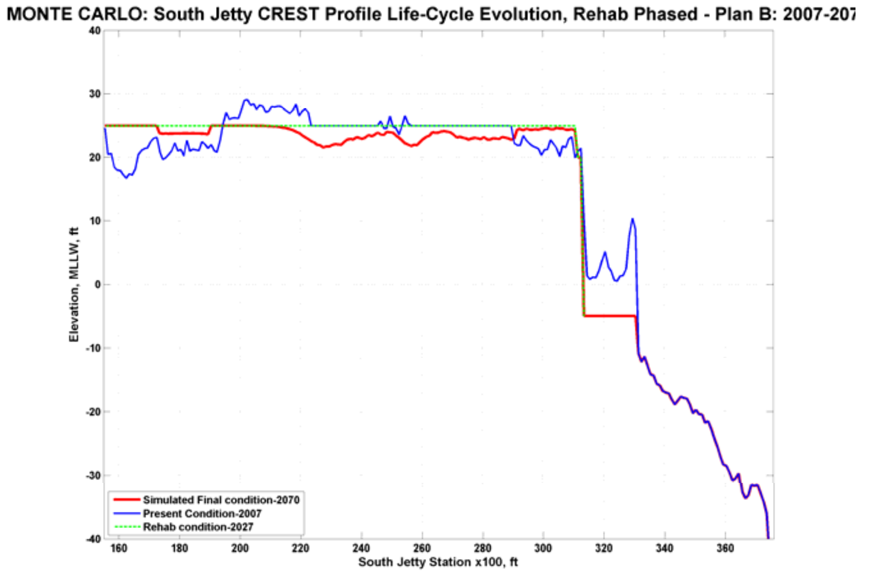

Figure A2-107e. Centerline profile for MCR South Jetty. Moderate Template Rehab - Immediate.

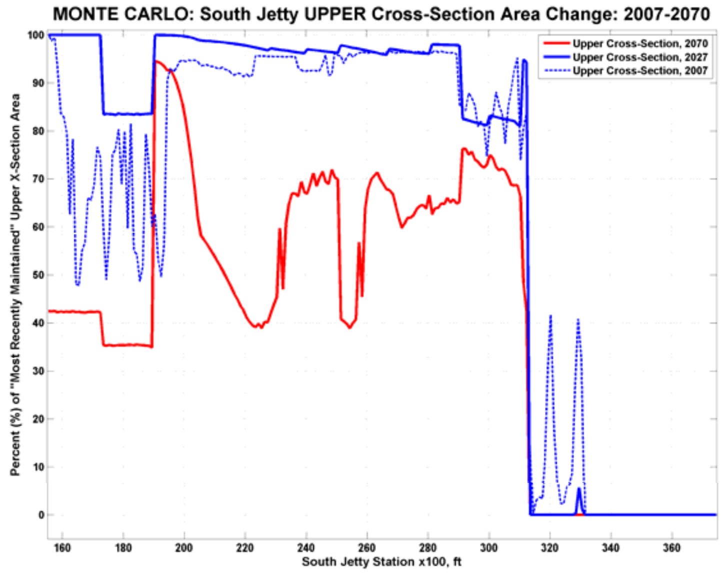

Figure A2-107f. Variation of upper cross-section area for given station of MCR South Jetty. Moderate Template Rehab - Immediate.

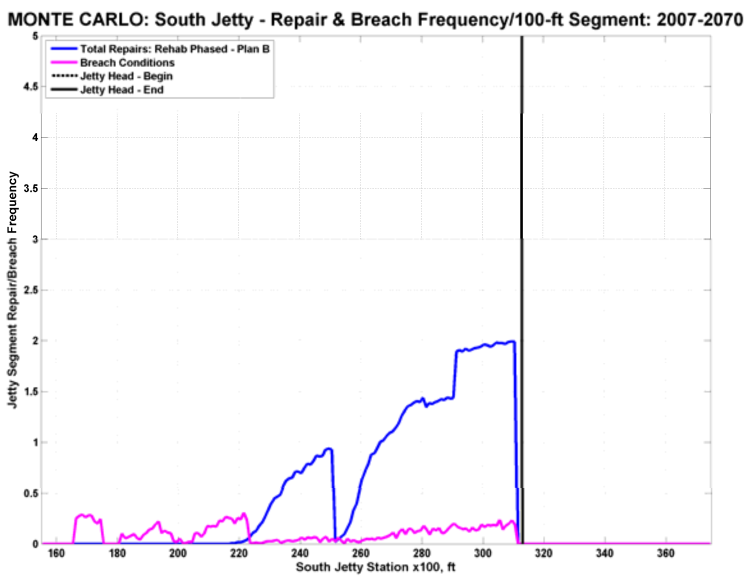

Figure A2-107g. Frequency and location of repairs and breaches for MCR South Jetty. Moderate Template Rehab - Immediate.

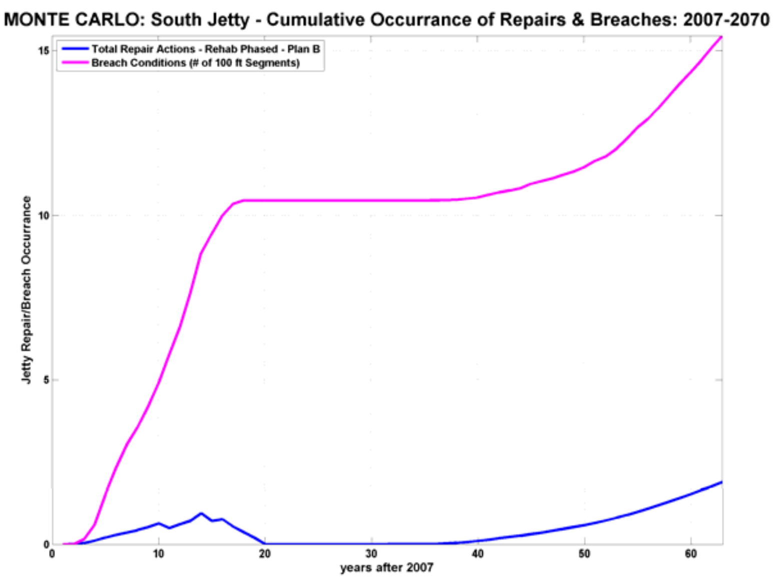

Figure A2-107h. Cumulative occurrence of repairs and breach conditions for MCR South Jetty. Moderate Template Rehab - Immediate.

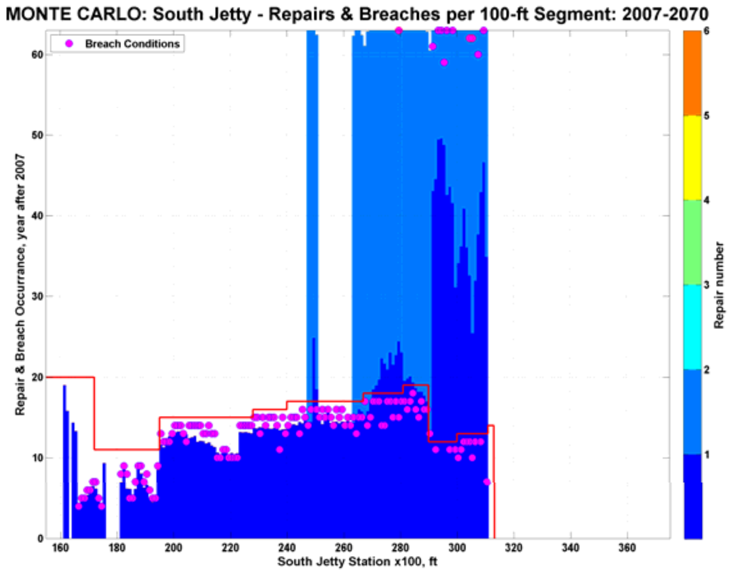

Figure A2-108a. Forecast repair occurrence for MCR South Jetty, shown for each 100 ft jetty segment. Large Template Rehab - Immediate. RED line marks time of REHAB phase implementation

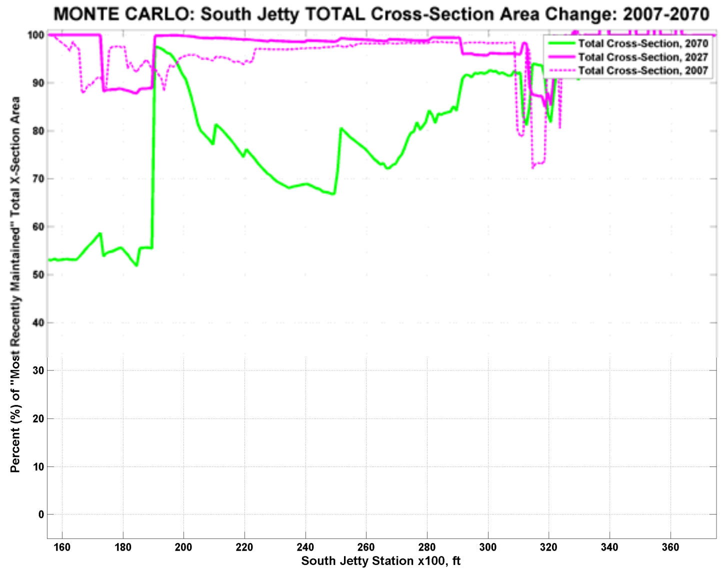

Figure A2-108b. Variation in total cross-section area along MCR South Jetty during forecast period. Large Template Rehab - Immediate.RED line marks time of REHAB phase implementation

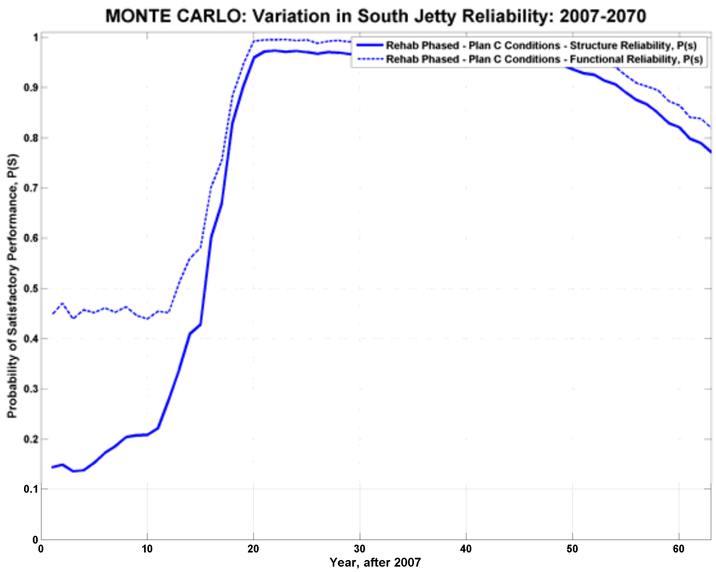

Figure A2-108c. Forecast reliability for MCR South Jetty. Large Template Rehab - Immediate.

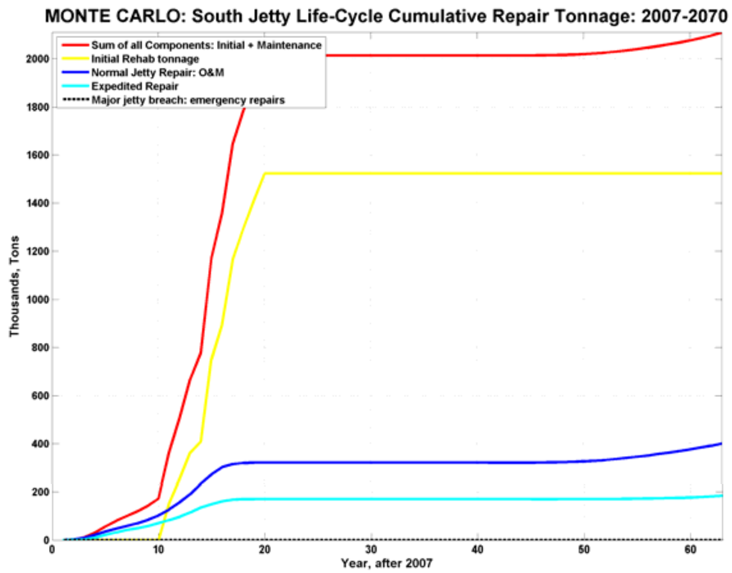

Figure A2-108d. Life-cycle cumulative repair tonnage for MCR South Jetty. Large Template Rehab - Immediate.

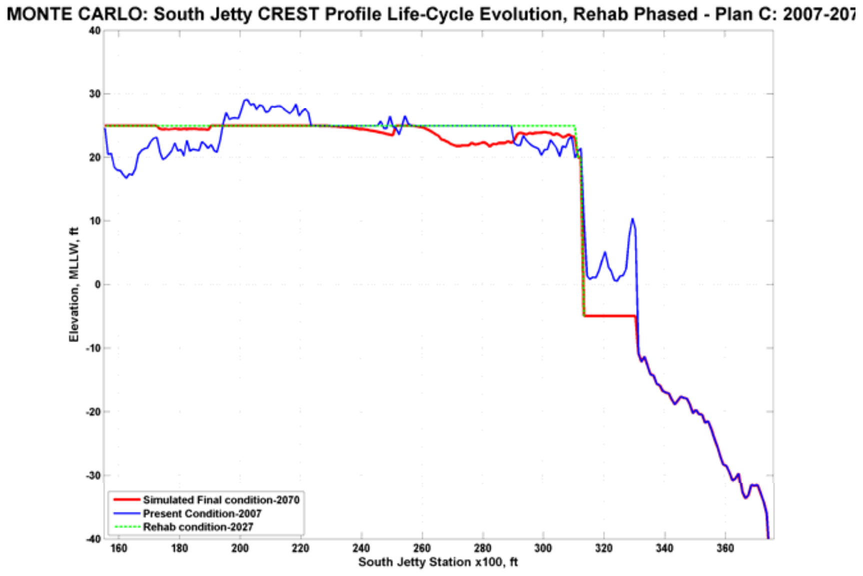

Figure A2-108e. Centerline profile for MCR South Jetty. Large Template Rehab - Immediate.

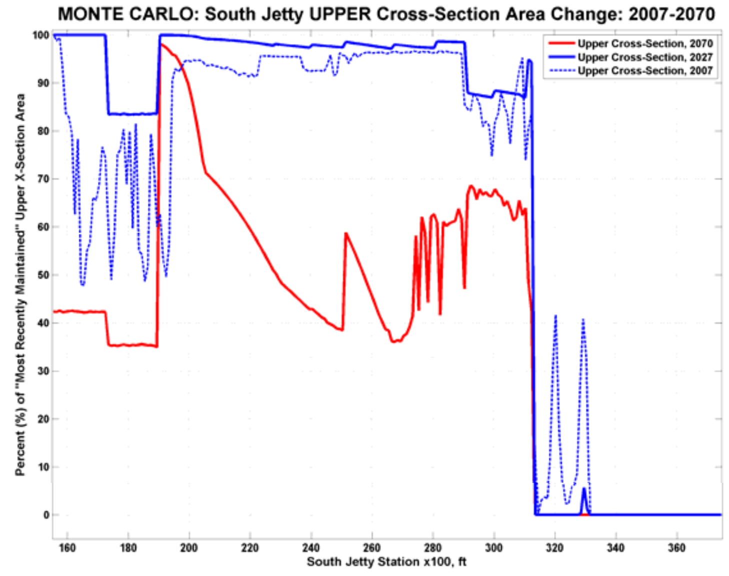

Figure A2-108f. Variation of upper cross-section area for given station of MCR South Jetty. Large Template Rehab - Immediate.

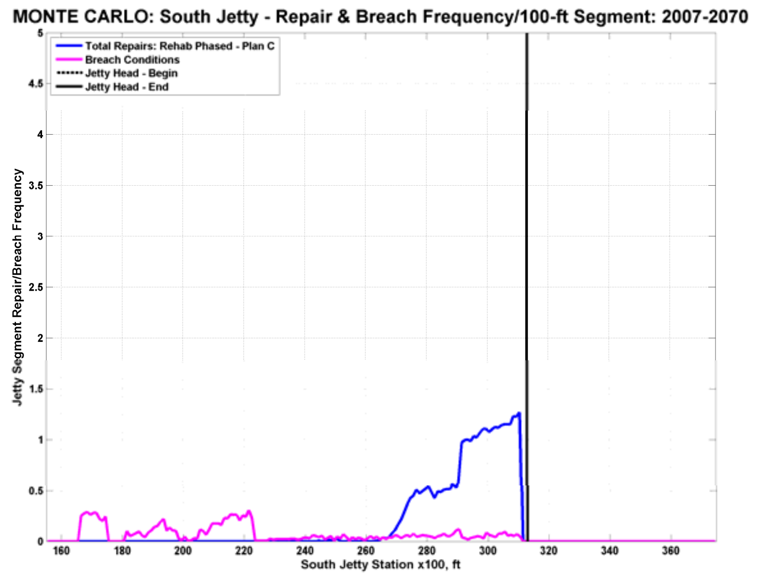

Figure A2-108g. Frequency and location of repairs and breaches for MCR South Jetty. Large Template Rehab - Immediate.

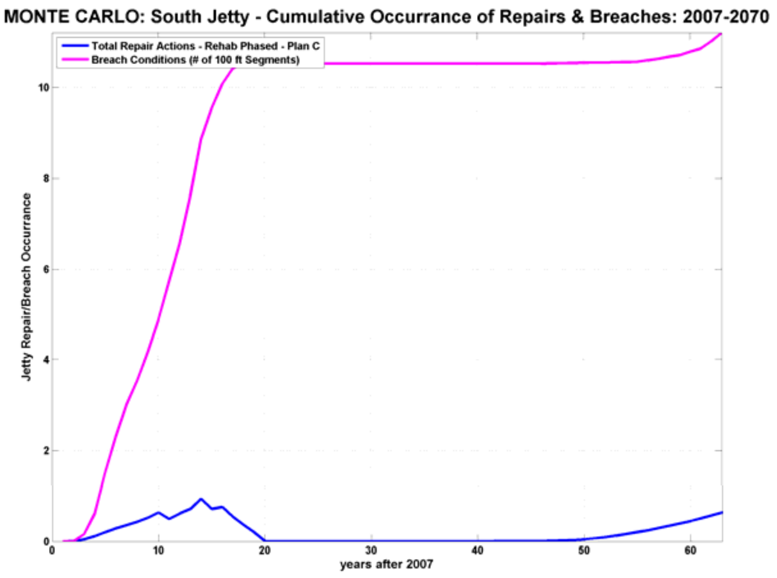

Figure A2-108h. Cumulative occurrence of repairs and breach conditions for MCR South Jetty. Large Template Rehab - Immediate.

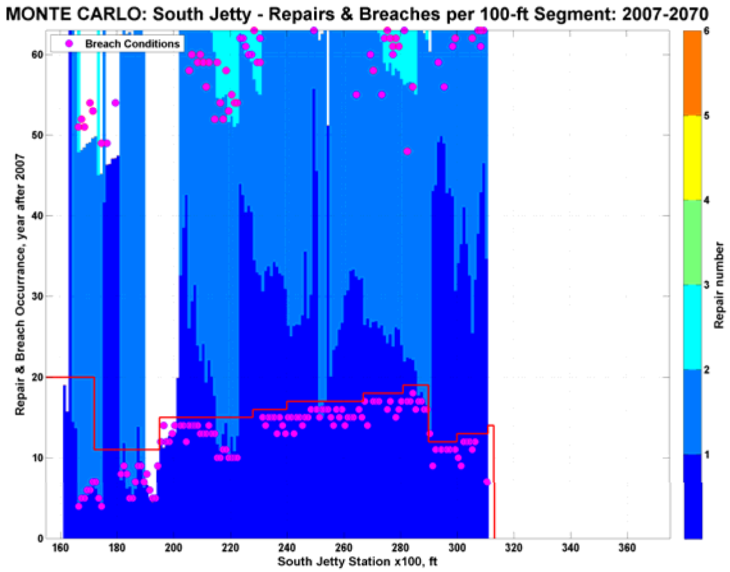

Figure A2-109a. Forecast repair occurrence for MCR South Jetty, shown for each 100 ft jetty segment. Composite 4 Medium Rehab - Immediate. RED line marks time of REHAB phase implementation

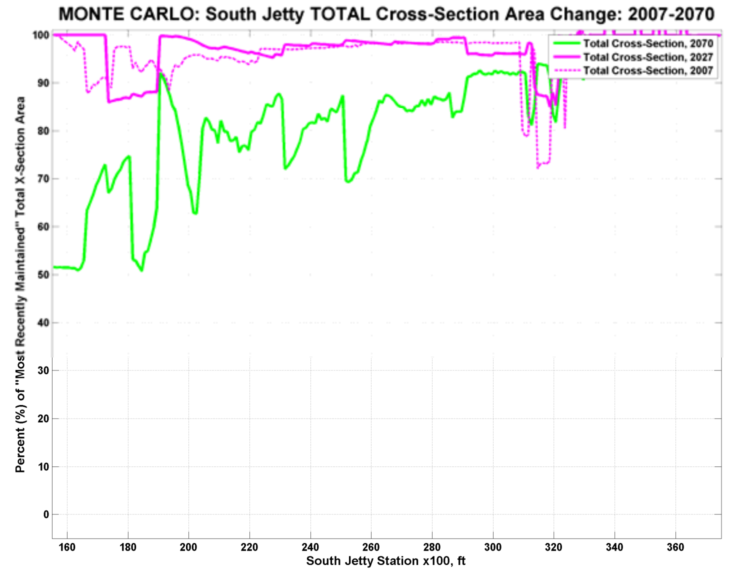

Figure A2-109b. Variation in total cross-section area along MCR South Jetty during forecast period. Composite 4 Medium Rehab - Immediate.RED line marks time of REHAB phase implementation

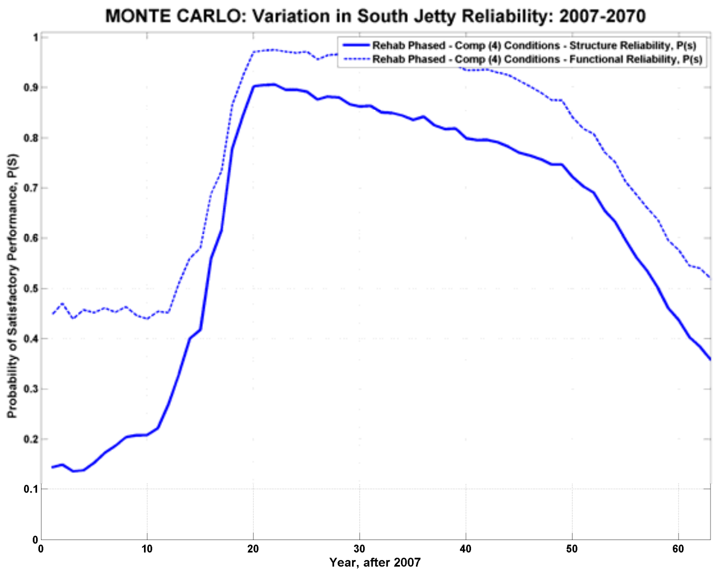

Figure A2-109c. Forecast reliability for MCR South Jetty. Composite 4 Medium Rehab - Immediate.

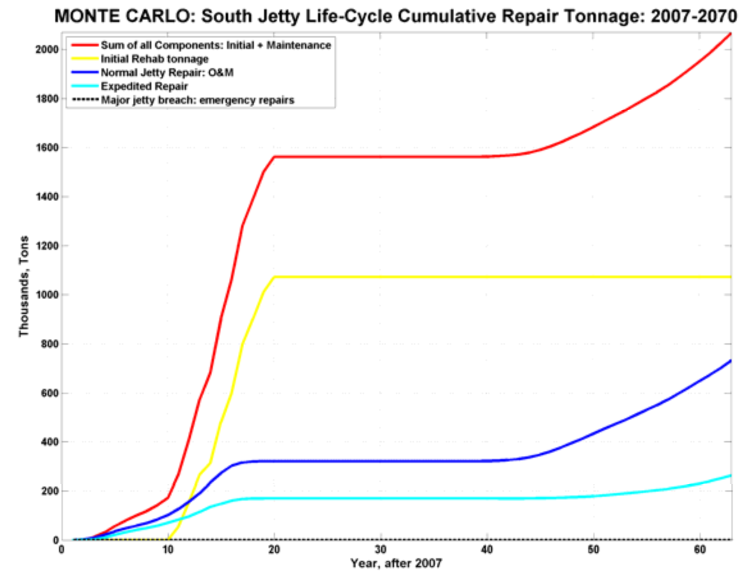

Figure A2-109d. Life-cycle cumulative repair tonnage for MCR South Jetty. Composite 4 Medium Rehab - Immediate.

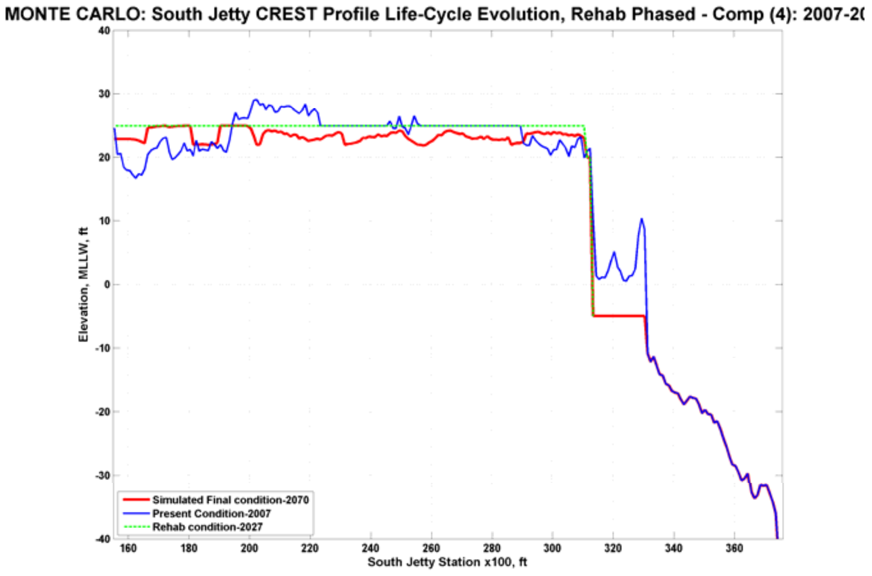

Figure A2-109e. Centerline profile for MCR South Jetty. Composite 4 Medium Rehab - Immediate.

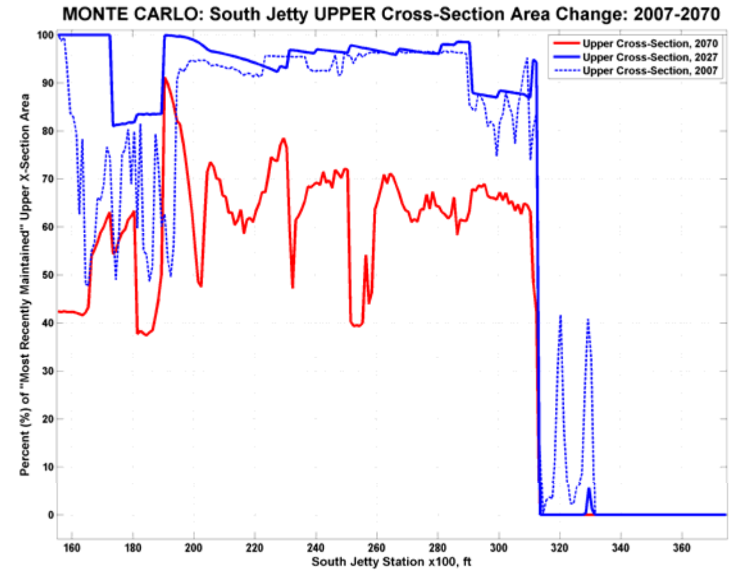

Figure A2-109f. Variation of upper cross-section area for given station of MCR South Jetty. Composite 4 Medium Rehab - Immediate.

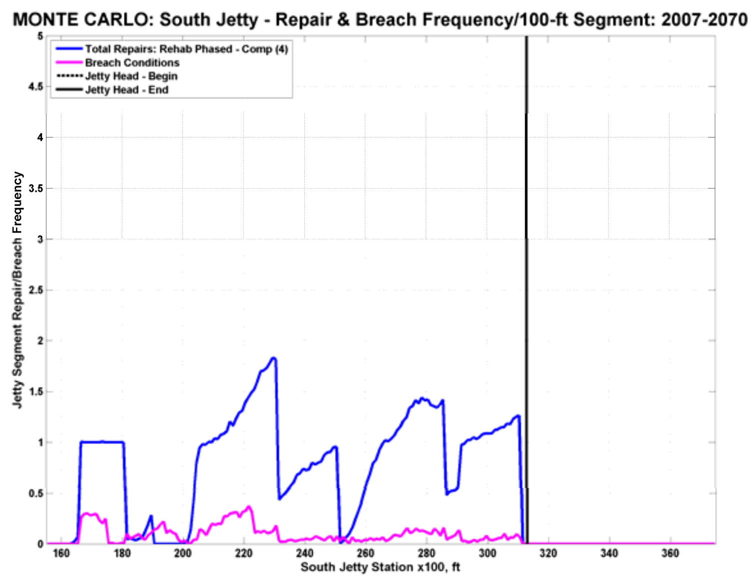

Figure A2-109g. Frequency and location of repairs and breaches for MCR South Jetty. Composite 4 Medium Rehab - Immediate.

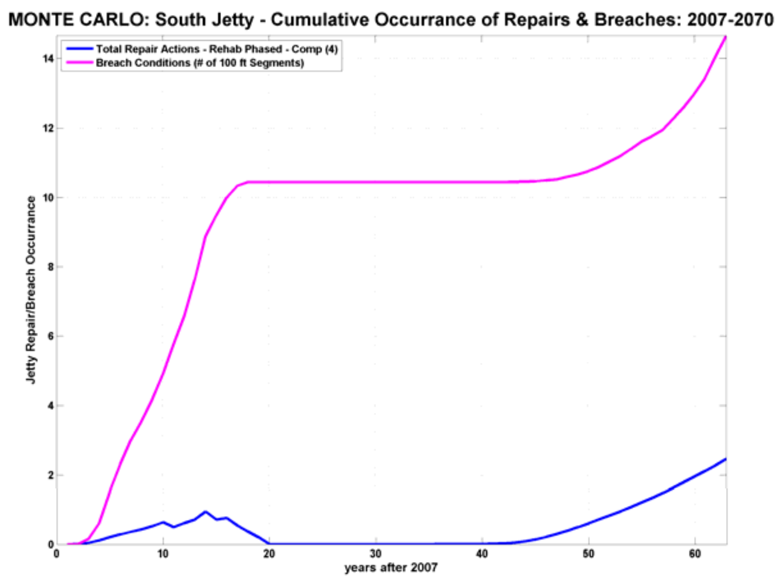

Figure A2-109h. Cumulative occurrence of repairs and breach conditions for MCR South Jetty. Composite 4 Medium Rehab - Immediate.

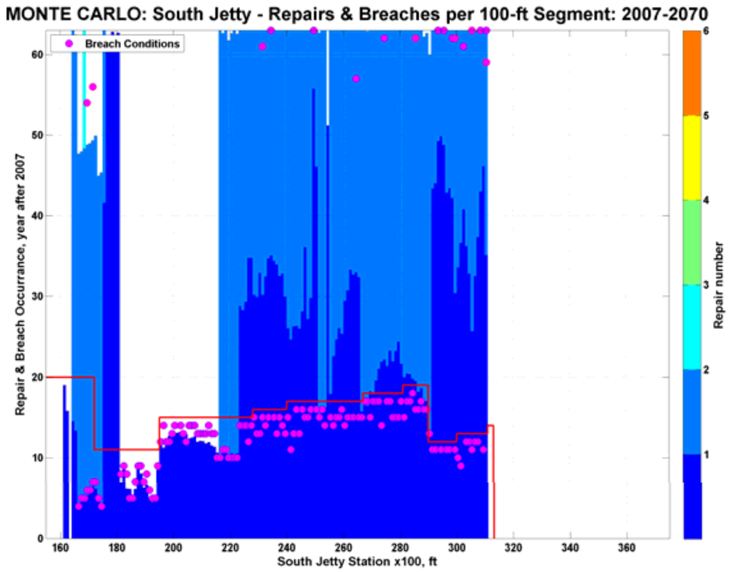

Figure A2-110a. Forecast repair occurrence for MCR South Jetty, shown for each 100 ft jetty segment. Composite 1 Large Rehab - Immediate. RED line marks time of REHAB phase implementation

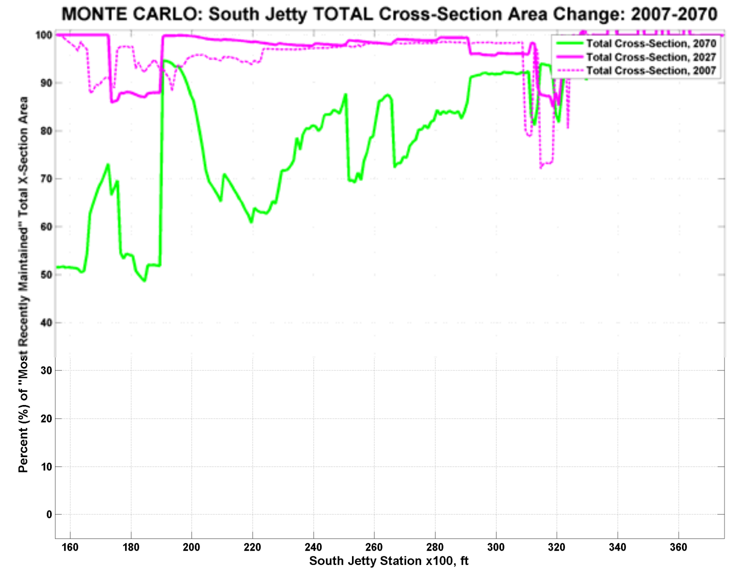

Figure A2-110b. Variation in total cross-section area along MCR South Jetty during forecast period. Composite 1 Large Rehab - Immediate.RED line marks time of REHAB phase implementation

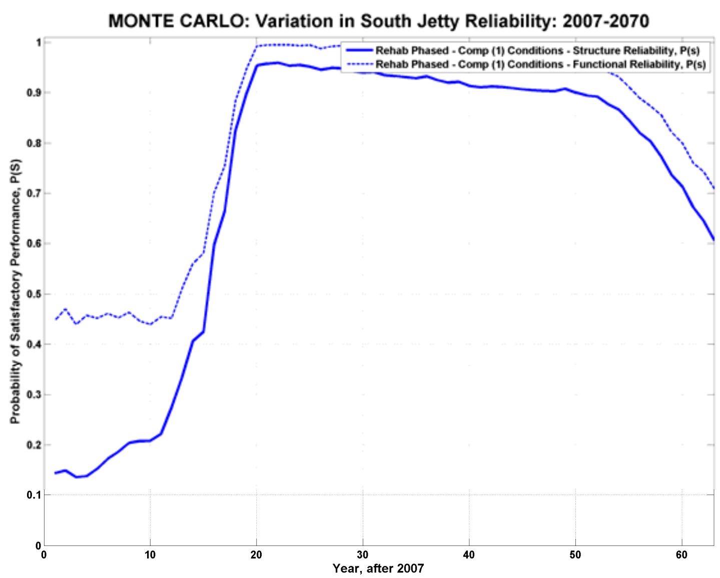

Figure A2-110c. Forecast reliability for MCR South Jetty. Composite 1 Large Rehab - Immediate.

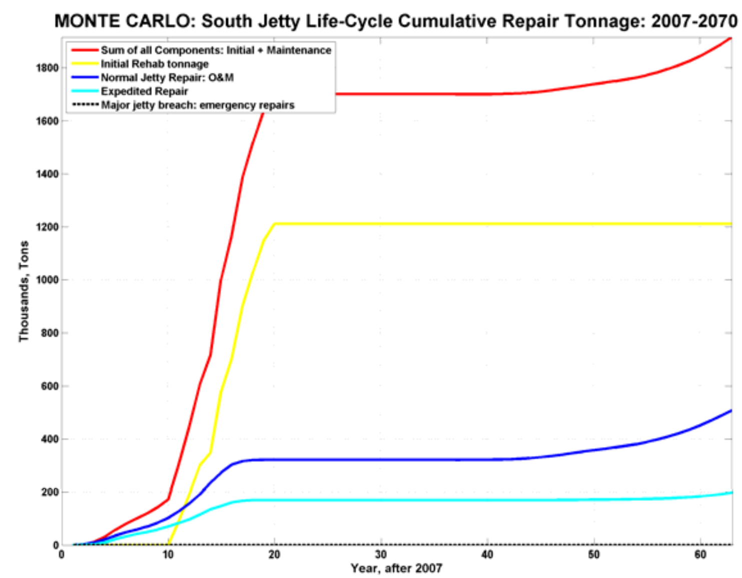

Figure A2-110d. Life-cycle cumulative repair tonnage for MCR South Jetty. Composite 1 Large Rehab - Immediate.

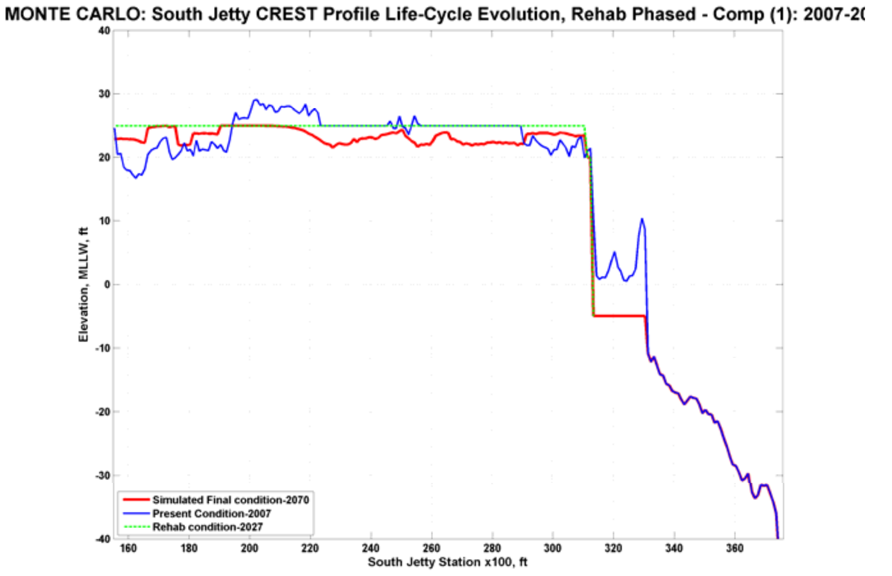

Figure A2-110e. Centerline profile for MCR South Jetty. Composite 1 Large Rehab - Immediate.

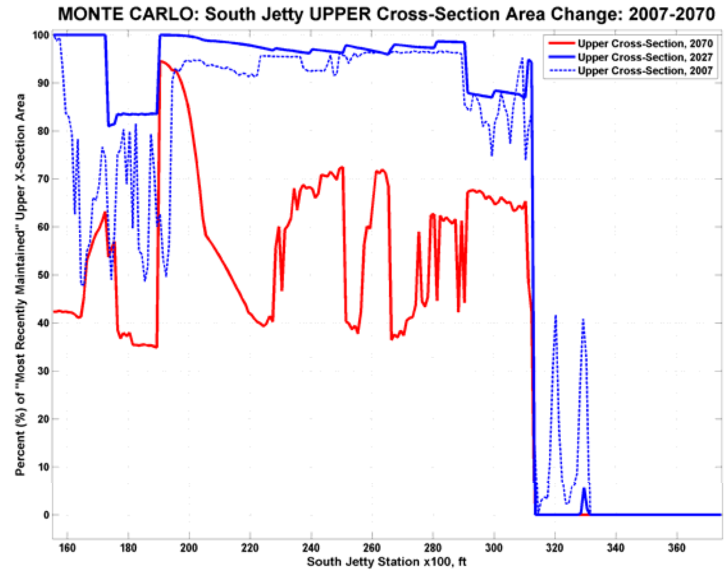

Figure A2-110f. Variation of upper cross-section area for given station of MCR South Jetty. Composite 1 Large Rehab - Immediate.

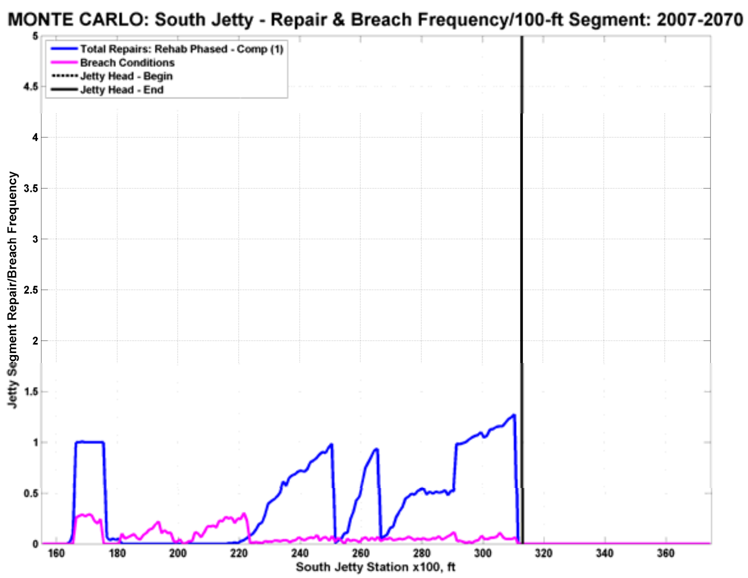

Figure A2-110g. Frequency and location of repairs and breaches for MCR South Jetty. Composite 1 Large Rehab - Immediate.

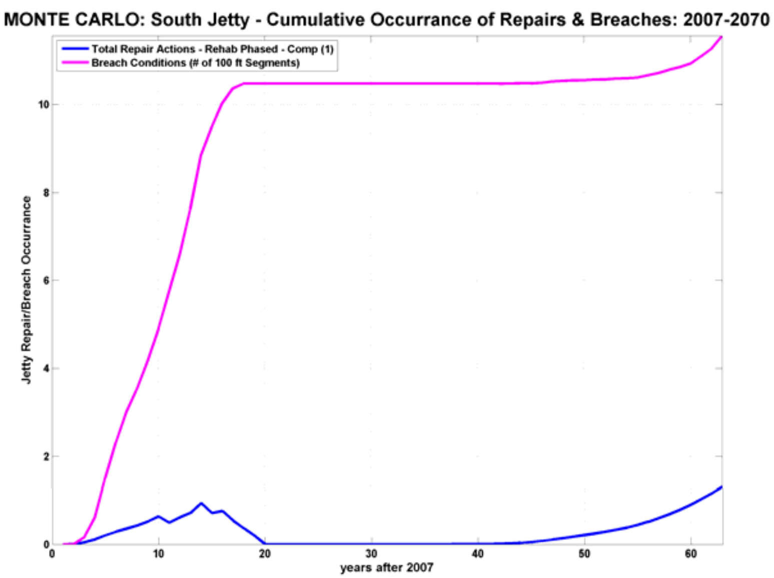

Figure A2-110h. Cumulative occurrence of repairs and breach conditions for MCR South Jetty. Composite 1 Large Rehab - Immediate.

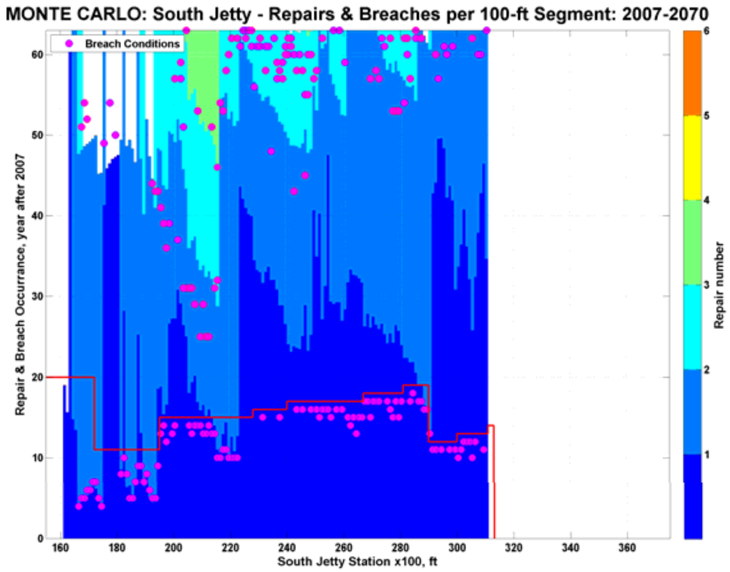

Figure A2-111a. Forecast repair occurrence for MCR South Jetty, shown for each 100 ft jetty segment. Composite 5 Modified 2 Rehab - Immediate. RED line marks time of REHAB phase implementation

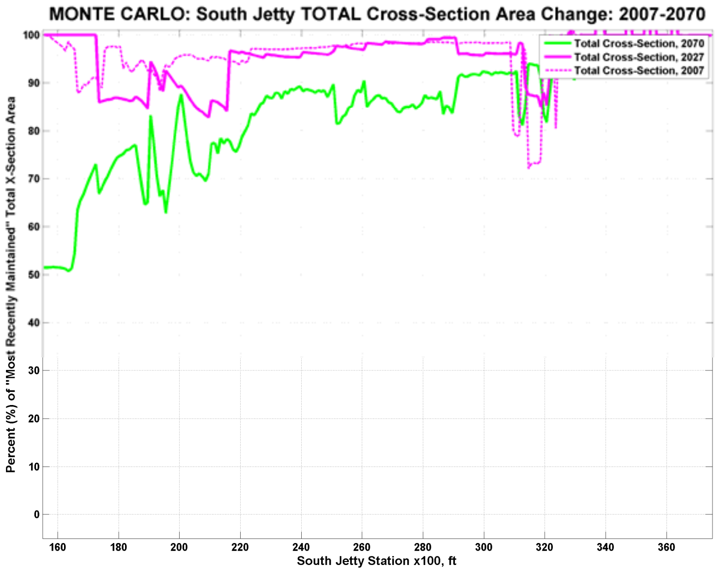

Figure A2-111b. Variation in total cross-section area along MCR South Jetty during forecast period. Composite 5 Modified 2 Rehab - Immediate.RED line marks time of REHAB phase implementation

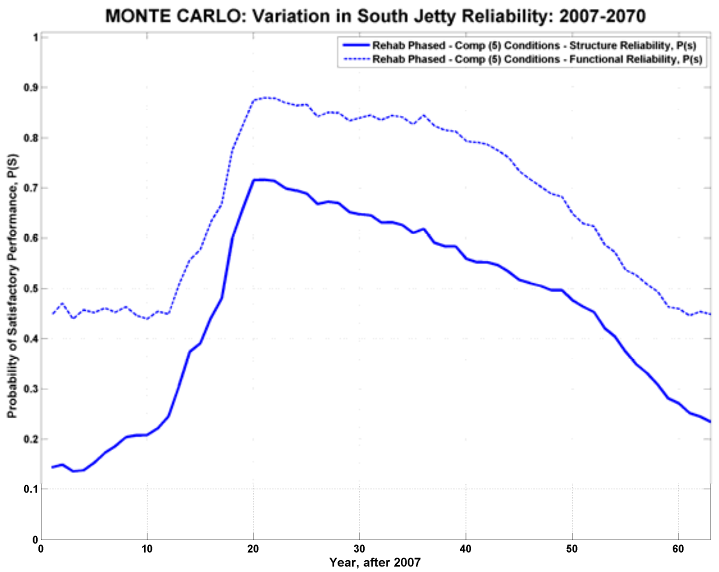

Figure A2-111c. Forecast reliability for MCR South Jetty. Composite 5 Modified 2 Rehab - Immediate.

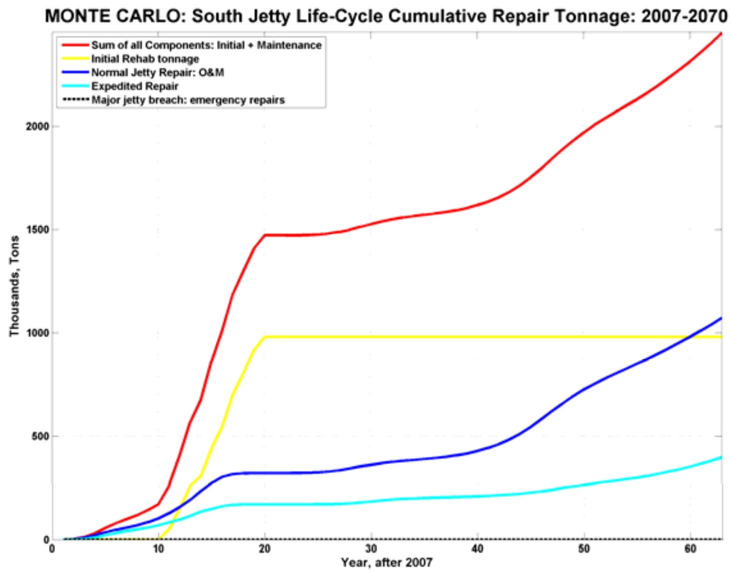

Figure A2-111d. Life-cycle cumulative repair tonnage for MCR South Jetty. Composite 5 Modified 2 Rehab - Immediate.

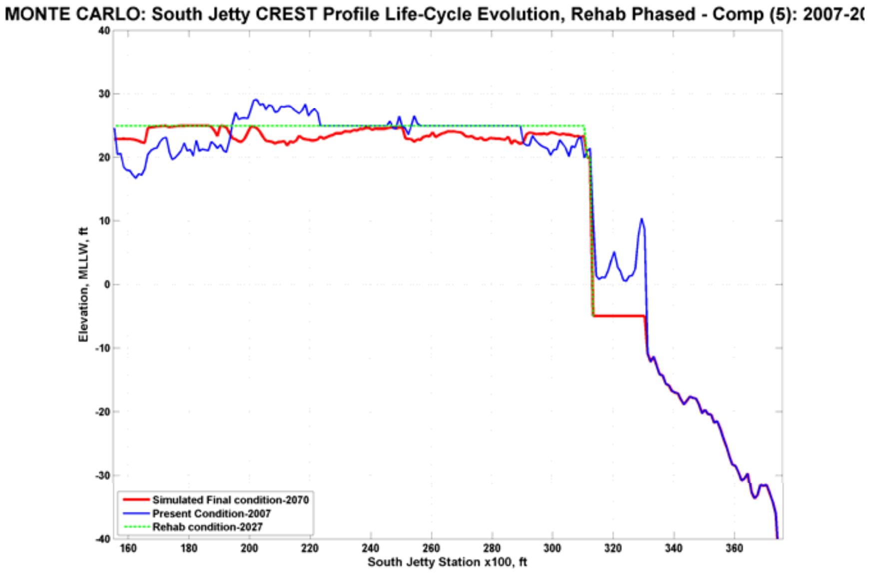

Figure A2-111e. Centerline profile for MCR South Jetty. Composite 5 Modified 2 Rehab - Immediate.

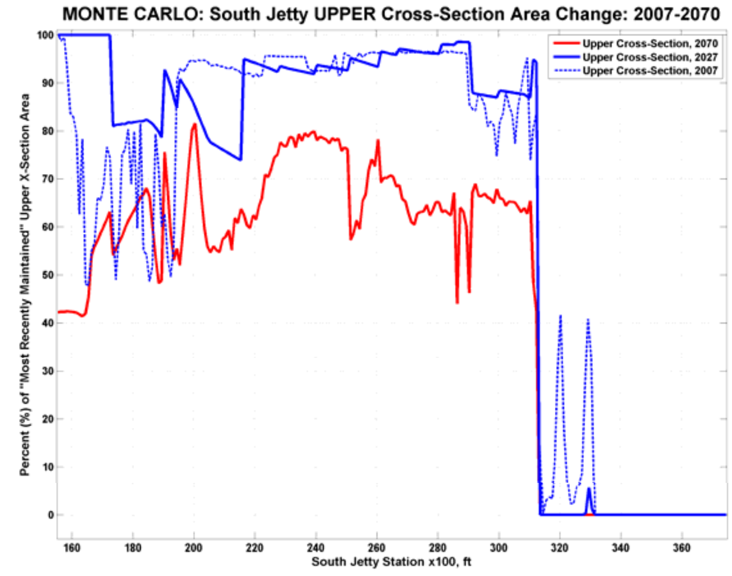

Figure A2-111f. Variation of upper cross-section area for given station of MCR South Jetty. Composite 5 Modified 2 Rehab - Immediate.

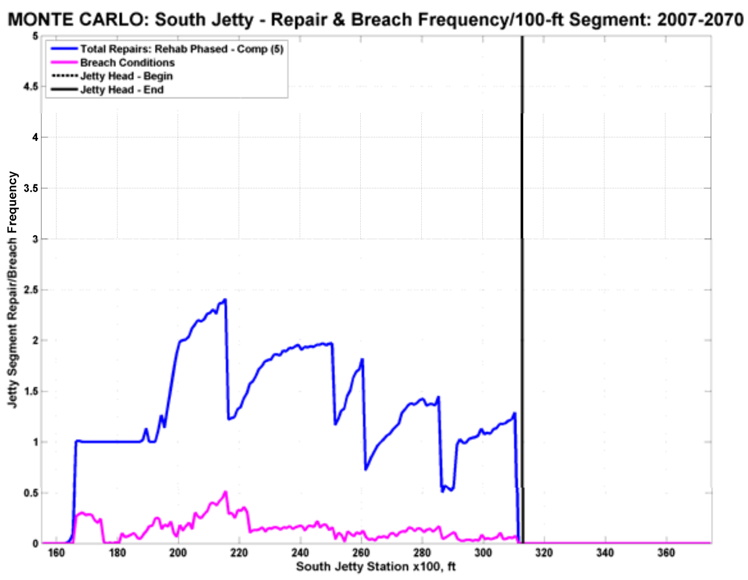

Figure A2-111g. Frequency and location of repairs and breaches for MCR South Jetty. Composite 5 Modified 2 Rehab - Immediate.

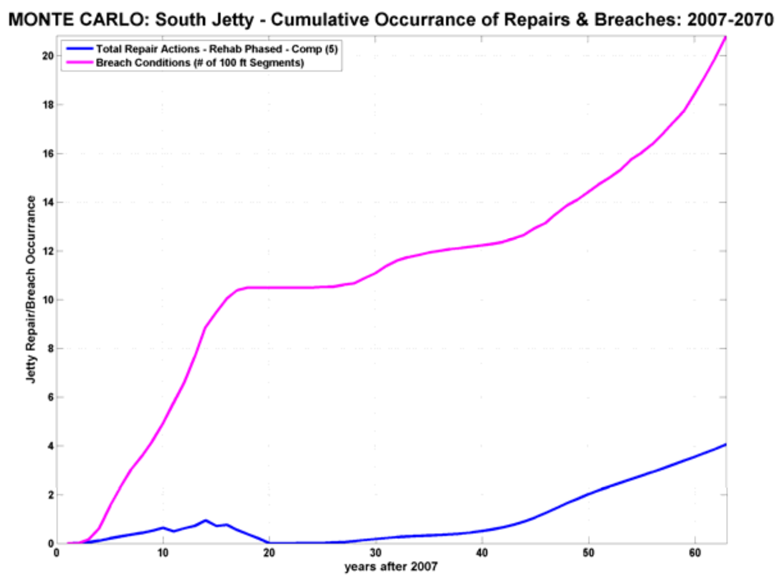

Figure A2-111h. Cumulative occurrence of repairs and breach conditions for MCR South Jetty. Composite 5 Modified 2 Rehab - Immediate.

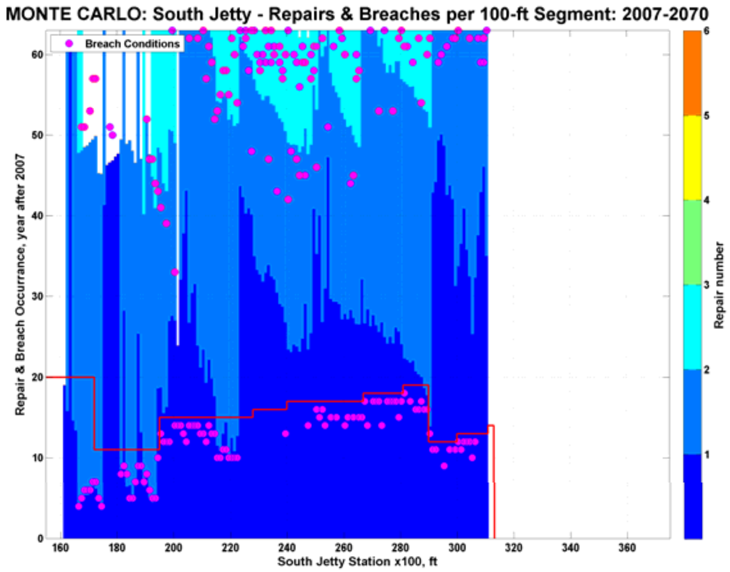

Figure A2-112a. Forecast repair occurrence for MCR South Jetty, shown for each 100 ft jetty segment. Composite 2 Modified 1 Rehab - Immediate. RED line marks time of REHAB phase implementation

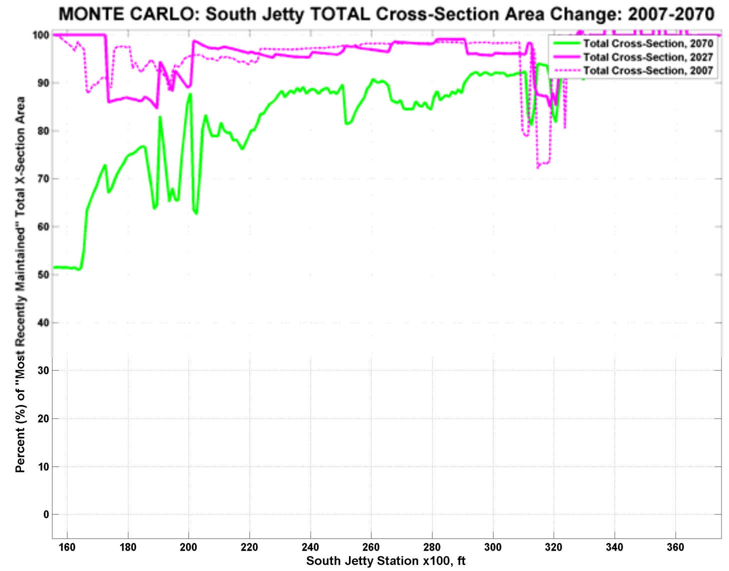

Figure A2-112b. Variation in total cross-section area along MCR South Jetty during forecast period. Composite 2 Modified 1 Rehab - Immediate.RED line marks time of REHAB phase implementation

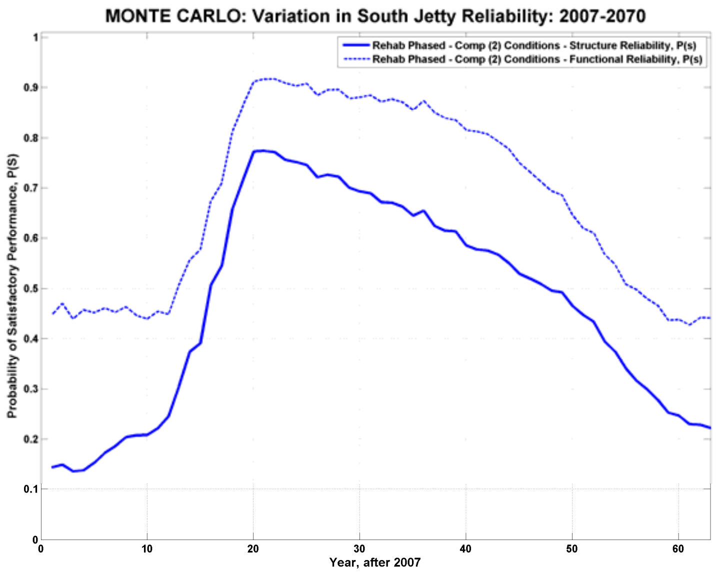

Figure A2-112c. Forecast reliability for MCR South Jetty. Composite 2 Modified 1 Rehab - Immediate.

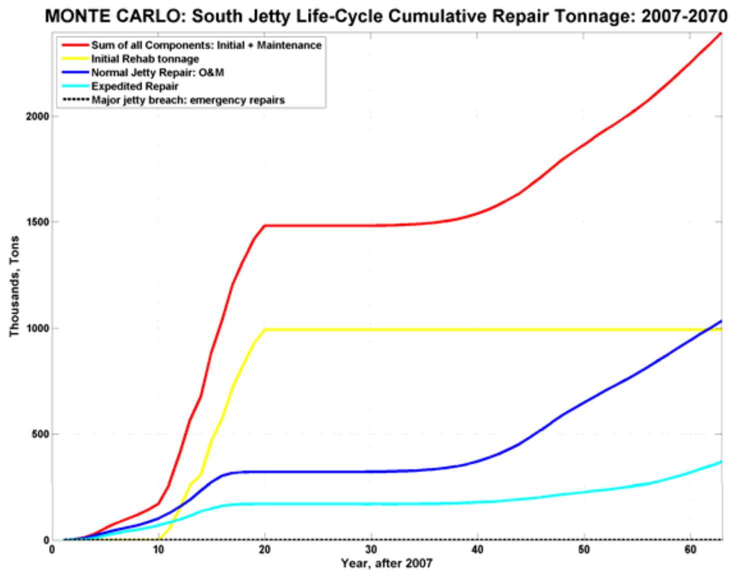

Figure A2-112d. Life-cycle cumulative repair tonnage for MCR South Jetty. Composite 2 Modified 1 Rehab - Immediate.

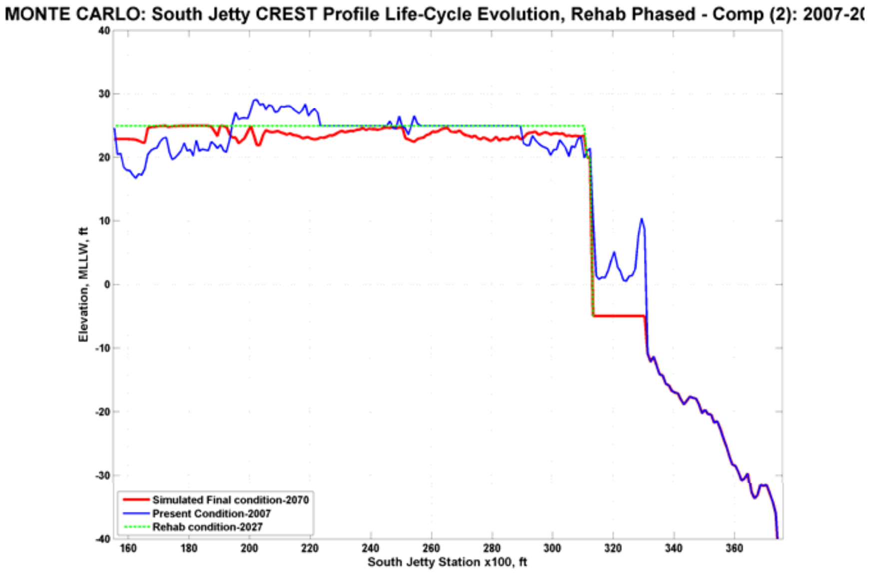

Figure A2-112e. Centerline profile for MCR South Jetty. Composite 2 Modified 1 Rehab - Immediate.

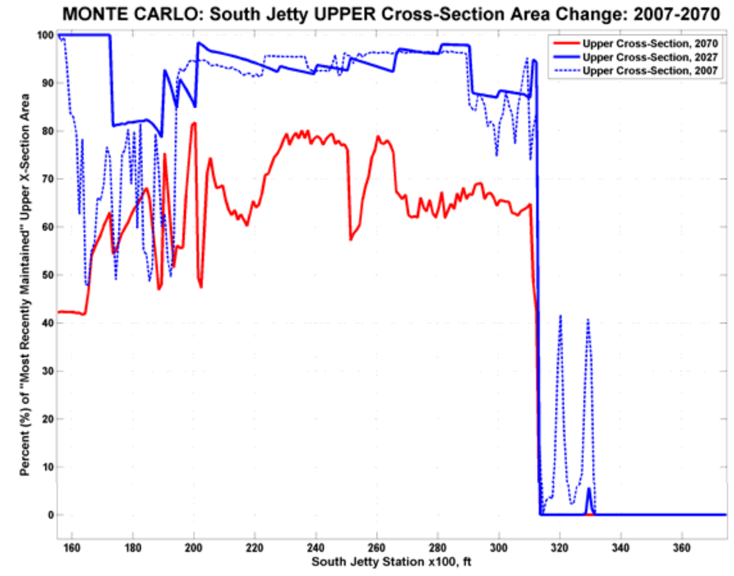

Figure A2-112f. Variation of upper cross-section area for given station of MCR South Jetty. Composite 2 Modified 1 Rehab - Immediate.

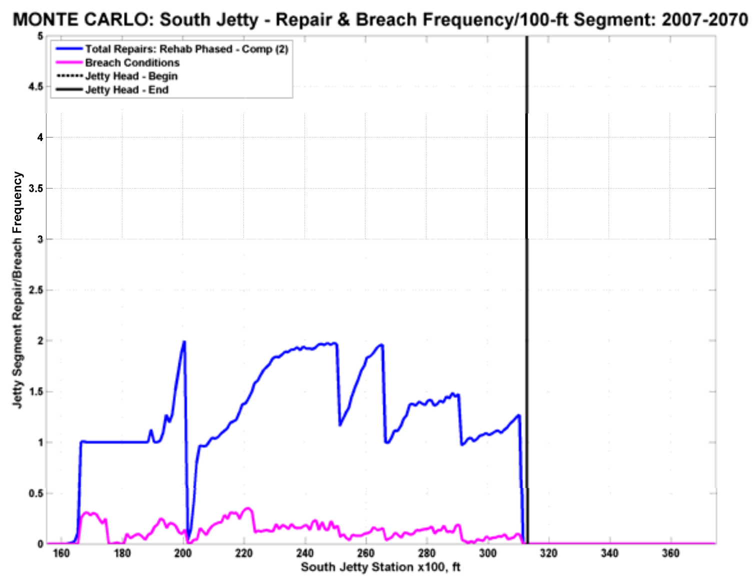

Figure A2-112g. Frequency and location of repairs and breaches for MCR South Jetty. Composite 2 Modified 1 Rehab - Immediate.

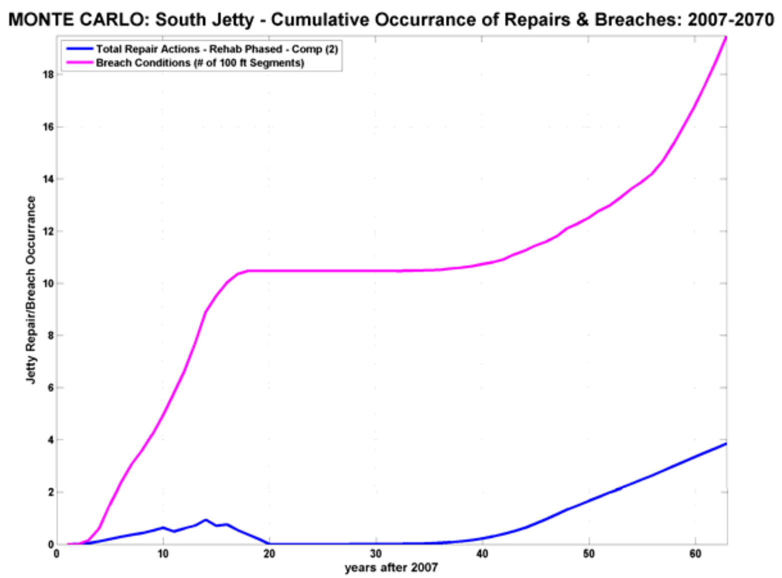

Figure A2-112h. Cumulative occurrence of repairs and breach conditions for MCR South Jetty. Composite 2 Modified 1 Rehab - Immediate.

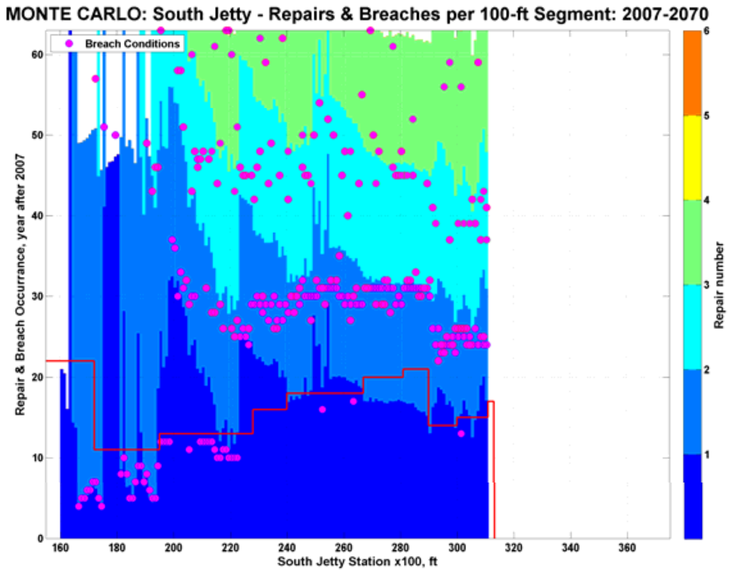

Figure A2-113a. Forecast repair occurrence for MCR South Jetty, shown for each 100 ft jetty segment. Minimum Template Rehab - Scheduled. RED line marks time of REHAB phase implementation

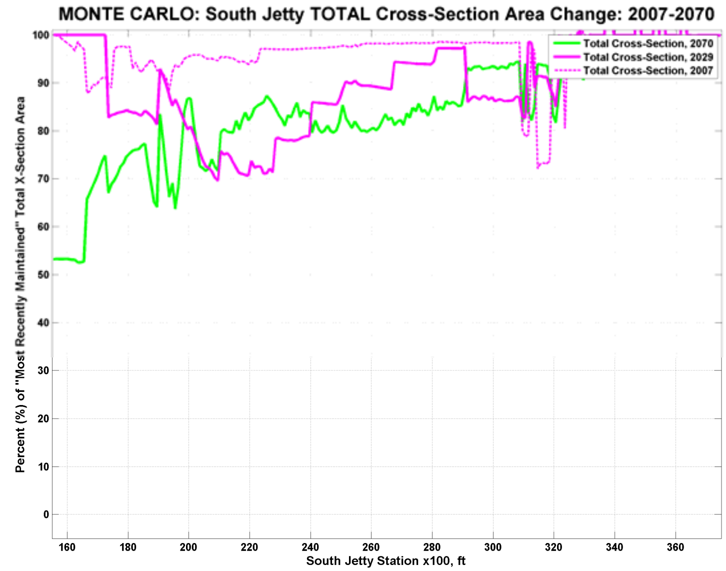

Figure A2-113b. Variation in total cross-section area along MCR South Jetty during forecast period. Minimum Template Rehab - Scheduled.RED line marks time of REHAB phase implementation

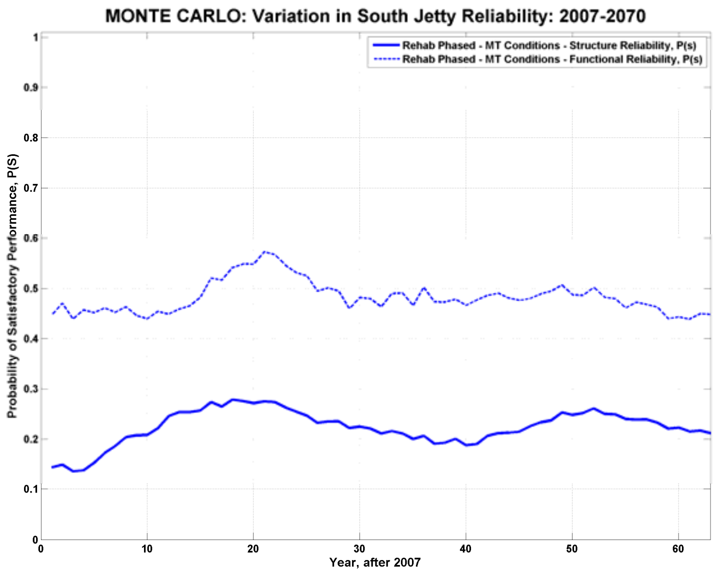

Figure A2-113c. Forecast reliability for MCR South Jetty. Minimum Template Rehab - Scheduled.

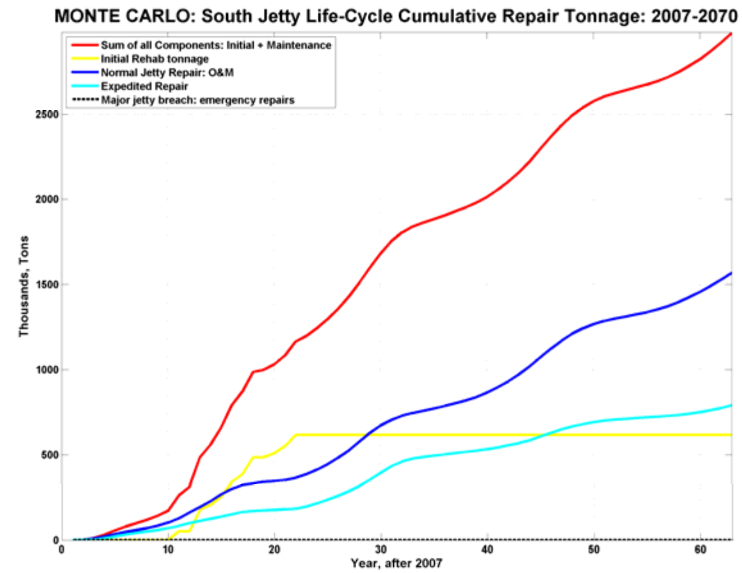

Figure A2-113d. Life-cycle cumulative repair tonnage for MCR South Jetty. Minimum Template Rehab - Scheduled.

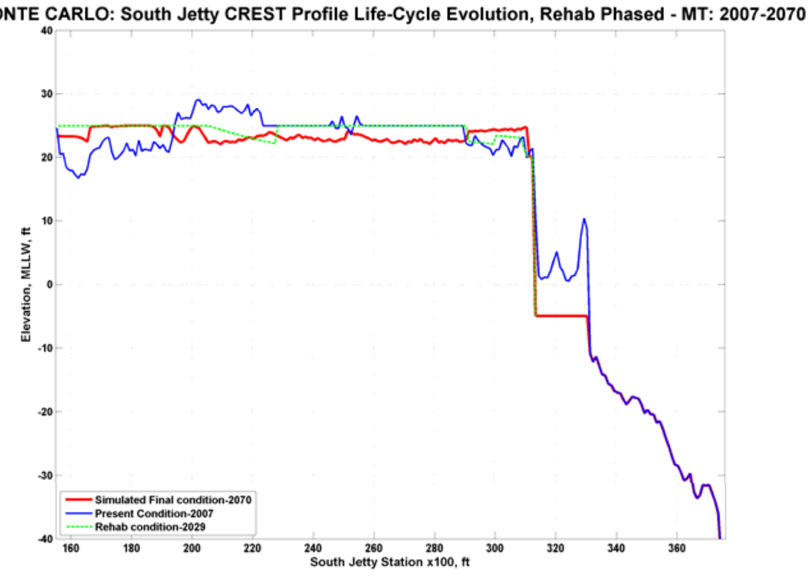

Figure A2-113e. Centerline profile for MCR South Jetty. Minimum Template Rehab - Scheduled.

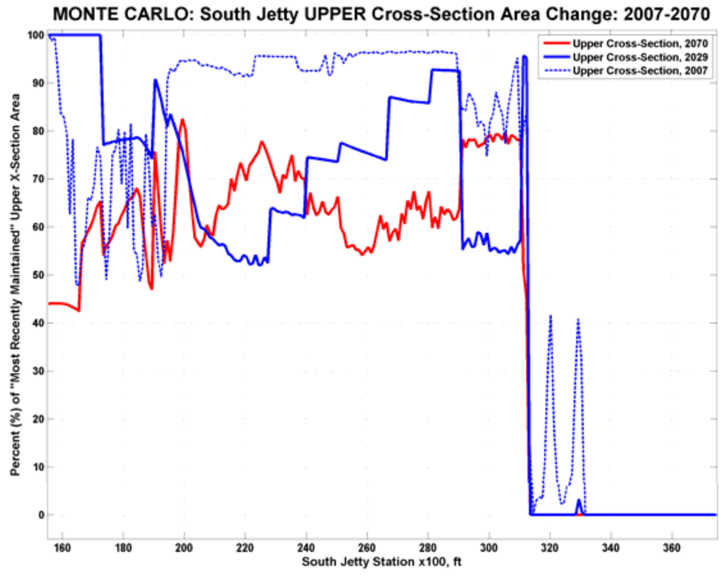

Figure A2-113f. Variation of upper cross-section area for given station of MCR South Jetty. Minimum Template Rehab - Scheduled.

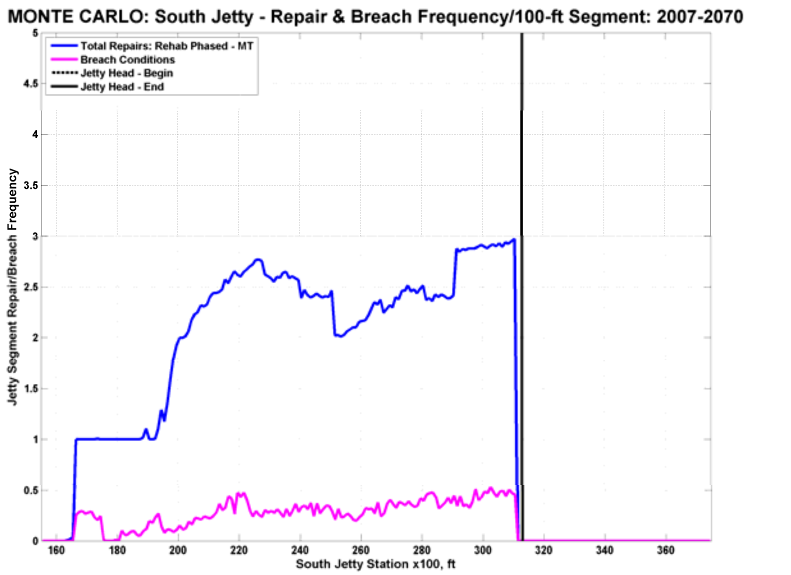

Figure A2-113g. Frequency and location of repairs and breaches for MCR South Jetty. Minimum Template Rehab - Scheduled.

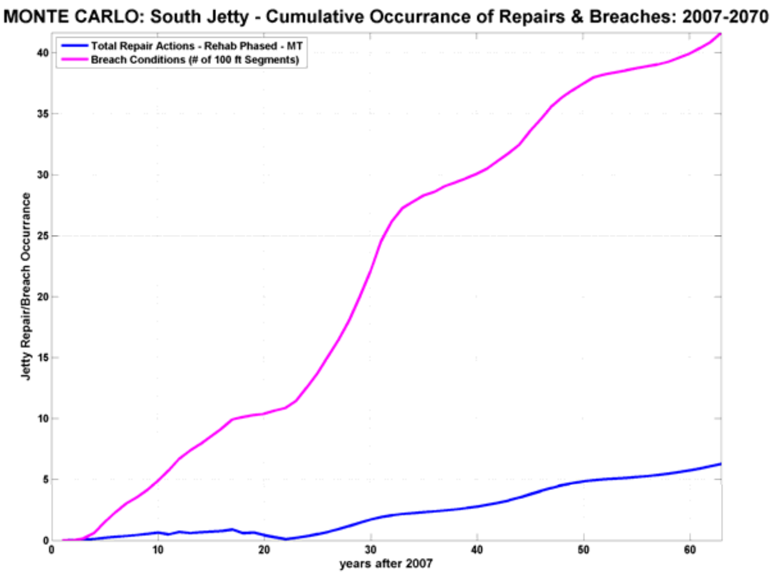

Figure A2-113h. Cumulative occurrence of repairs and breach conditions for MCR South Jetty. Minimum Template Rehab - Scheduled.

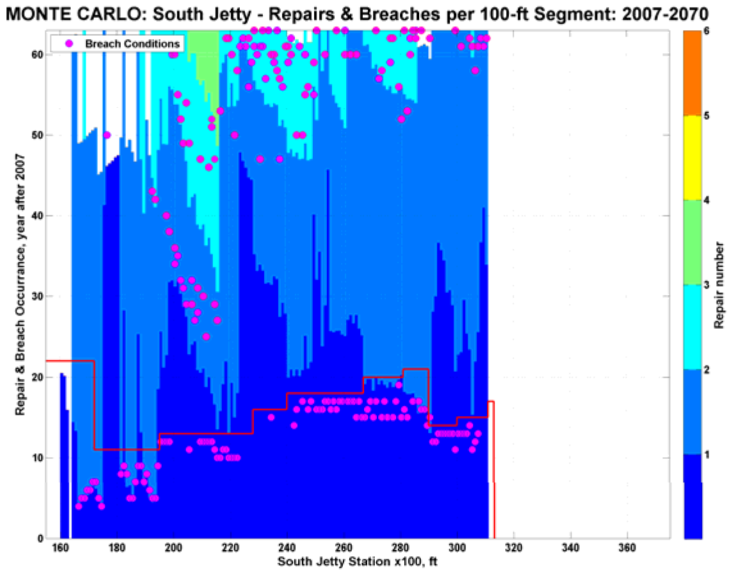

Figure A2-114a. Forecast repair occurrence for MCR South Jetty, shown for each 100 ft jetty segment. Composite 5 Modified 2 Rehab - Scheduled. RED line marks time of REHAB phase implementation

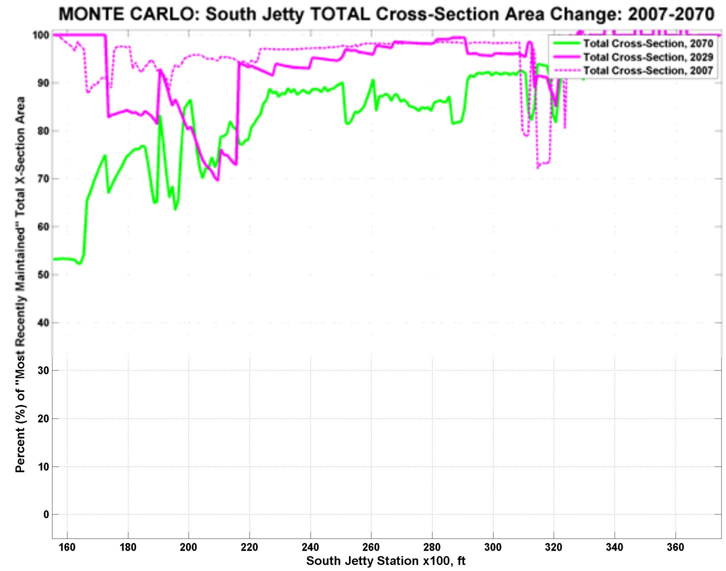

Figure A2-114b. Variation in total cross-section area along MCR South Jetty during forecast period. Composite 5 Modified 2 Rehab - Scheduled.RED line marks time of REHAB phase implementation

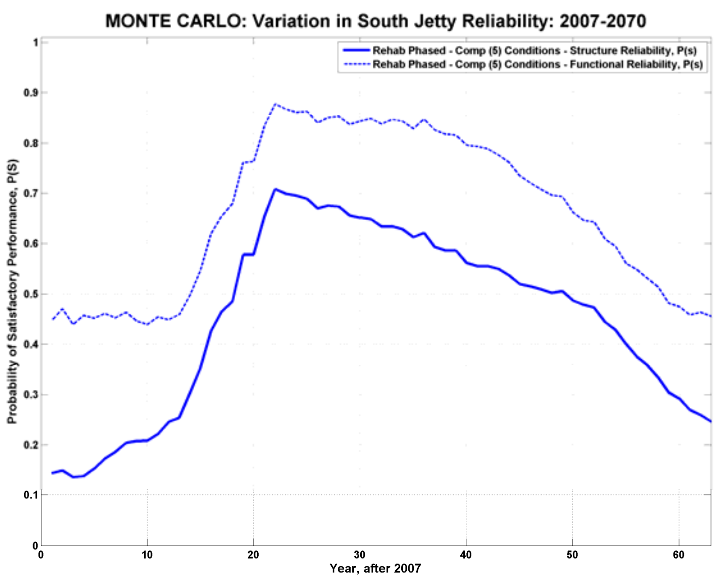

Figure A2-114c. Forecast reliability for MCR South Jetty. Composite 5 Modified 2 Rehab - Scheduled.

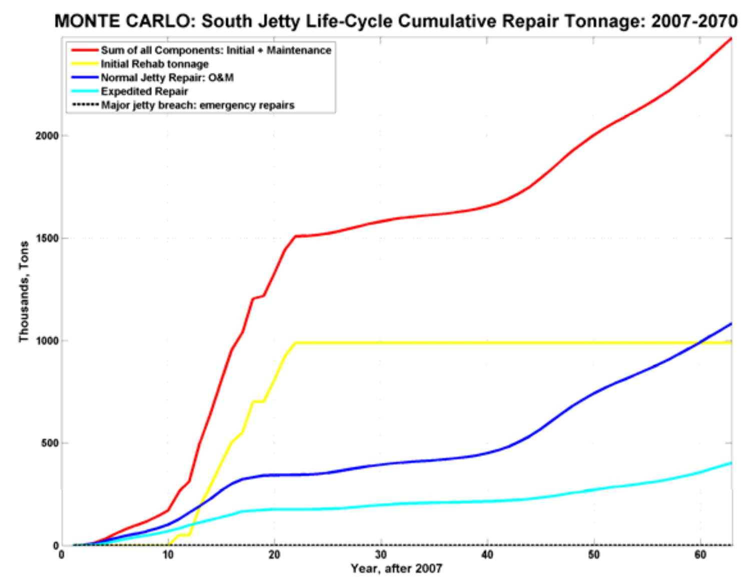

Figure A2-114d. Life-cycle cumulative repair tonnage for MCR South Jetty. Composite 5 Modified 2 Rehab - Scheduled.

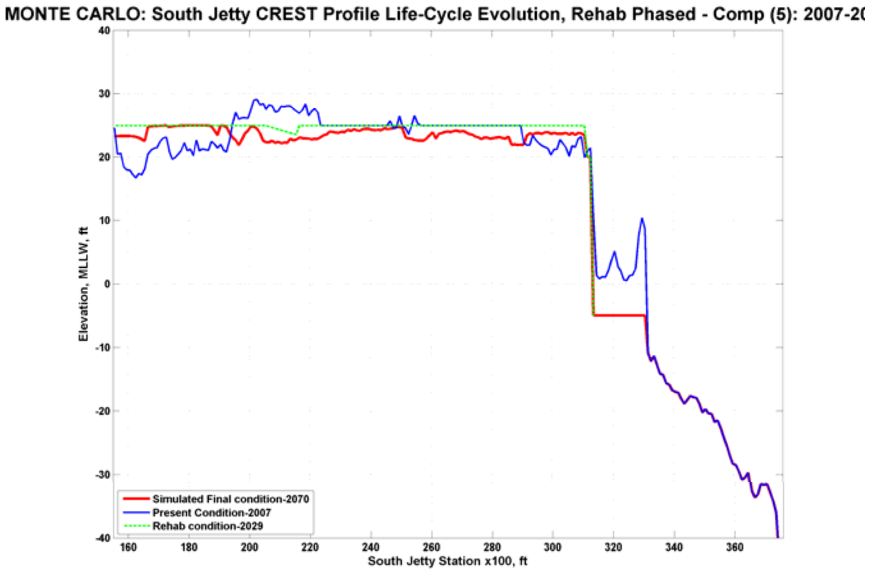

Figure A2-114e. Centerline profile for MCR South Jetty. Composite 5 Modified 2 Rehab - Scheduled.

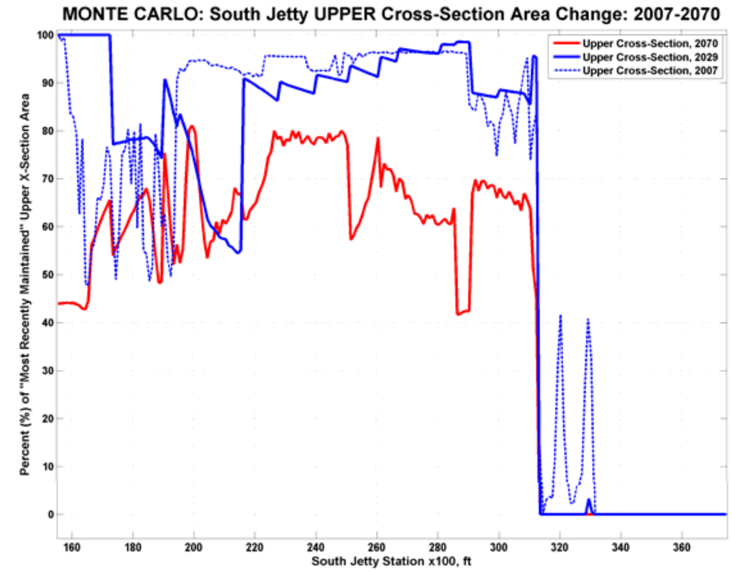

Figure A2-114f. Variation of upper cross-section area for given station of MCR South Jetty. Composite 5 Modified 2 Rehab - Scheduled.

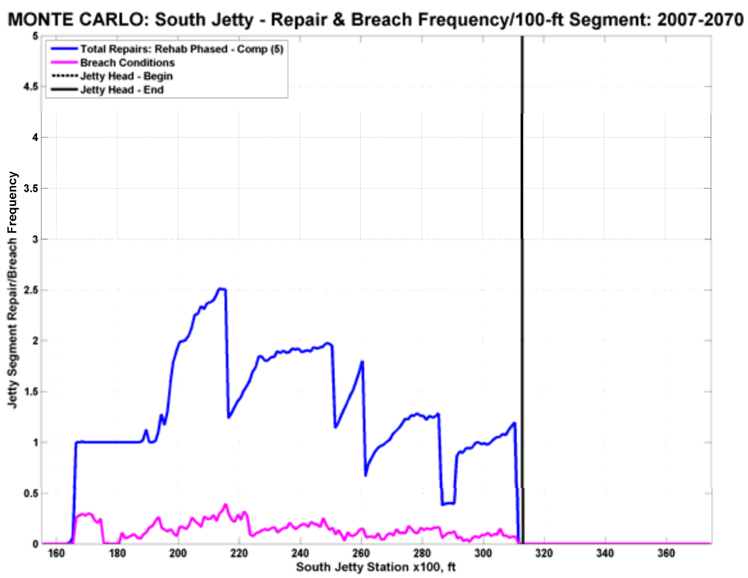

Figure A2-114g. Frequency and location of repairs and breaches for MCR South Jetty. Composite 5 Modified 2 Rehab - Scheduled.

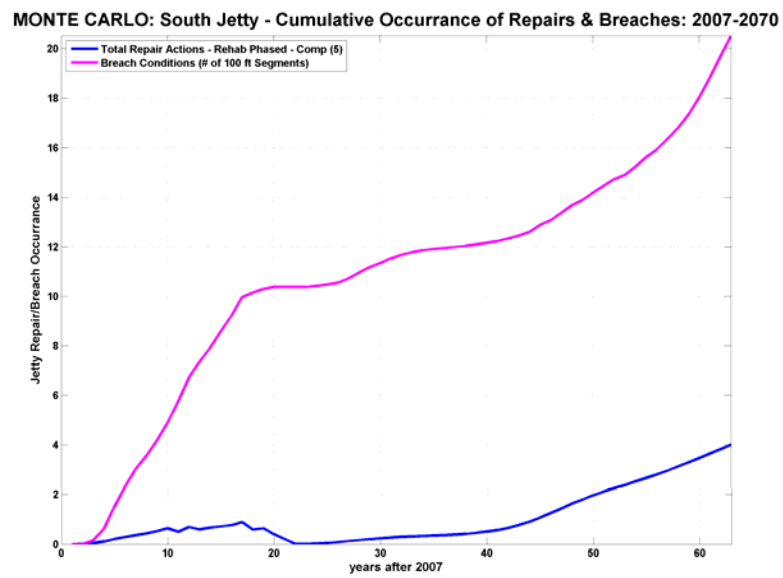

Figure A2-114h. Cumulative occurrence of repairs and breach conditions for MCR South Jetty. Composite 5 Modified 2 Rehab - Scheduled.

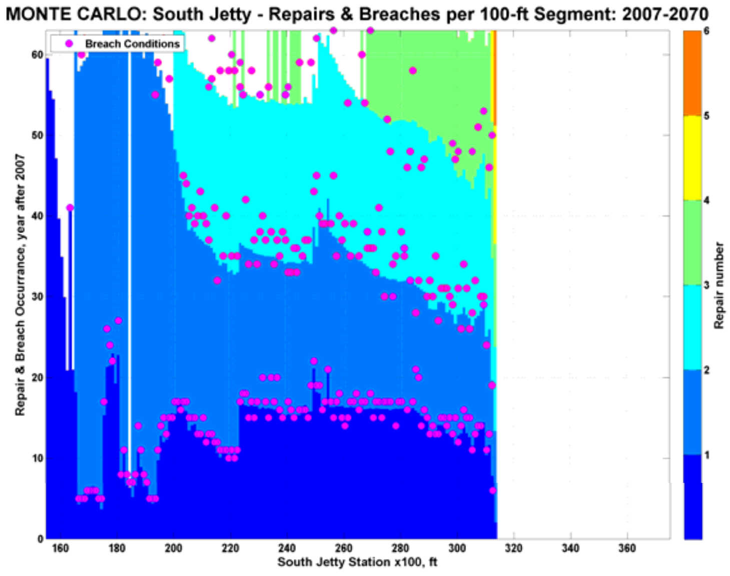

Figure A2-115a. Forecast repair occurrence for MCR South Jetty, shown for each 100 ft jetty segment. Base Condition (Hold Head).

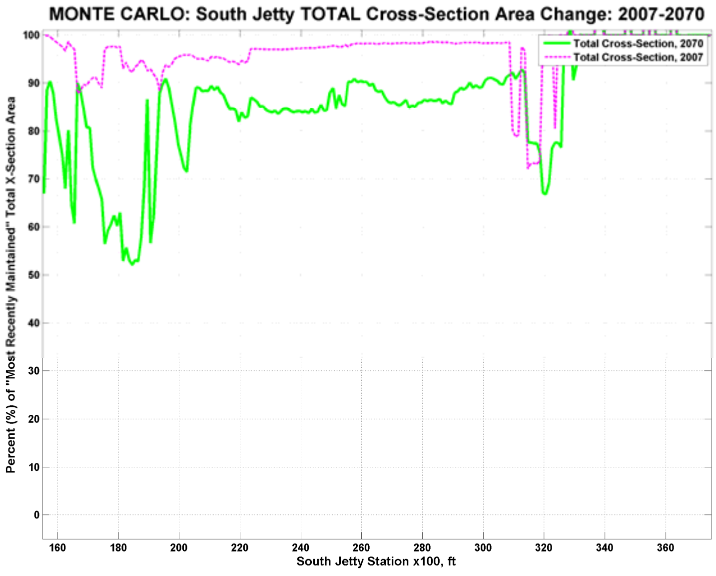

Figure A2-115b. Variation in total cross-section area along MCR South Jetty during forecast period. Base Condition (Hold Head).

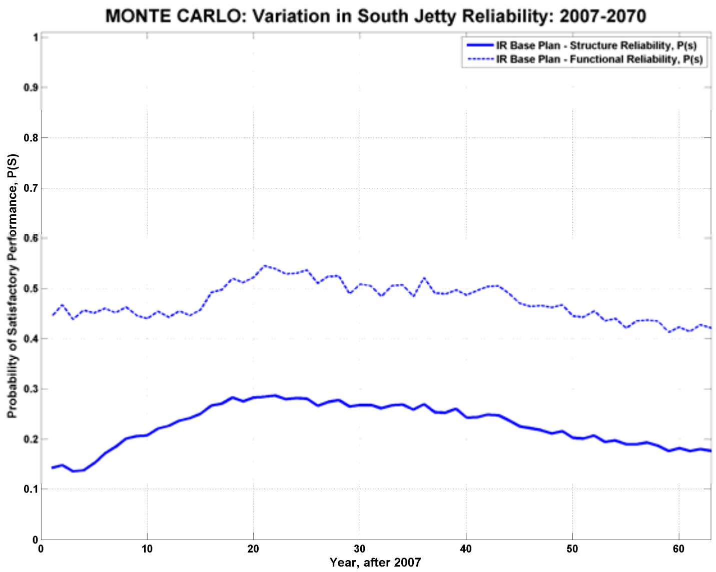

Figure A2-115c. Forecast reliability for MCR South Jetty. Base Condition (Hold Head).

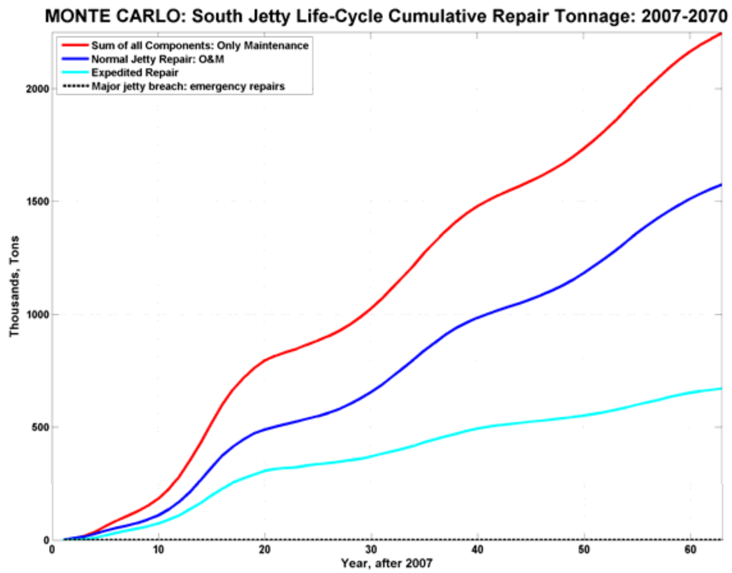

Figure A2-115d. Life-cycle cumulative repair tonnage for MCR South Jetty. Base Condition (Hold Head).

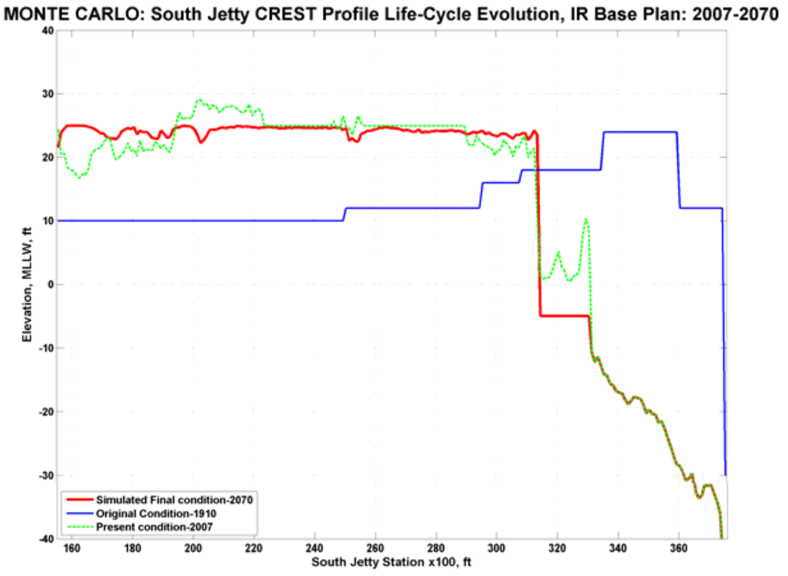

Figure A2-115e. Centerline profile for MCR South Jetty. Base Condition (Hold Head).

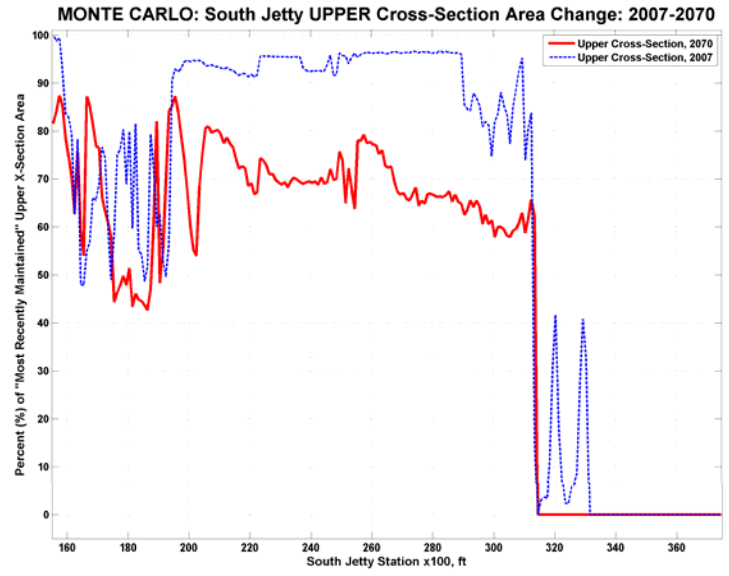

Figure A2-115f. Variation of upper cross-section area for given station of MCR South Jetty. Base Condition (Hold Head).

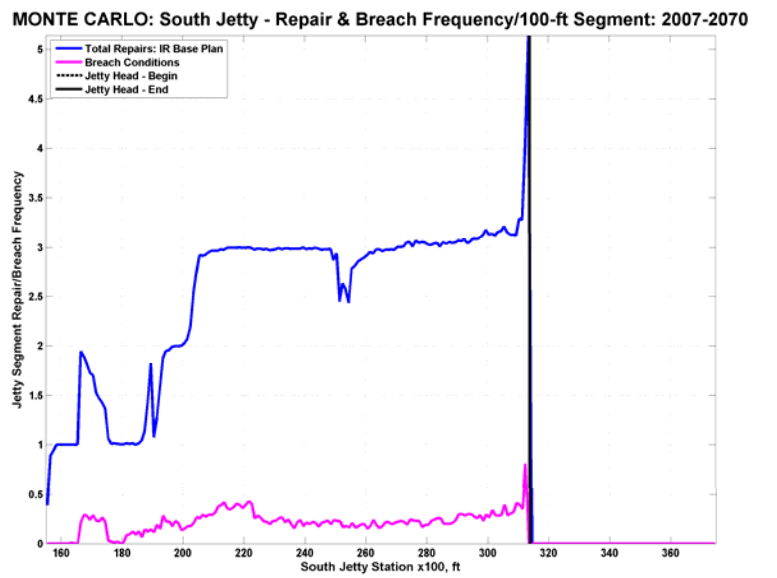

Figure A2-115g. Frequency and location of repairs and breaches for MCR South Jetty. Base Condition (Hold Head).

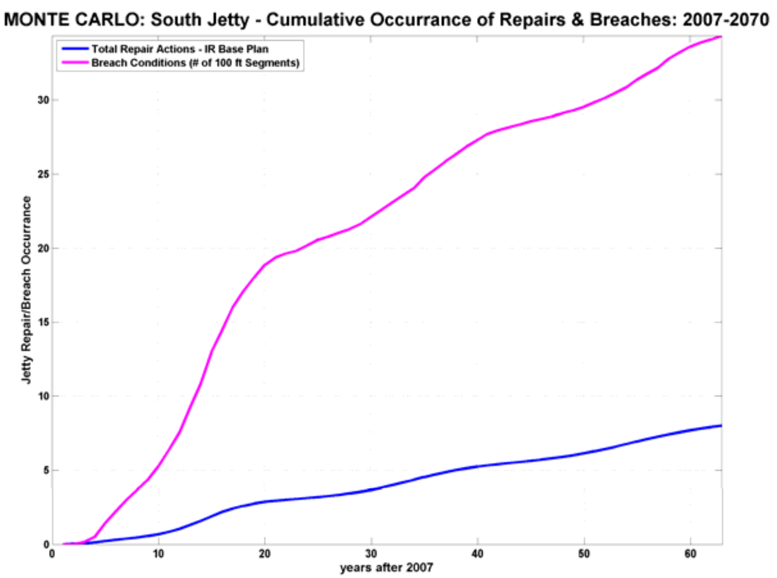

Figure A2-115h. Cumulative occurrence of repairs and breach conditions for MCR South Jetty. Base Condition (Hold Head).

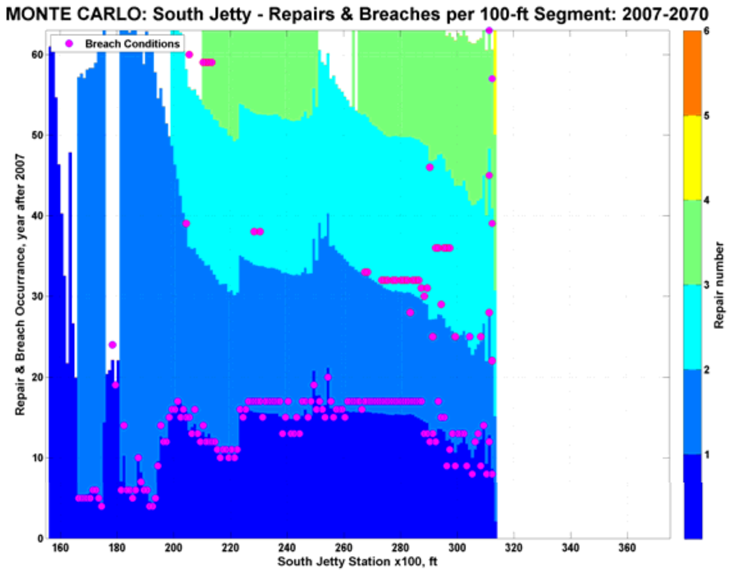

Figure A2-116a. Forecast repair occurrence for MCR South Jetty, shown for each 100 ft jetty segment. Scheduled Repair w/ Engineering Features (Hold Head)

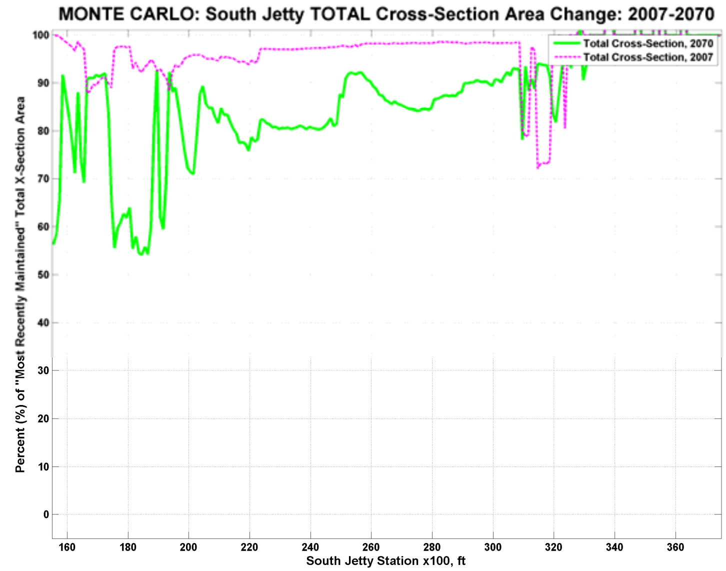

Figure A2-116b. Variation in total cross-section area along MCR South Jetty during forecast period. Scheduled Repair w/ Engineering Features (Hold Head)

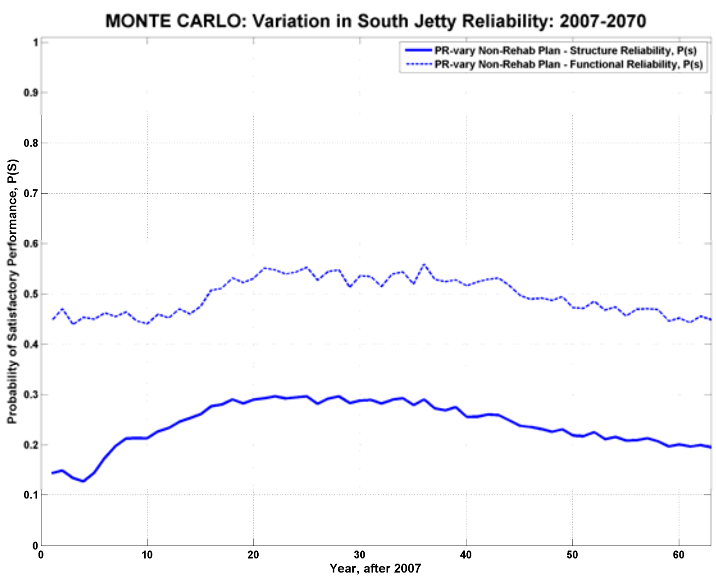

Figure A2-116c. Forecast reliability for MCR South Jetty. Scheduled Repair w/ Engineering Features (Hold Head).

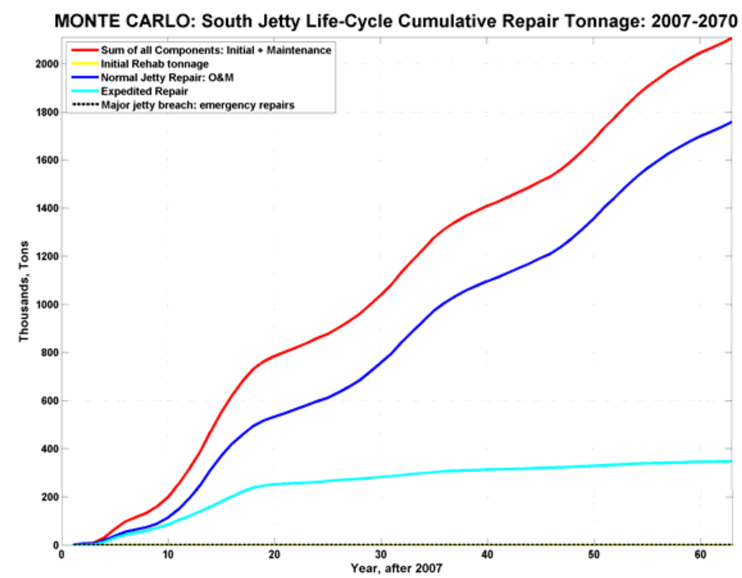

Figure A2-116d. Life-cycle cumulative repair tonnage for MCR South Jetty. Scheduled Repair w/ Engineering Features (Hold Head).

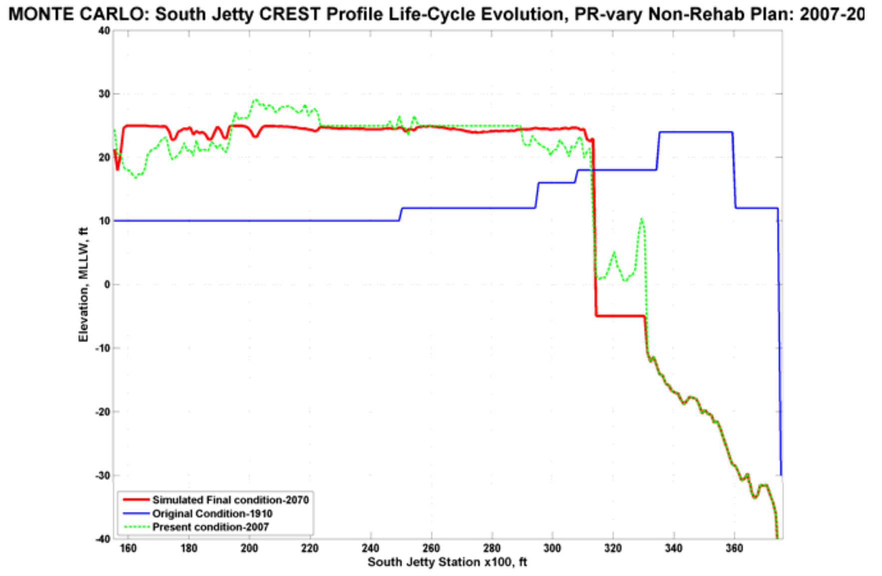

Figure A2-116e. Centerline profile for MCR South Jetty. Scheduled Repair w/ Engineering Features (Hold Head).

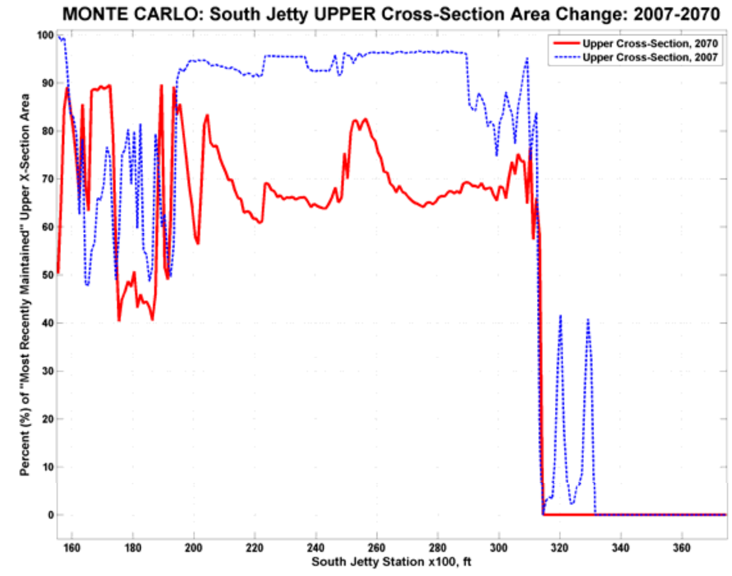

Figure A2-116f. Variation of upper cross-section area for given station of MCR South Jetty. Scheduled Repair w/ Engineering Features (Hold Head).

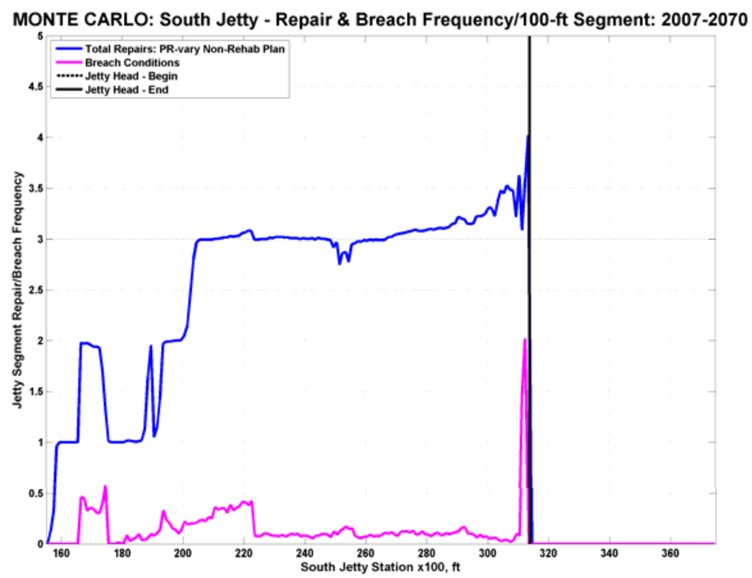

Figure A2-116g. Frequency and location of repairs and breaches for MCR South Jetty. Scheduled Repair w/ Engineering Features (Hold Head).

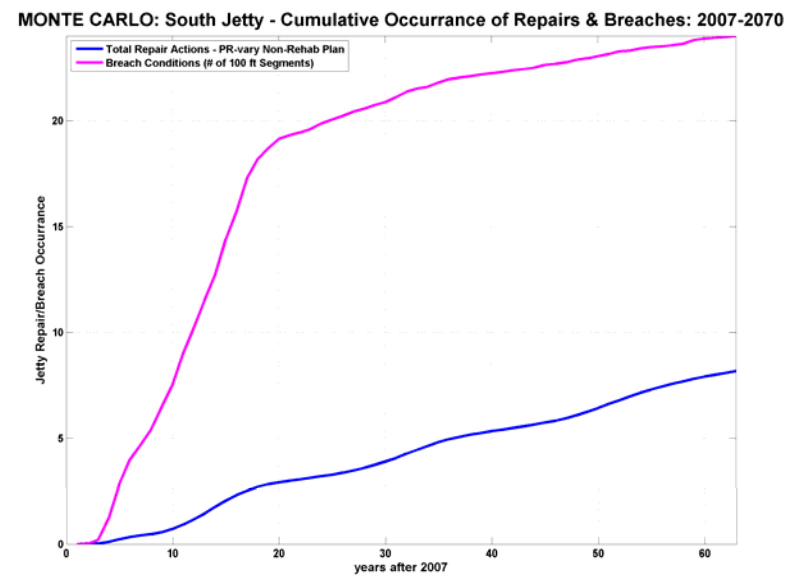

Figure A2-116h. Cumulative occurrence of repairs and breach conditions for MCR South Jetty. Scheduled Repair w/ Engineering Features (Hold Head)

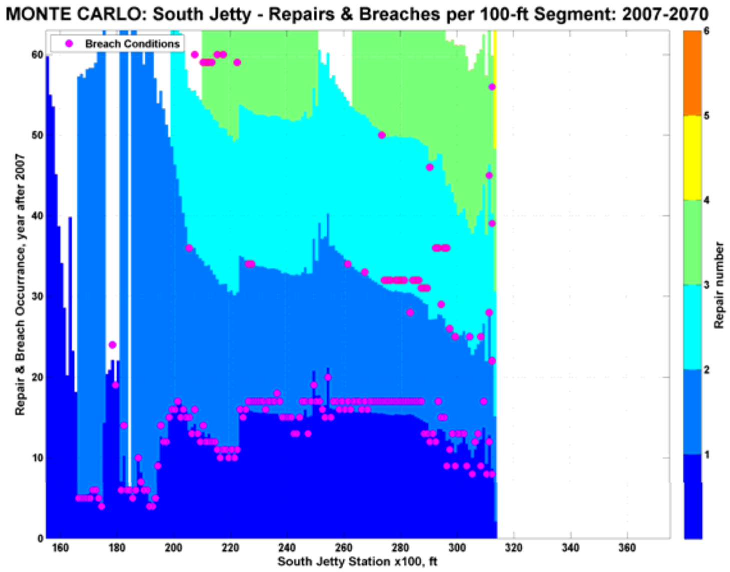

Figure A2-117a. Forecast repair occurrence for MCR South Jetty, shown for each 100 ft jetty segment. Scheduled Repair w/ Head Capping (Hold Head).

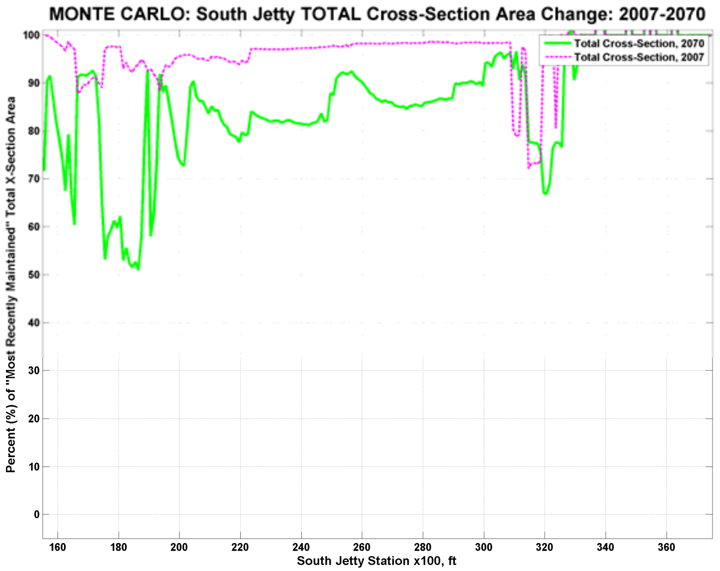

Figure A2-117b. Variation in total cross-section area along MCR South Jetty during forecast period. Scheduled Repair w/ Head Capping (Hold Head).

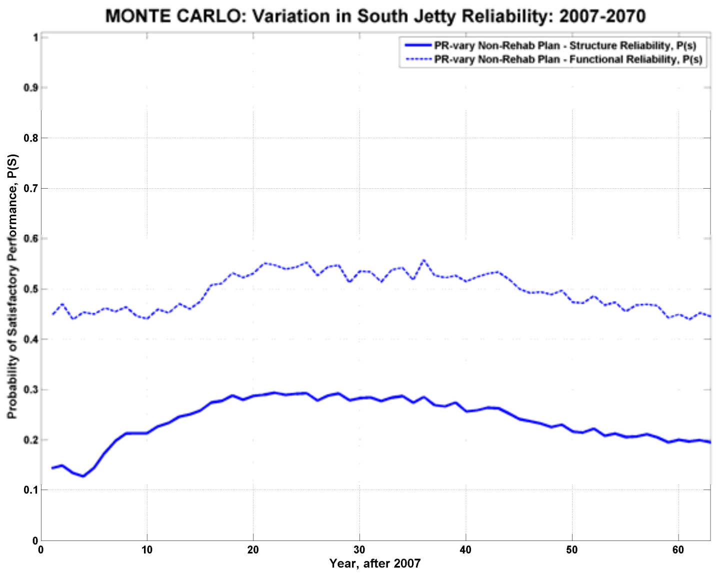

Figure A2-117c. Forecast reliability for MCR South Jetty. Scheduled Repair w/ Head Capping (Hold Head).

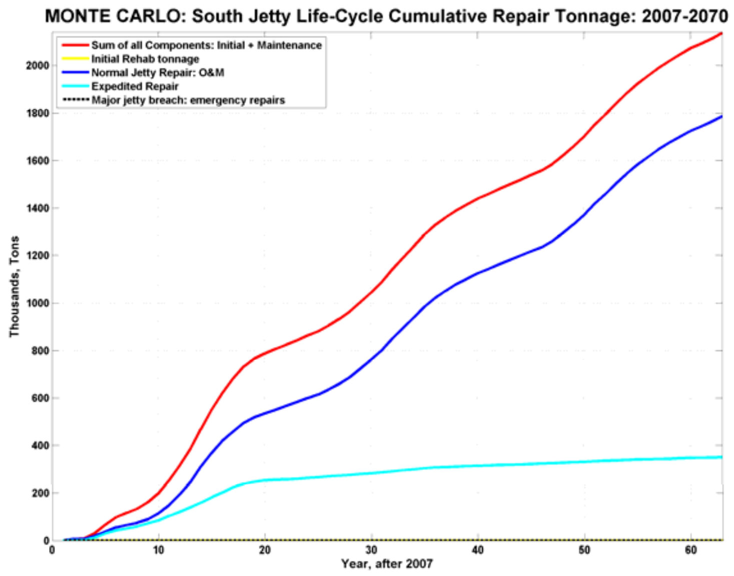

Figure A2-117d. Life-cycle cumulative repair tonnage for MCR South Jetty. Scheduled Repair w/ Head Capping (Hold Head).

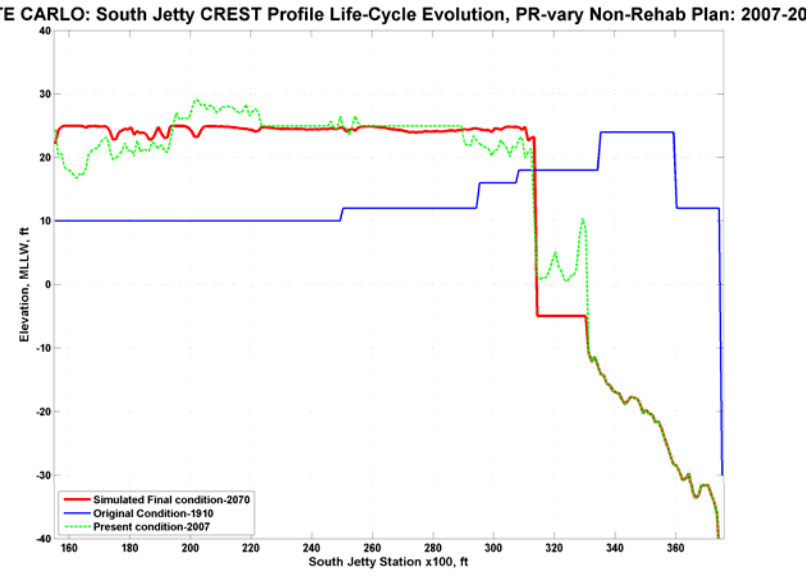

Figure A2-117e. Centerline profile for MCR South Jetty. Scheduled Repair w/ Head Capping (Hold Head).

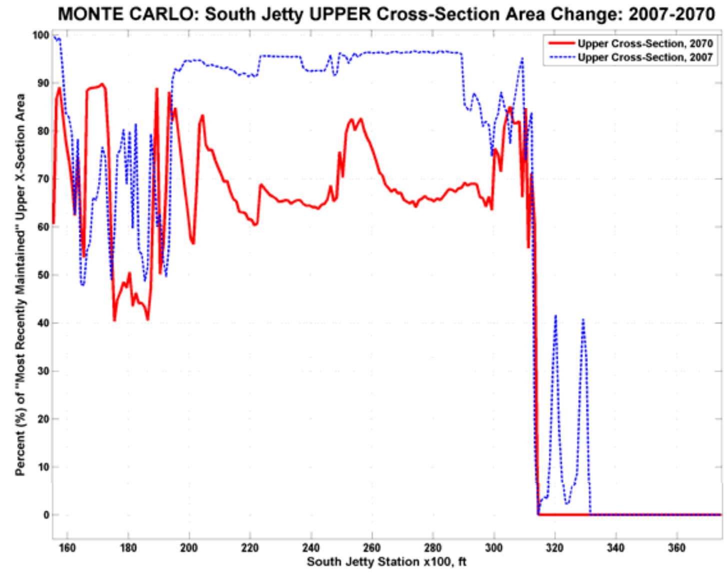

Figure A2-117f. Variation of upper cross-section area for given station of MCR South Jetty. Scheduled Repair w/ Head Capping (Hold Head).

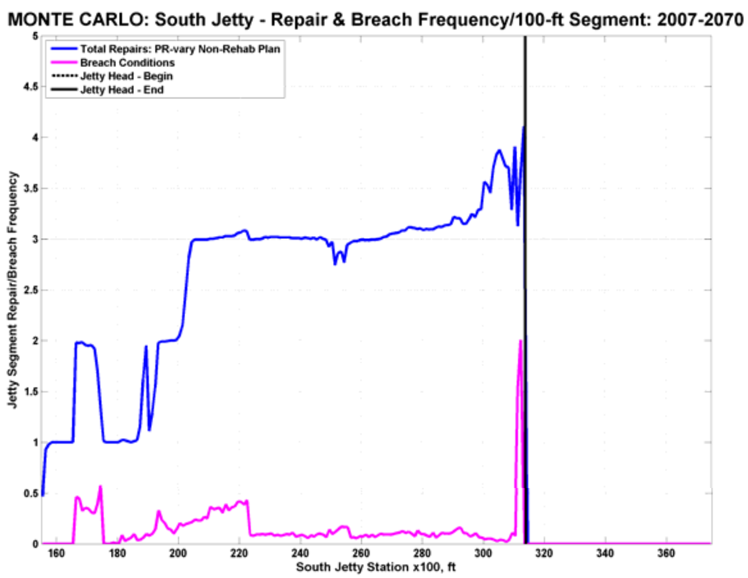

Figure A2-117g. Frequency and location of repairs and breaches for MCR South Jetty. Scheduled Repair w/ Head Capping (Hold Head).

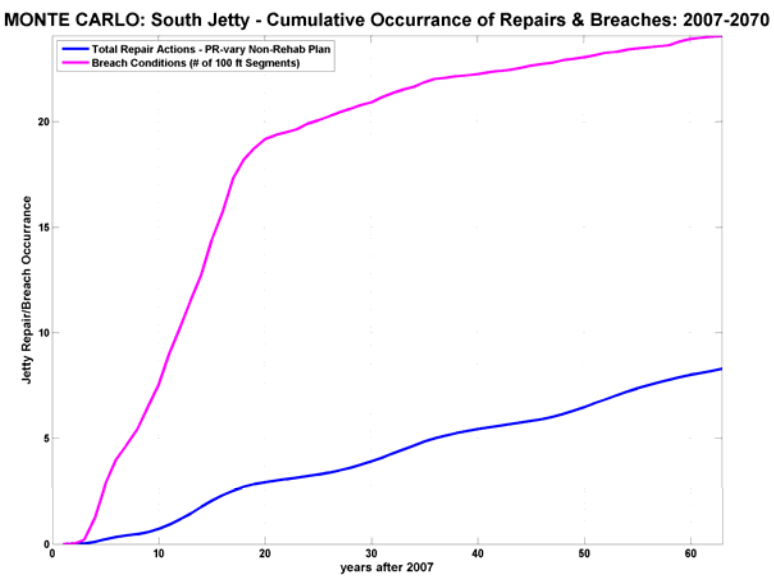

Figure A2-117h. Cumulative occurrence of repairs and breach conditions for MCR South Jetty. Scheduled Repair w/ Head Capping (Hold Head).

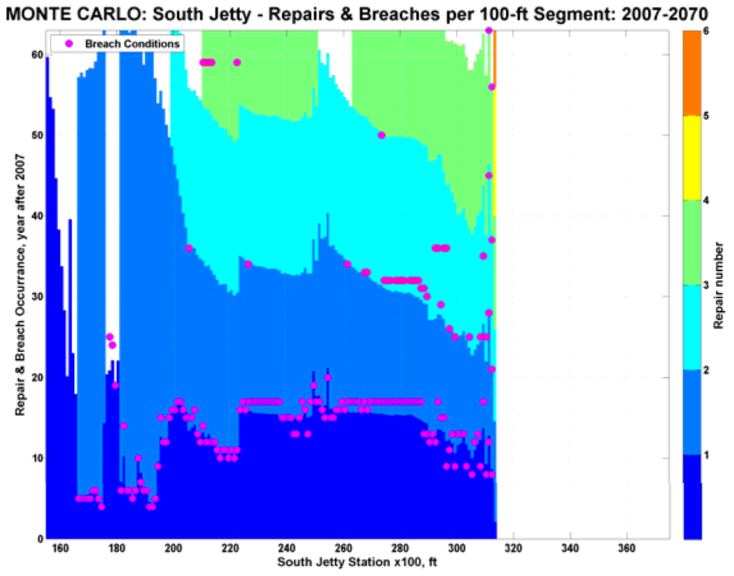

Figure A2-118a. Forecast repair occurrence for MCR South Jetty, shown for each 100 ft jetty segment. Scheduled Repair (Hold Head).

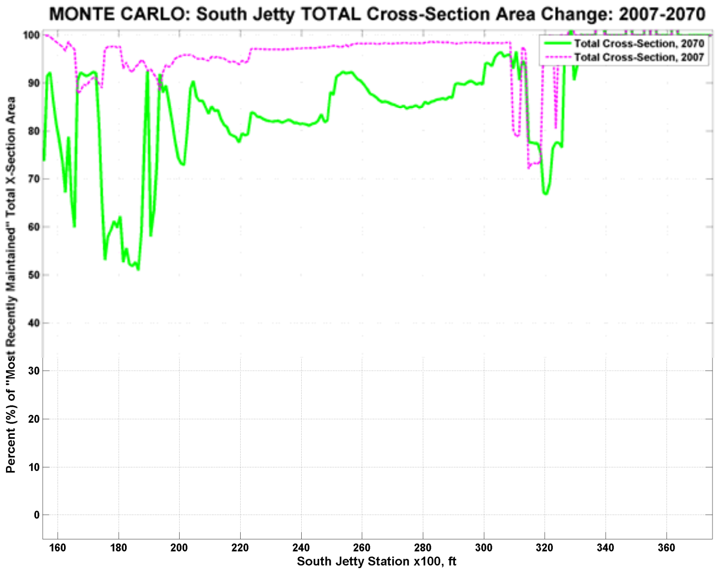

Figure A2-118b. Variation in total cross-section area along MCR South Jetty during forecast period. Scheduled Repair (Hold Head).

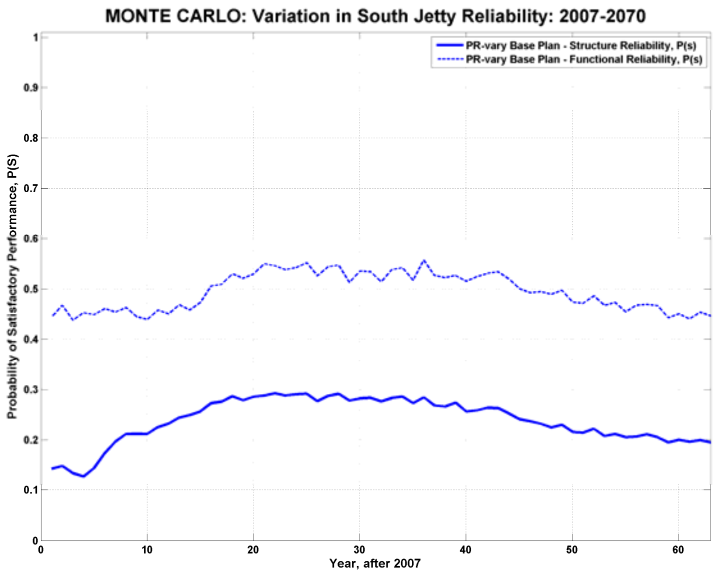

Figure A2-118c. Forecast reliability for MCR South Jetty. Scheduled Repair (Hold Head).

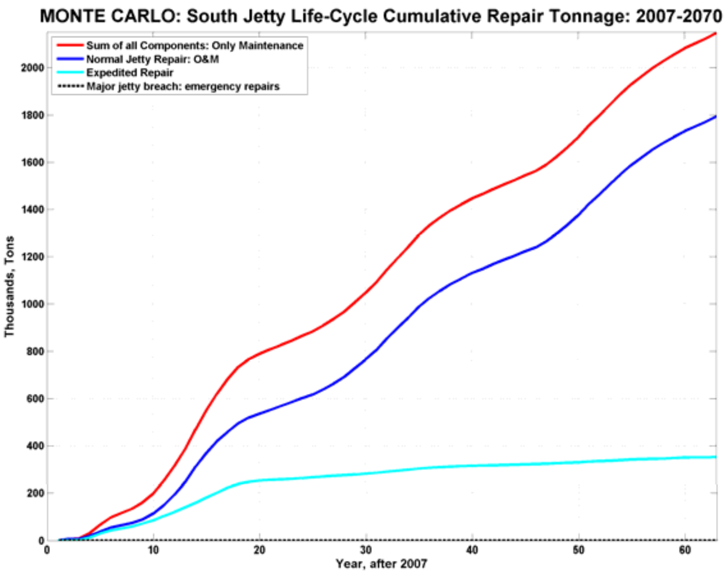

Figure A2-118d. Life-cycle cumulative repair tonnage for MCR South Jetty. Scheduled Repair (Hold Head).

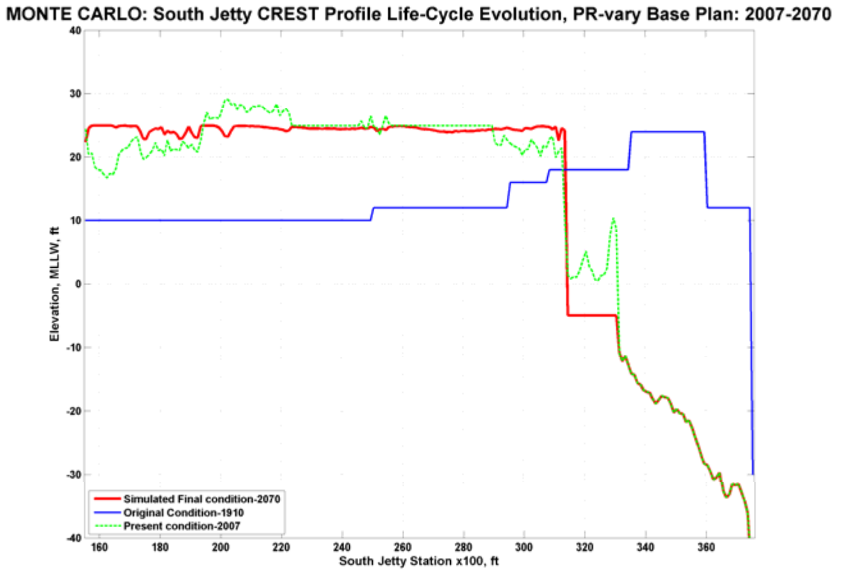

Figure A2-118e. Centerline profile for MCR South Jetty. Scheduled Repair (Hold Head).

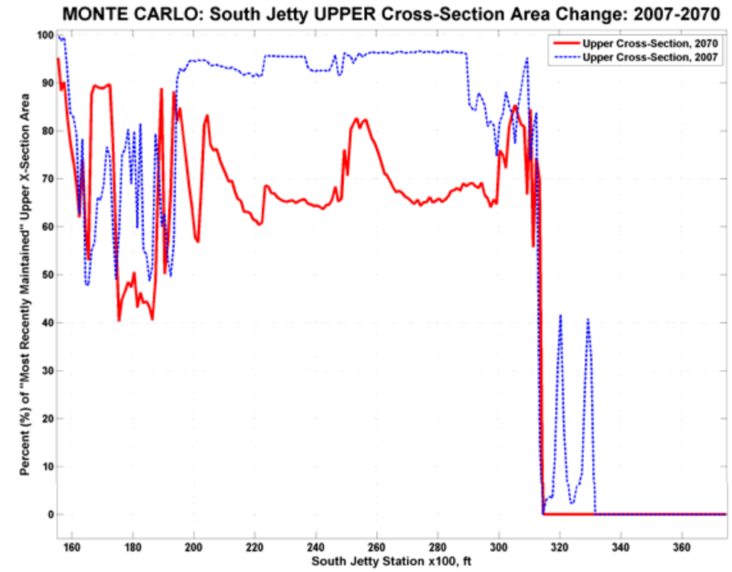

Figure A2-118f. Variation of upper cross-section area for given station of MCR South Jetty. Scheduled Repair (Hold Head).

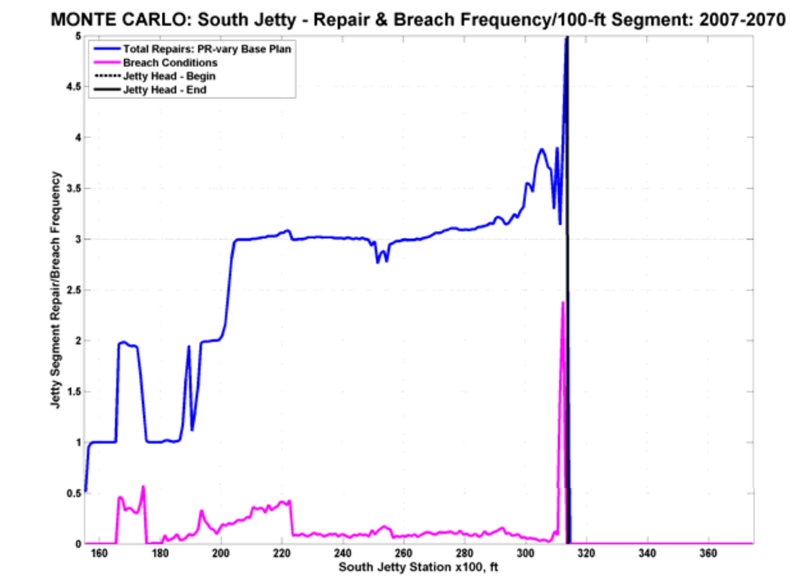

Figure A2-118g. Frequency and location of repairs and breaches for MCR South Jetty. Scheduled Repair (Hold Head).

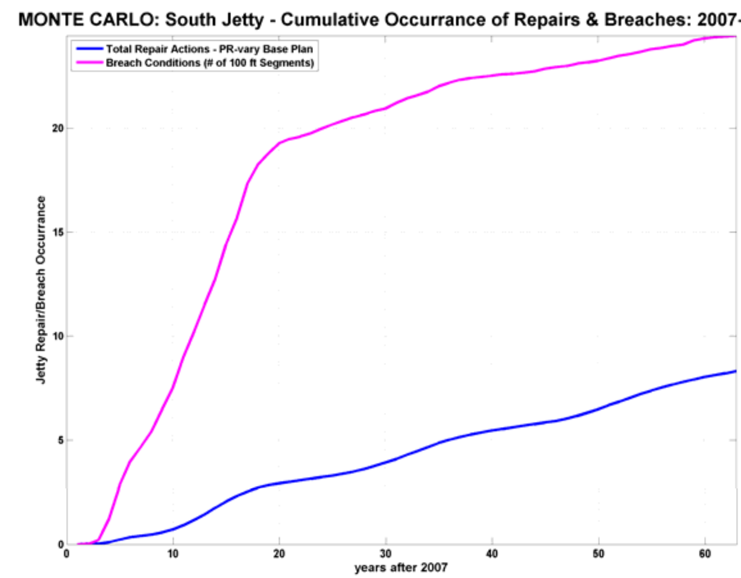

Figure A2-118h. Cumulative occurrence of repairs and breach conditions for MCR South Jetty. Scheduled Repair (Hold Head).

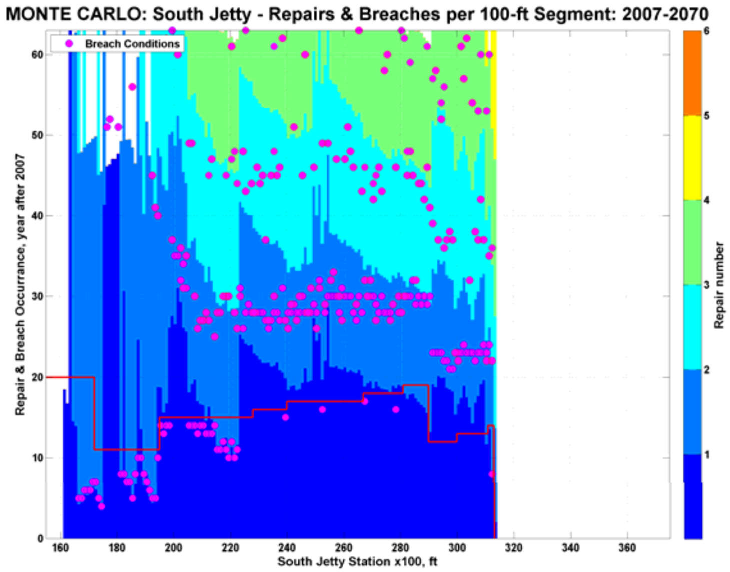

Figure A2-119a. Forecast repair occurrence for MCR South Jetty, shown for each 100 ft jetty segment. Minimum Template Rehab - Immediate (Hold Head). RED line marks time of REHAB phase implementation

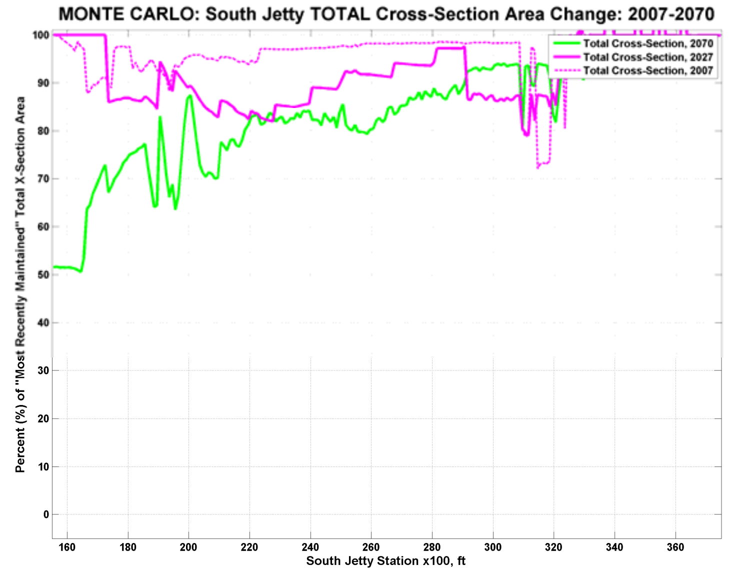

Figure A2-119b. Variation in total cross-section area along MCR South Jetty during forecast period. Minimum Template Rehab - Immediate (Hold Head).RED line marks time of REHAB phase implementation

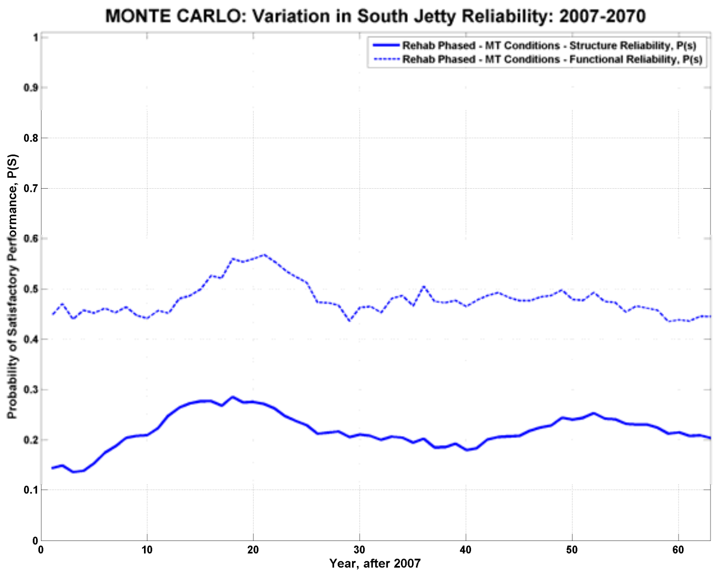

Figure A2-119c. Forecast reliability for MCR South Jetty. Minimum Template Rehab - Immediate (Hold Head).

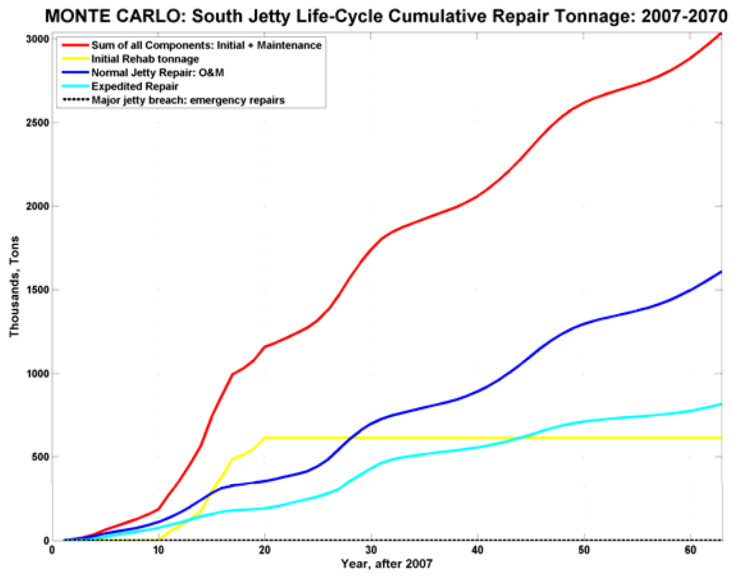

Figure A2-119d. Life-cycle cumulative repair tonnage for MCR South Jetty. Minimum Template Rehab - Immediate (Hold Head).

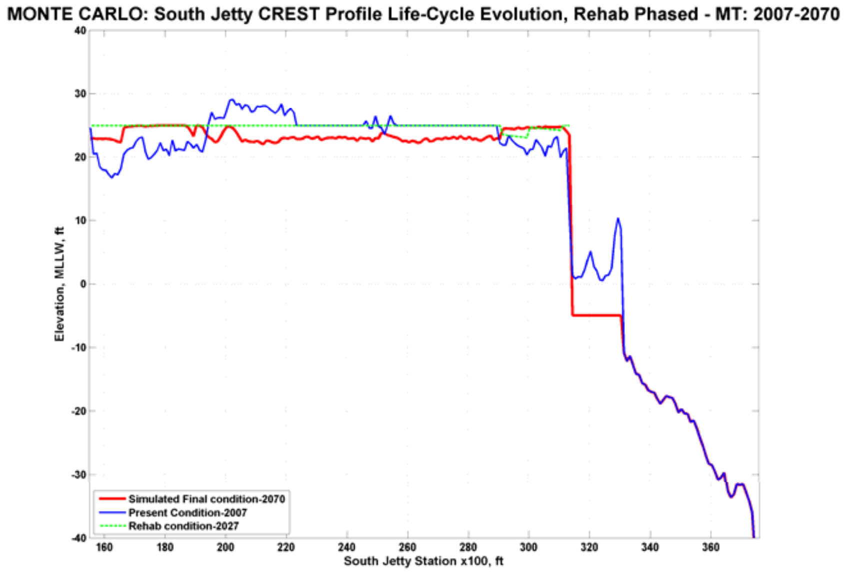

Figure A2-119e. Centerline profile for MCR South Jetty. Minimum Template Rehab - Immediate (Hold Head).

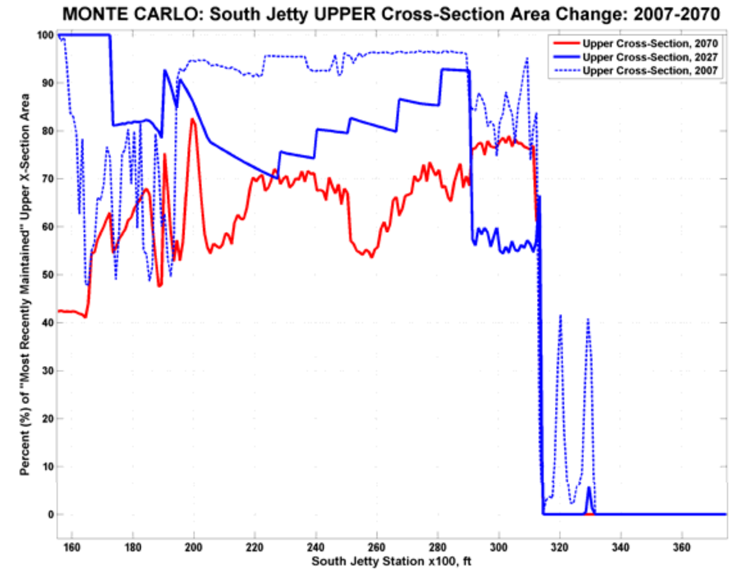

Figure A2-119f. Variation of upper cross-section area for given station of MCR South Jetty. Minimum Template Rehab - Immediate (Hold Head).

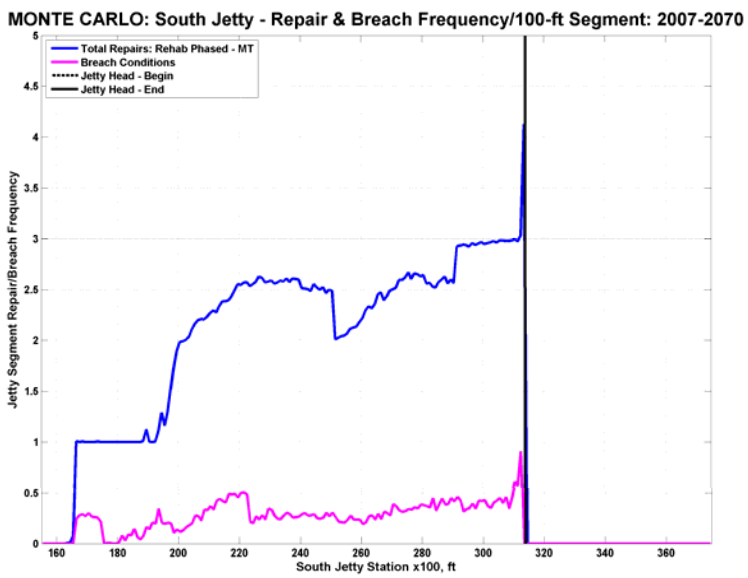

Figure A2-119g. Frequency and location of repairs and breaches for MCR South Jetty. Minimum Template Rehab - Immediate (Hold Head).

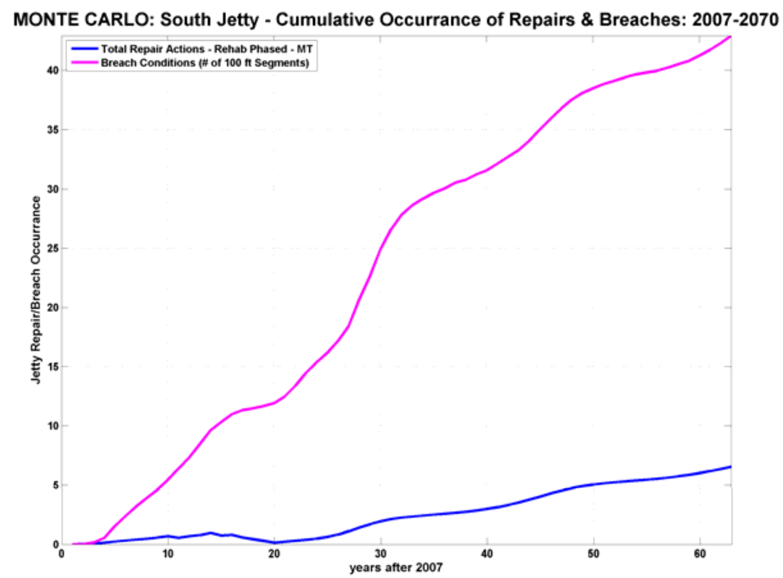

Figure A2-119h. Cumulative occurrence of repairs and breach conditions for MCR South Jetty. Minimum Template Rehab - Immediate (Hold Head).

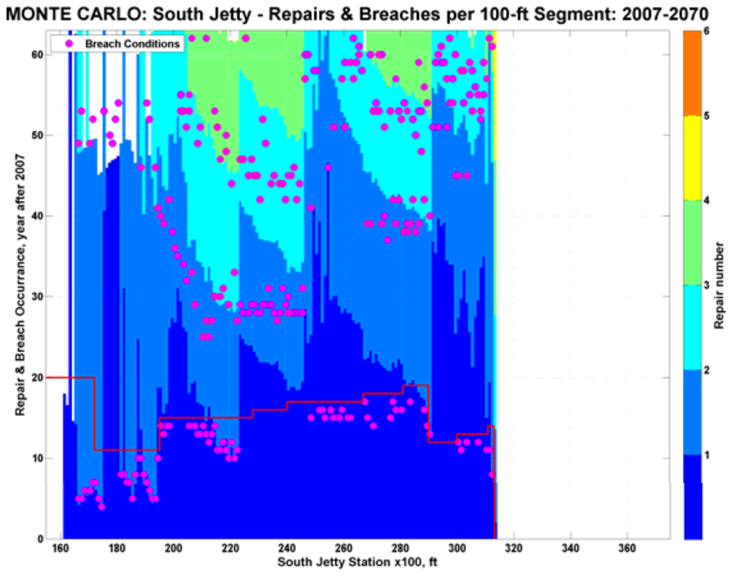

Figure A2-120a. Forecast repair occurrence for MCR South Jetty, shown for each 100 ft jetty segment. Composite 3 Small Rehab - Immediate (Hold Head). RED line marks time of REHAB phase implementation

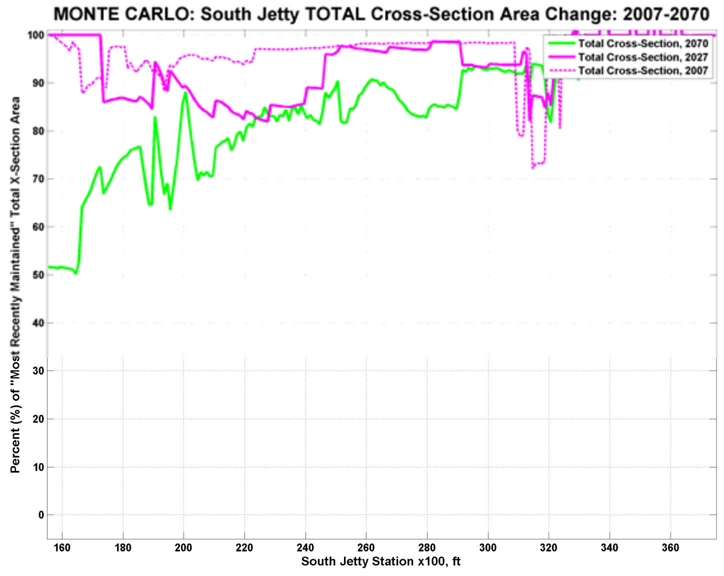

Figure A2-120b. Variation in total cross-section area along MCR South Jetty during forecast period. Composite 3 Small Rehab - Immediate (Hold Head).RED line marks time of REHAB phase implementation

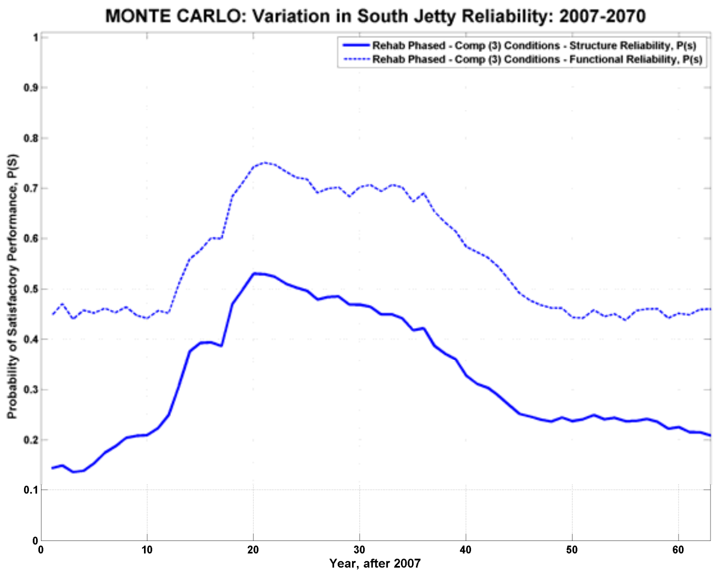

Figure A2-120c. Forecast reliability for MCR South Jetty. Composite 3 Small Rehab - Immediate (Hold Head).

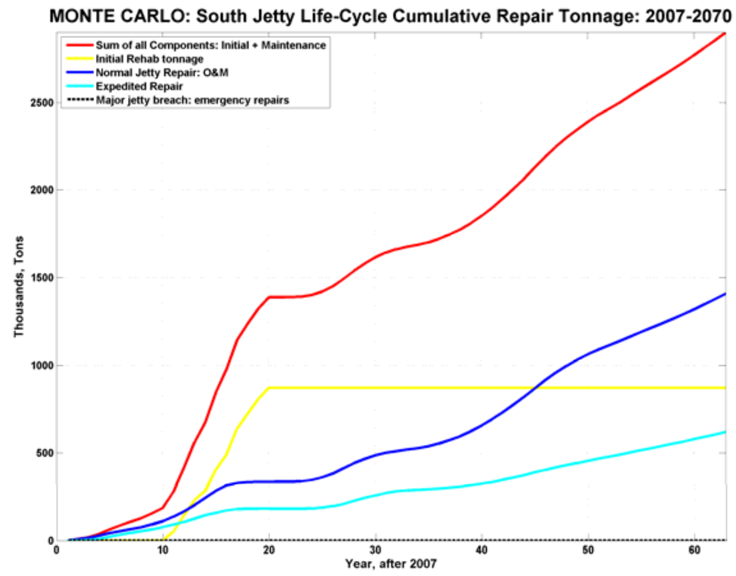

Figure A2-120d. Life-cycle cumulative repair tonnage for MCR South Jetty. Composite 3 Small Rehab - Immediate (Hold Head).

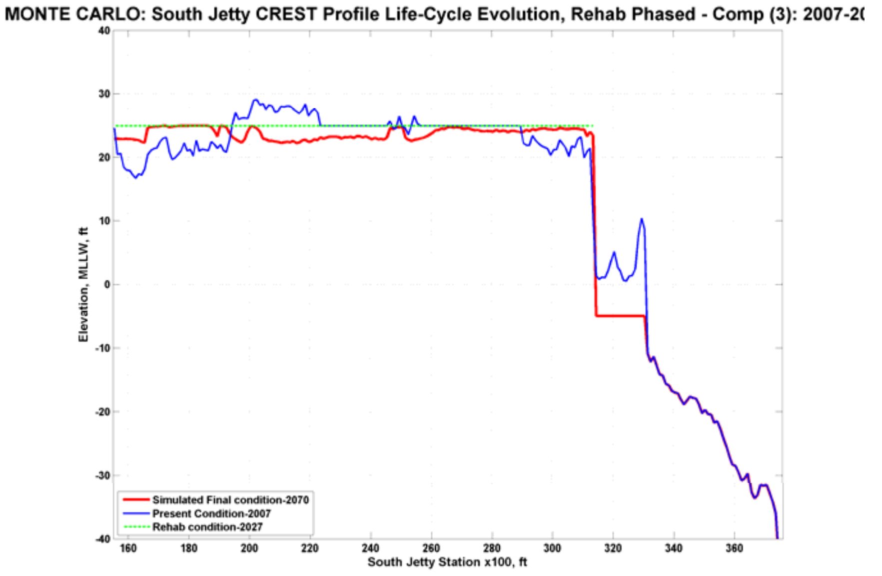

Figure A2-120e. Centerline profile for MCR South Jetty. Composite 3 Small Rehab - Immediate (Hold Head).

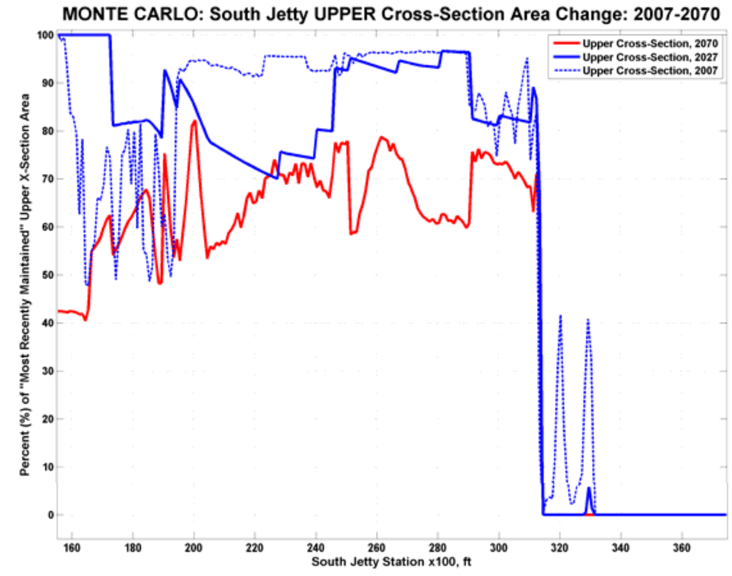

Figure A2-120f. Variation of upper cross-section area for given station of MCR South Jetty. Composite 3 Small Rehab - Immediate (Hold Head).

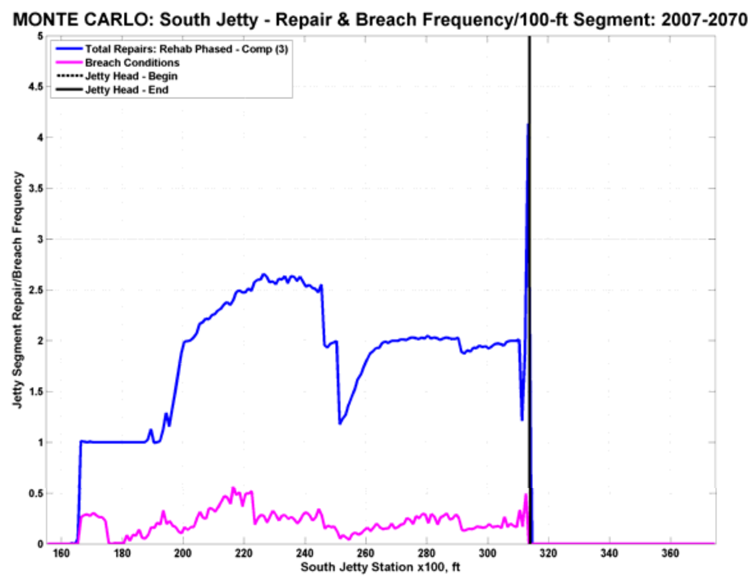

Figure A2-120g. Frequency and location of repairs and breaches for MCR South Jetty. Composite 3 Small Rehab - Immediate (Hold Head).

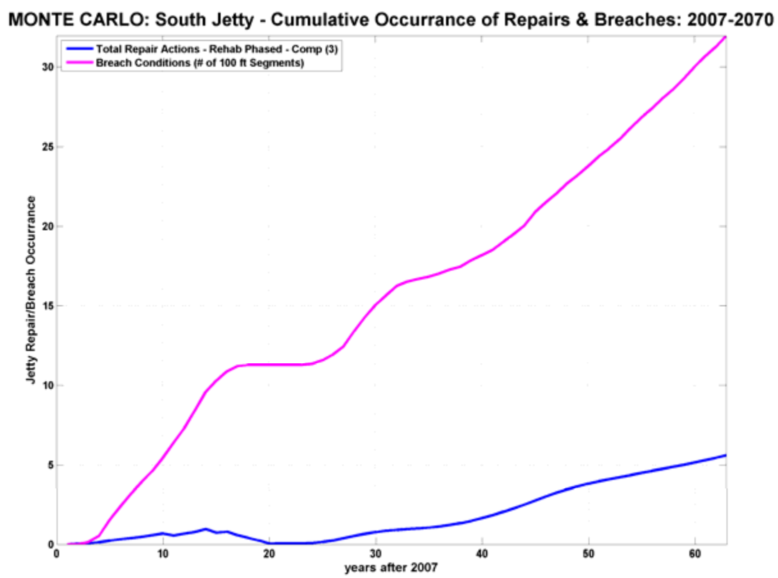

Figure A2-120h. Cumulative occurrence of repairs and breach conditions for MCR South Jetty. Composite 3 Small Rehab - Immediate (Hold Head).

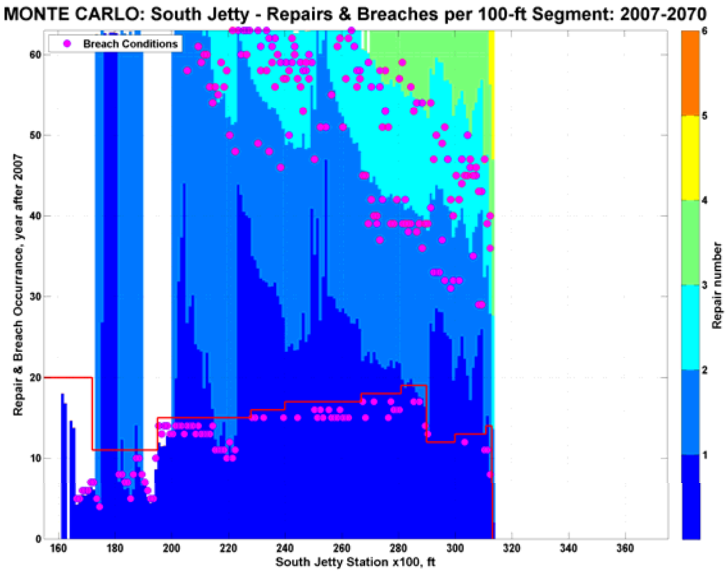

Figure A2-121a. Forecast repair occurrence for MCR South Jetty, shown for each 100 ft jetty segment. Small Template Rehab - Immediate (Hold Head). RED line marks time of REHAB phase implementation

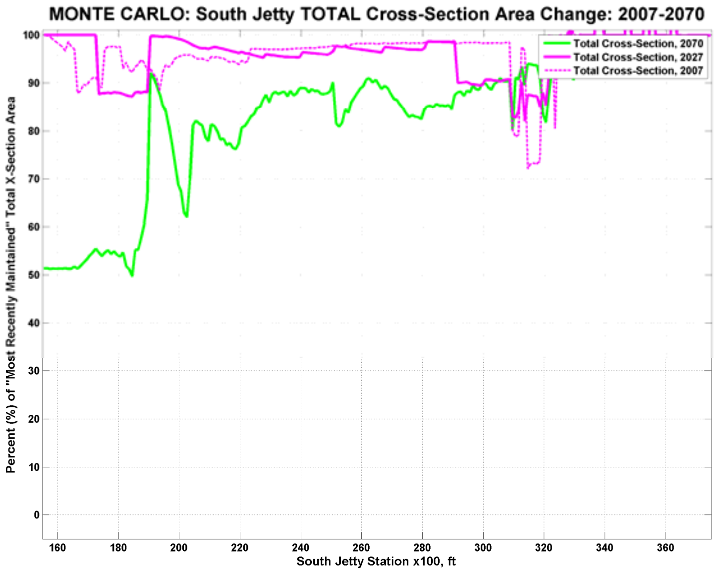

Figure A2-121b. Variation in total cross-section area along MCR South Jetty during forecast period. Small Template Rehab - Immediate (Hold Head).RED line marks time of REHAB phase implementation

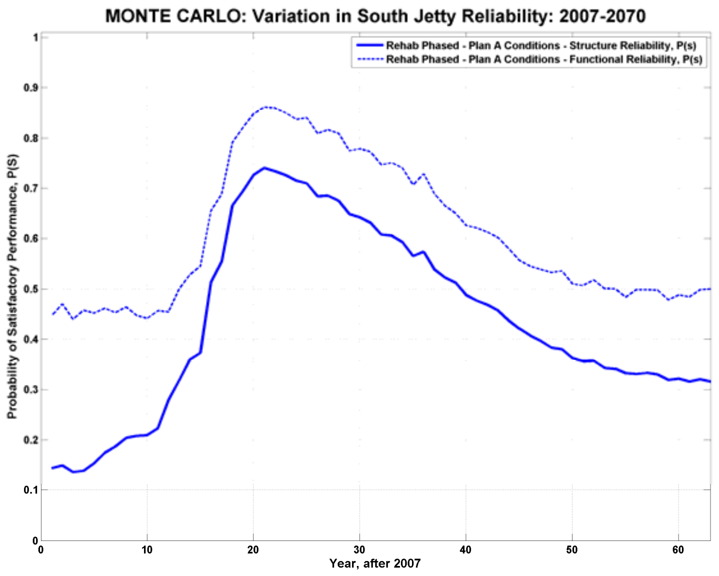

Figure A2-121c. Forecast reliability for MCR South Jetty. Small Template Rehab - Immediate (Hold Head).

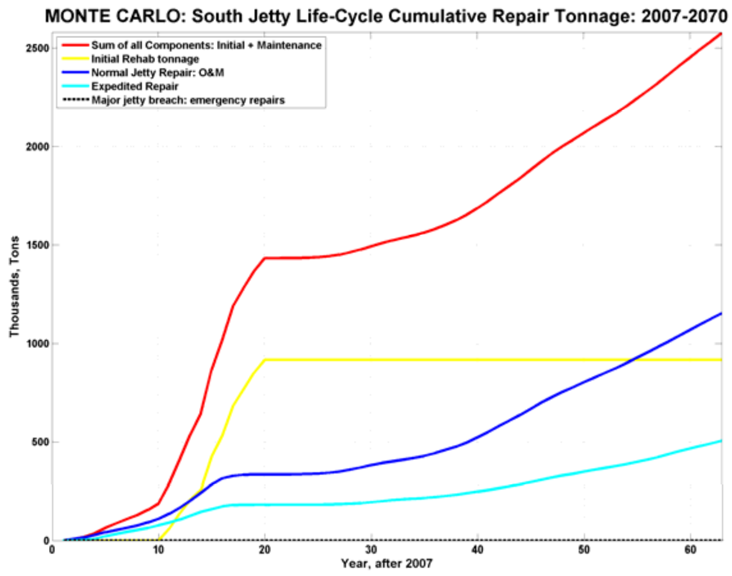

Figure A2-121d. Life-cycle cumulative repair tonnage for MCR South Jetty. Small Template Rehab - Immediate (Hold Head).

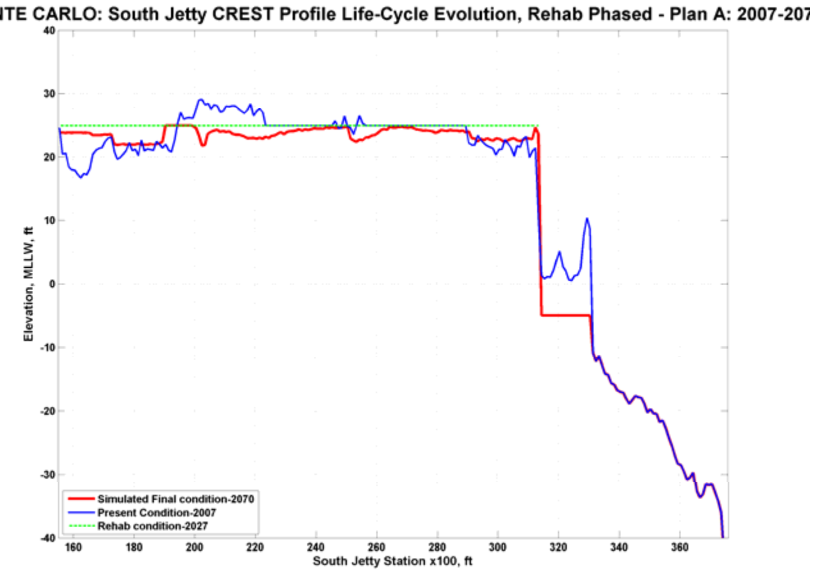

Figure A2-121e. Centerline profile for MCR South Jetty. Small Template Rehab - Immediate (Hold Head).

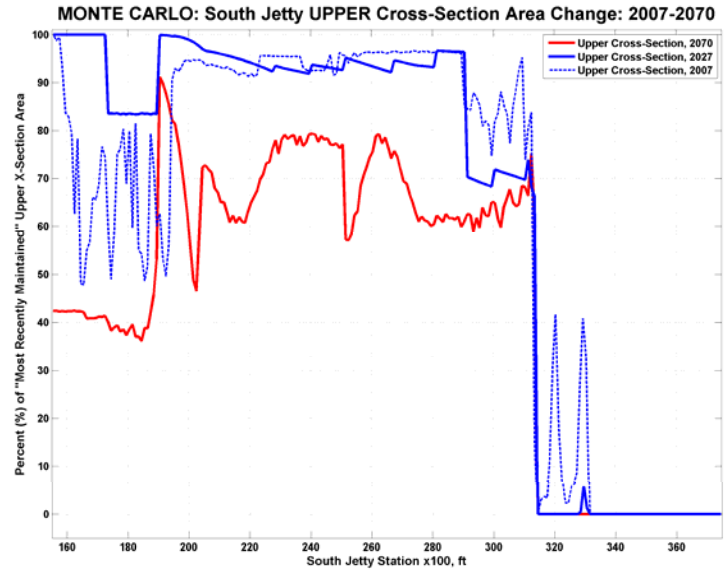

Figure A2-121f. Variation of upper cross-section area for given station of MCR South Jetty. Small Template Rehab - Immediate (Hold Head).

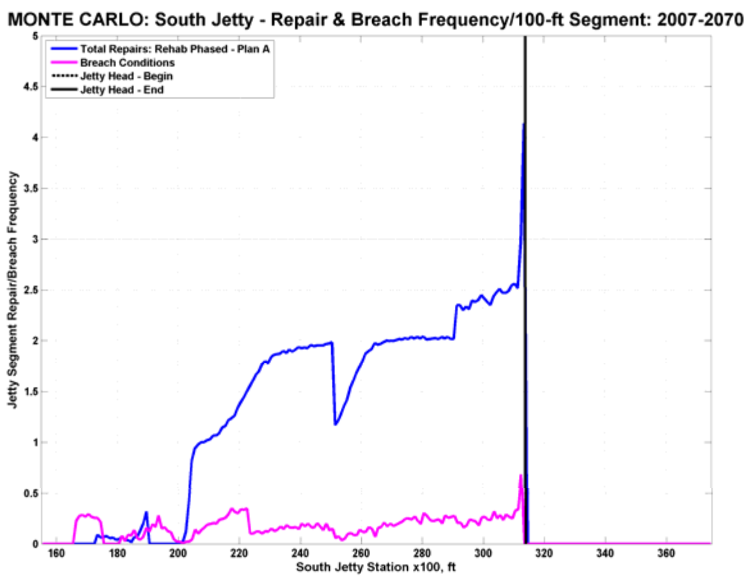

Figure A2-121g. Frequency and location of repairs and breaches for MCR South Jetty. Small Template Rehab - Immediate (Hold Head).

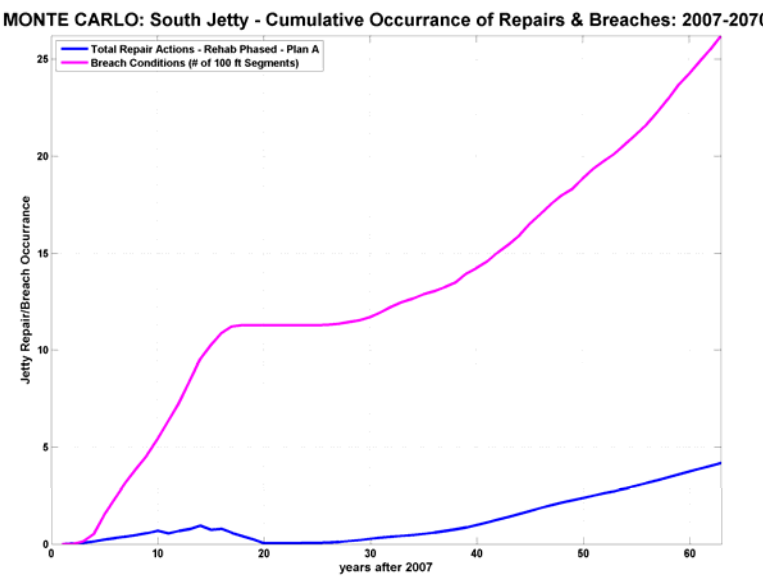

Figure A2-121h. Cumulative occurrence of repairs and breach conditions for MCR South Jetty. Small Template Rehab - Immediate (Hold Head).

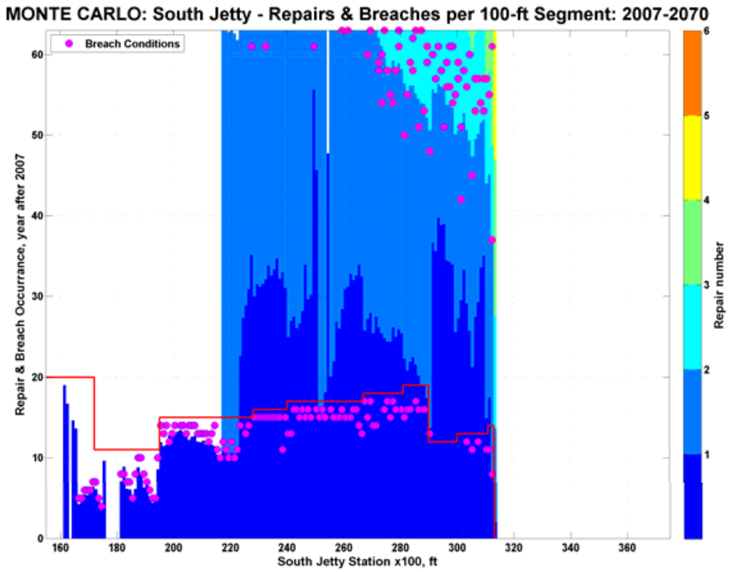

Figure A2-122a. Forecast repair occurrence for MCR South Jetty, shown for each 100 ft jetty segment. Moderate Template Rehab - Immediate (Hold Head). RED line marks time of REHAB phase implementation

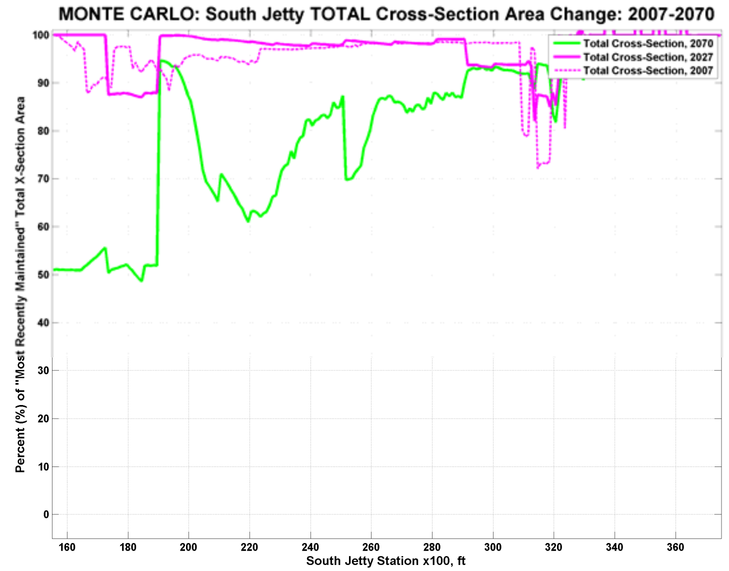

Figure A2-122b. Variation in total cross-section area along MCR South Jetty during forecast period. Moderate Template Rehab - Immediate (Hold Head).RED line marks time of REHAB phase implementation

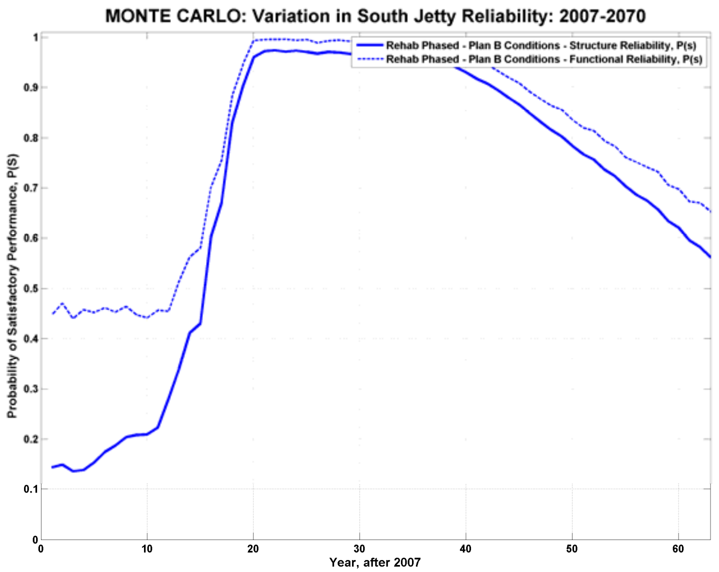

Figure A2-122c. Forecast reliability for MCR South Jetty. Moderate Template Rehab - Immediate (Hold Head).

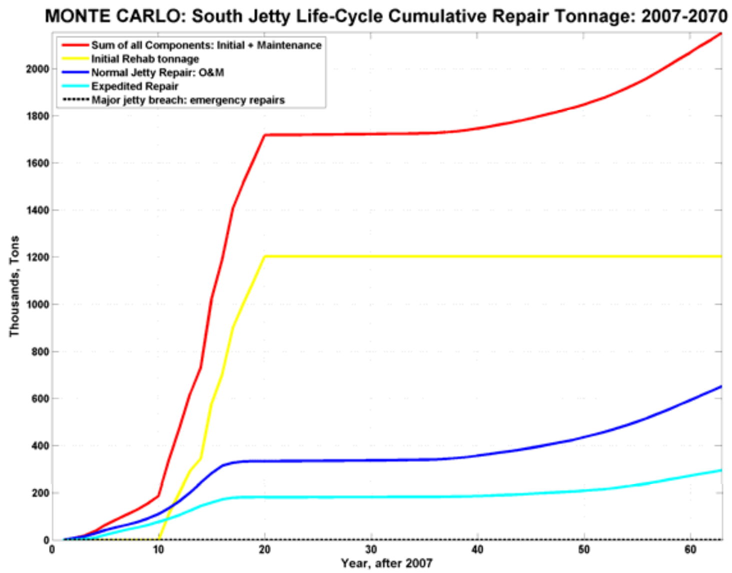

Figure A2-122d. Life-cycle cumulative repair tonnage for MCR South Jetty. Moderate Template Rehab - Immediate (Hold Head).

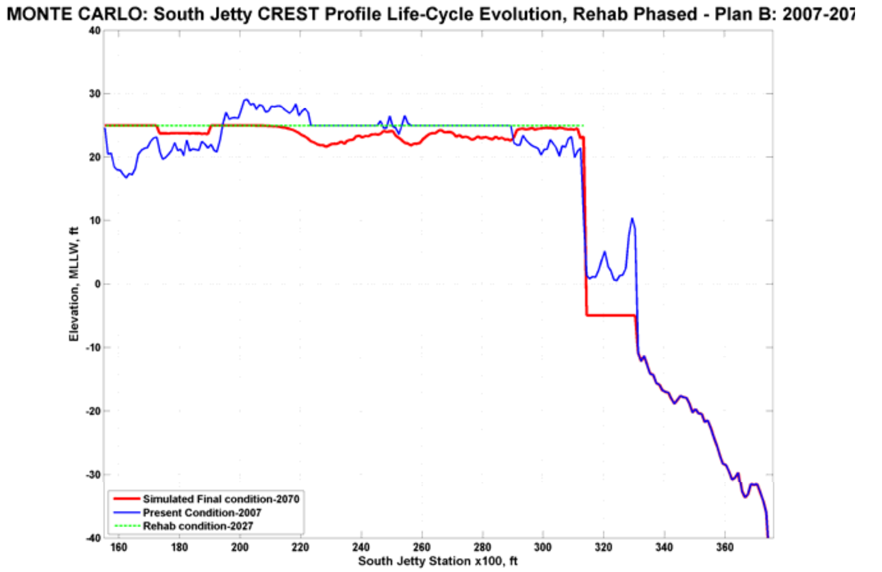

Figure A2-122e. Centerline profile for MCR South Jetty. Moderate Template Rehab - Immediate (Hold Head).

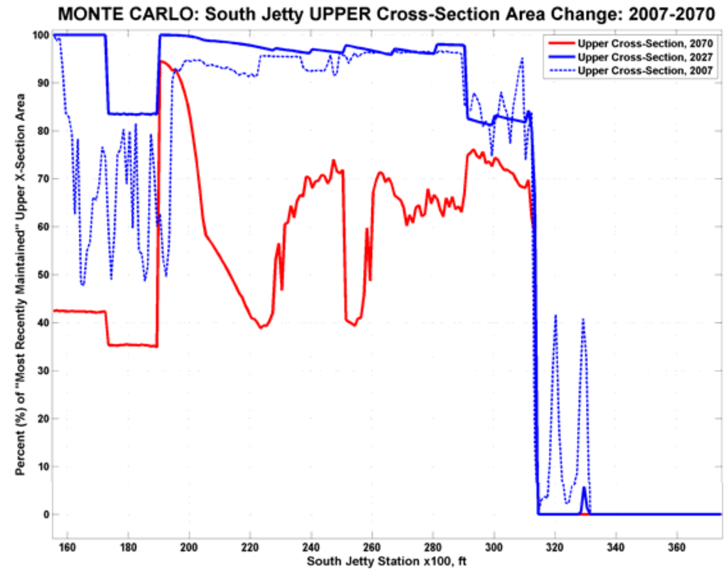

Figure A2-122f. Variation of upper cross-section area for given station of MCR South Jetty. Moderate Template Rehab - Immediate (Hold Head).

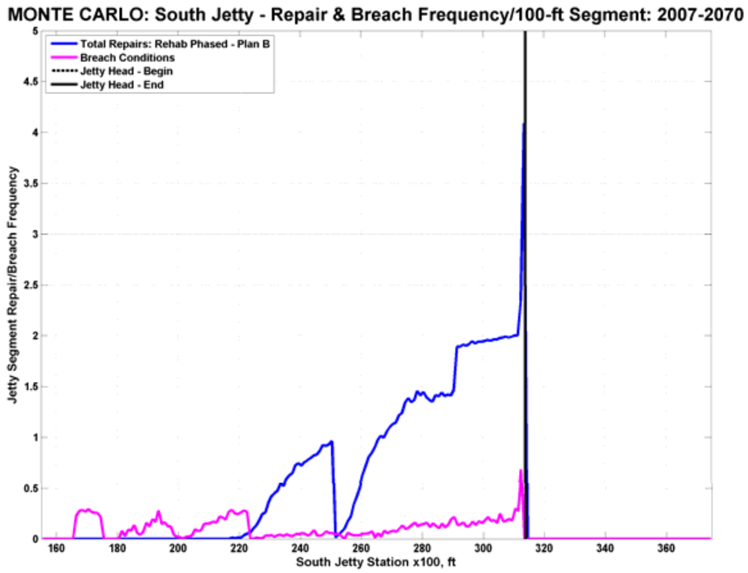

Figure A2-122g. Frequency and location of repairs and breaches for MCR South Jetty. Moderate Template Rehab - Immediate (Hold Head).

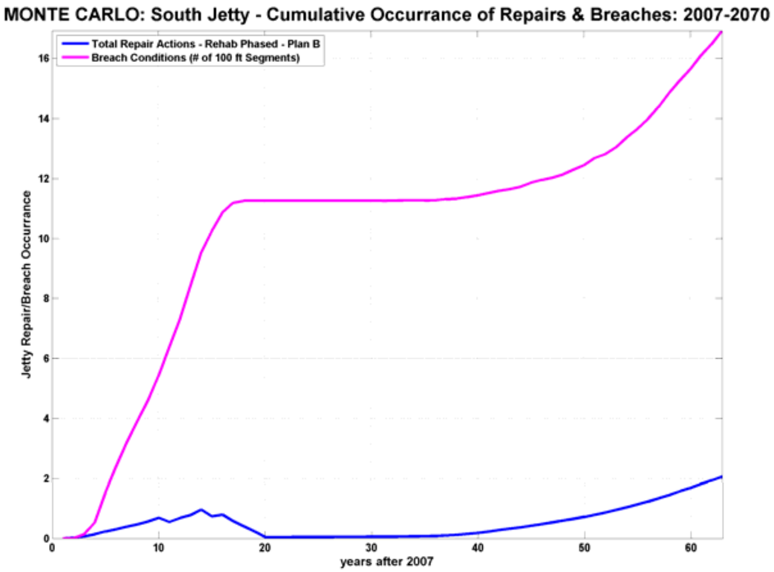

Figure A2-122h. Cumulative occurrence of repairs and breach conditions for MCR South Jetty. Moderate Template Rehab - Immediate (Hold Head).

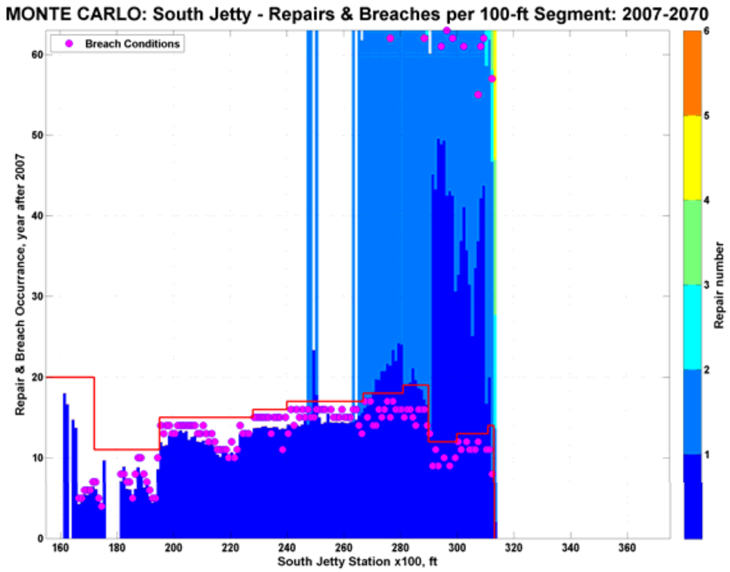

Figure A2-123a. Forecast repair occurrence for MCR South Jetty, shown for each 100 ft jetty segment. Large Template Rehab - Immediate (Hold Head). RED line marks time of REHAB phase implementation

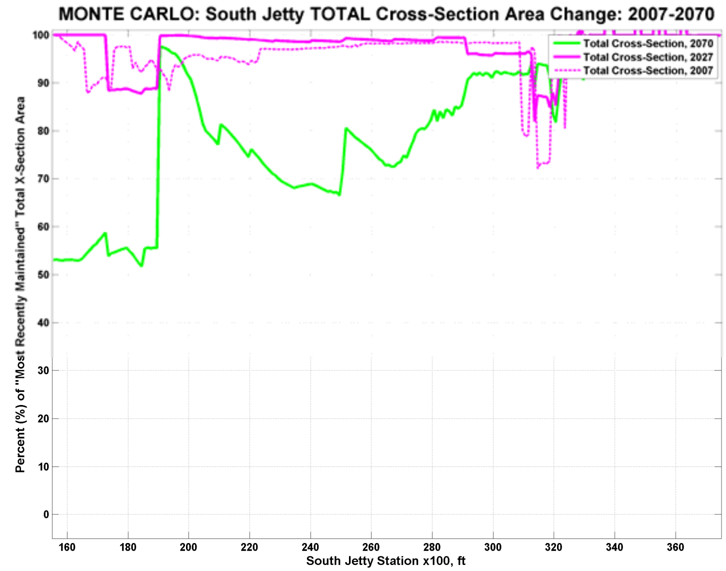

Figure A2-123b. Variation in total cross-section area along MCR South Jetty during forecast period. Large Template Rehab - Immediate (Hold Head).RED line marks time of REHAB phase implementation

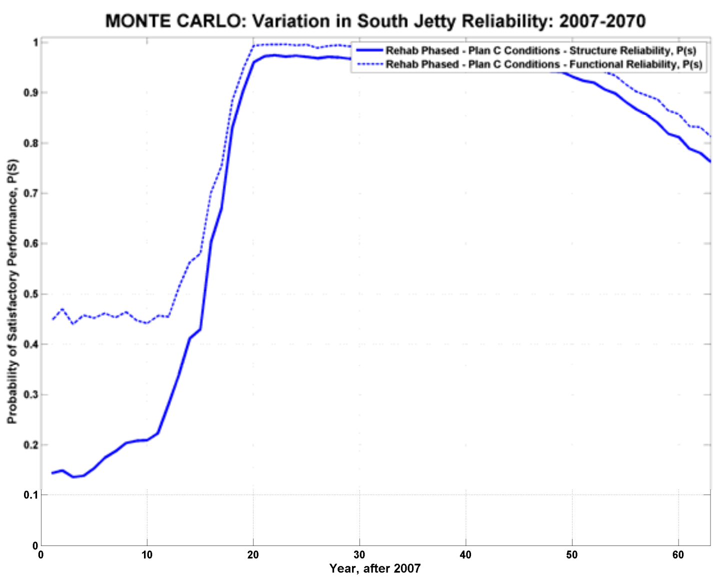

Figure A2-123c. Forecast reliability for MCR South Jetty. Large Template Rehab - Immediate (Hold Head).

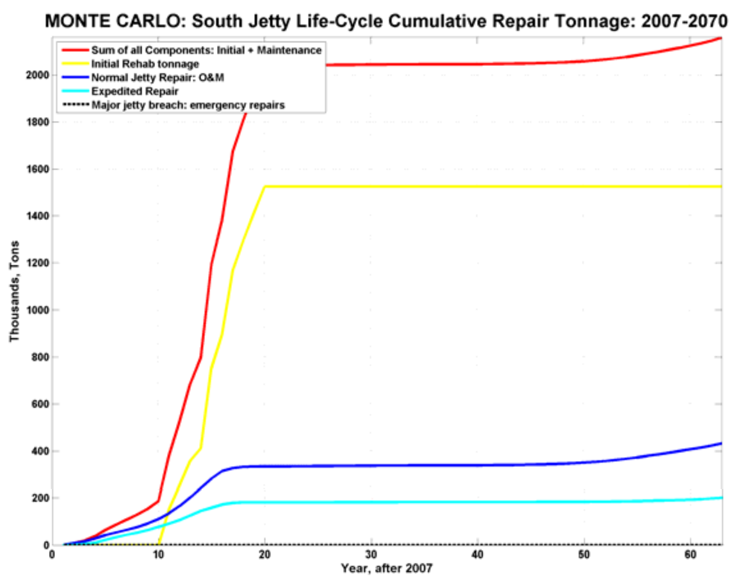

Figure A2-123d. Life-cycle cumulative repair tonnage for MCR South Jetty. Large Template Rehab - Immediate (Hold Head).

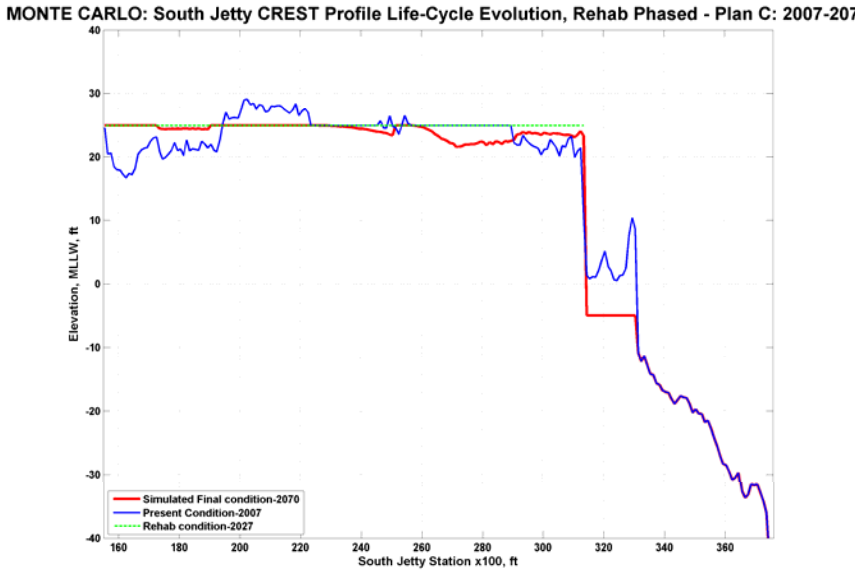

Figure A2-123e. Centerline profile for MCR South Jetty. Large Template Rehab - Immediate (Hold Head).

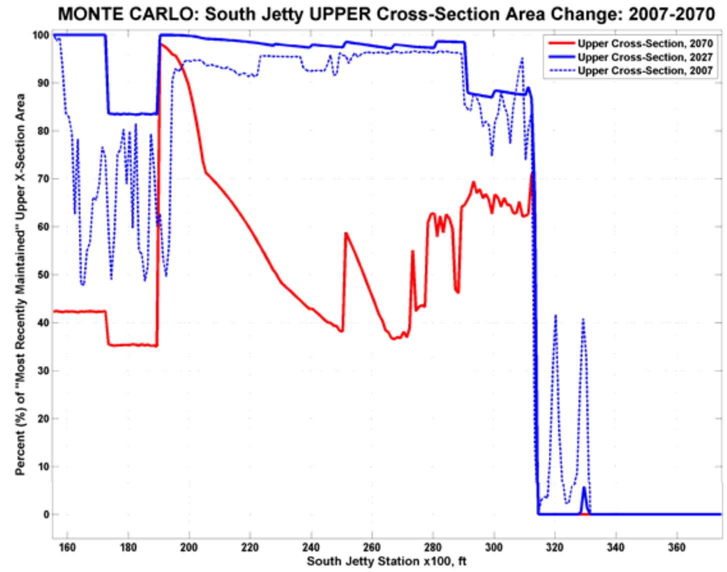

Figure A2-123f. Variation of upper cross-section area for given station of MCR South Jetty. Large Template Rehab - Immediate (Hold Head).

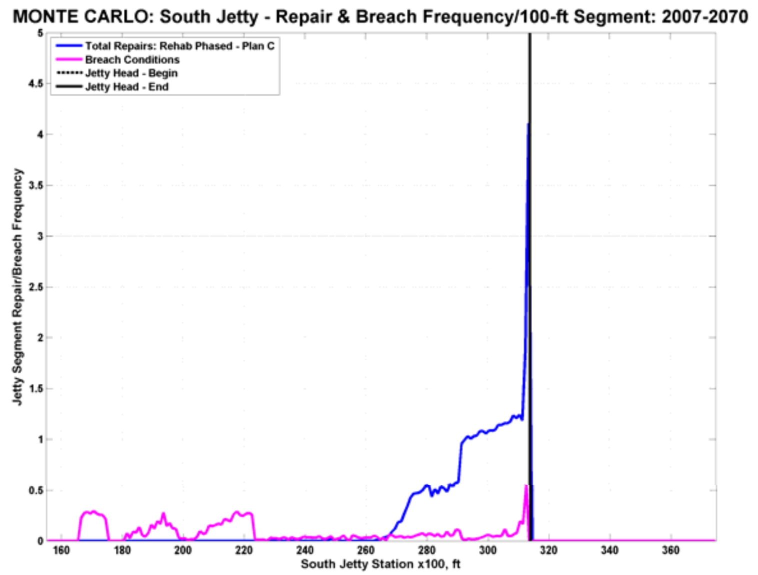

Figure A2-123g. Frequency and location of repairs and breaches for MCR South Jetty. Large Template Rehab - Immediate (Hold Head).

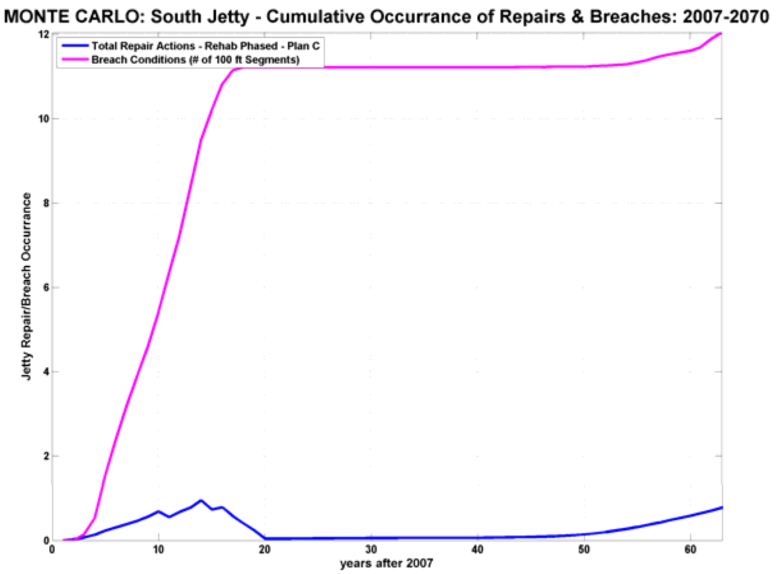

Figure A2-123h. Cumulative occurrence of repairs and breach conditions for MCR South Jetty. Large Template Rehab - Immediate (Hold Head).

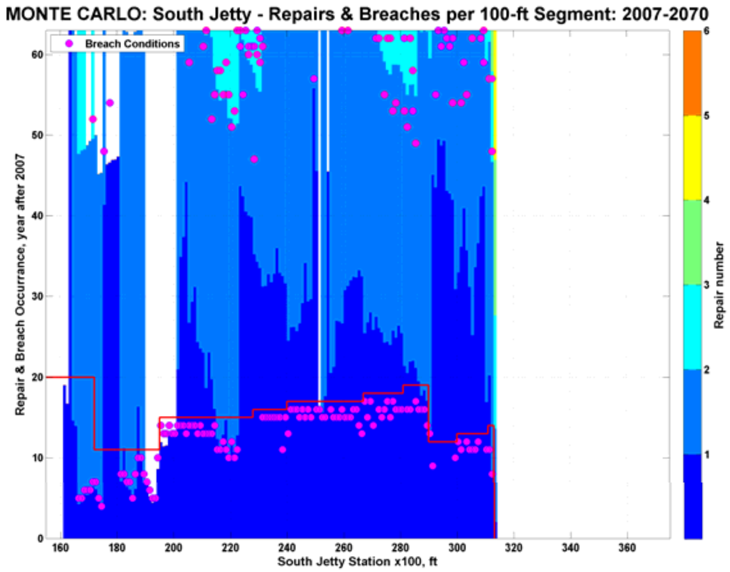

Figure A2-124a. Forecast repair occurrence for MCR South Jetty, shown for each 100 ft jetty segment. Composite 4 Medium Rehab - Immediate (Hold Head). RED line marks time of REHAB phase implementation

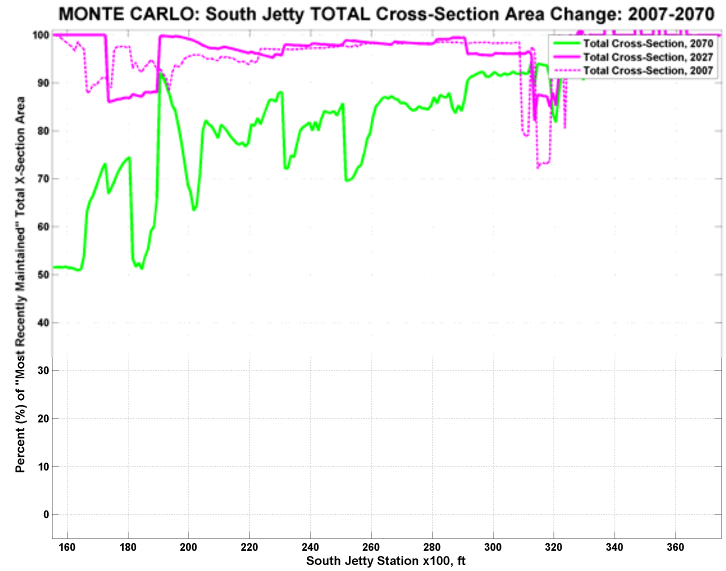

Figure A2-124b. Variation in total cross-section area along MCR South Jetty during forecast period. Composite 4 Medium Rehab - Immediate (Hold Head).RED line marks time of REHAB phase implementation

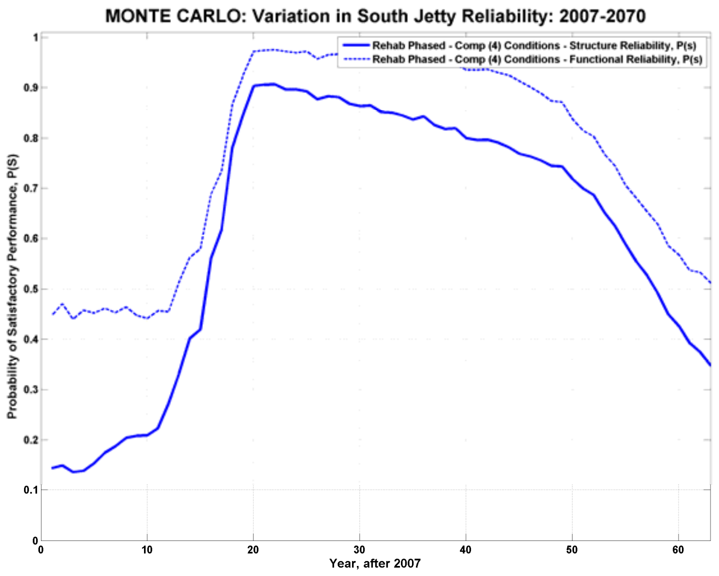

Figure A2-124c. Forecast reliability for MCR South Jetty. Composite 4 Medium Rehab - Immediate (Hold Head).

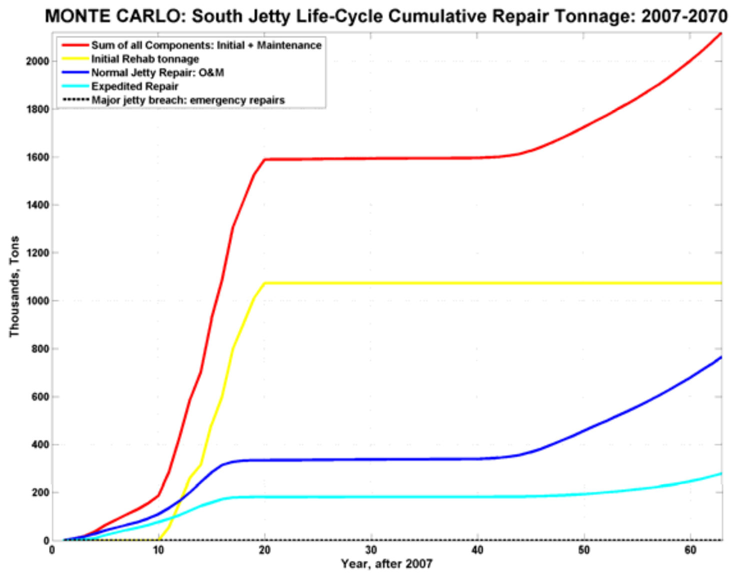

Figure A2-124d. Life-cycle cumulative repair tonnage for MCR South Jetty. Composite 4 Medium Rehab - Immediate (Hold Head).

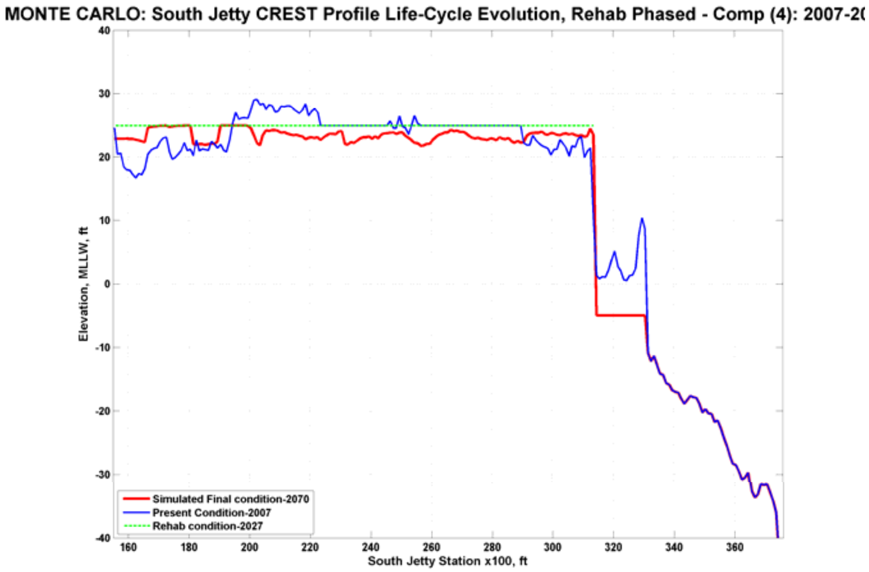

Figure A2-124e. Centerline profile for MCR South Jetty. Composite 4 Medium Rehab - Immediate (Hold Head).

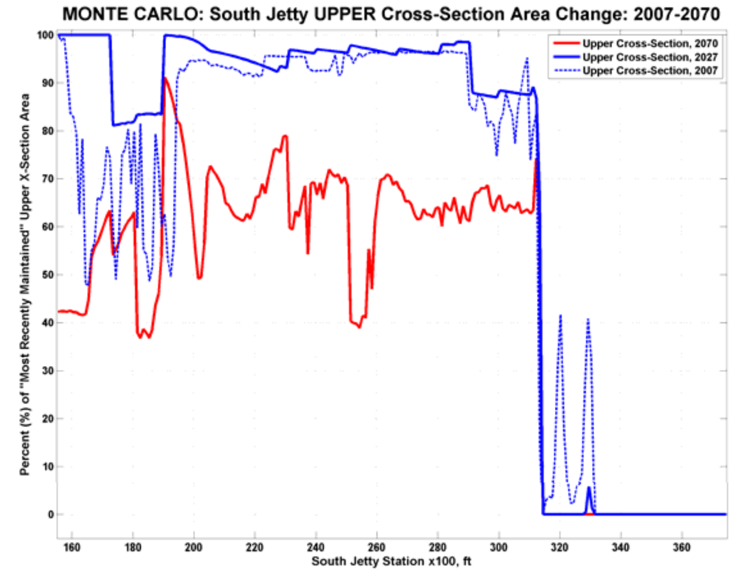

Figure A2-124f. Variation of upper cross-section area for given station of MCR South Jetty. Composite 4 Medium Rehab - Immediate (Hold Head).

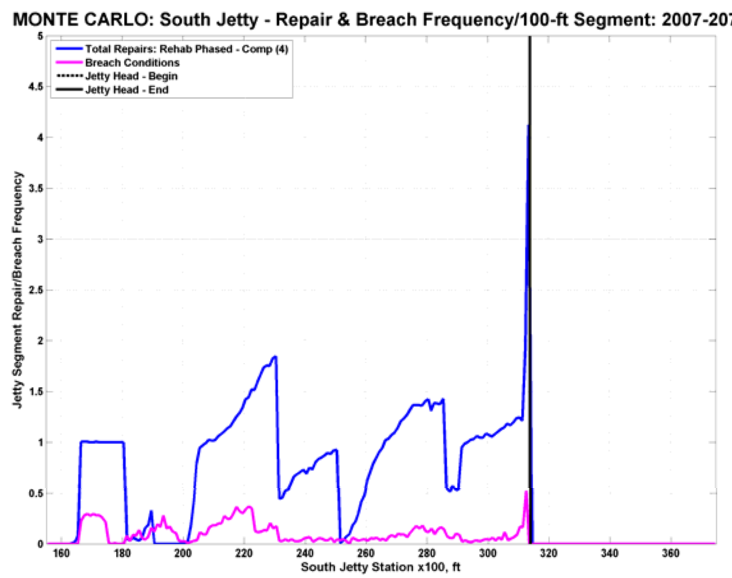

Figure A2-124g. Frequency and location of repairs and breaches for MCR South Jetty. Composite 4 Medium Rehab - Immediate (Hold Head).

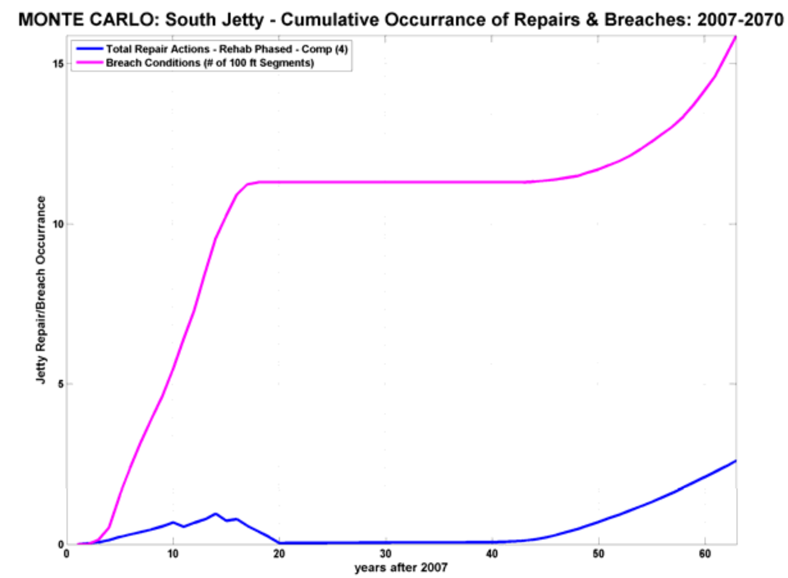

Figure A2-124h. Cumulative occurrence of repairs and breach conditions for MCR South Jetty. Composite 4 Medium Rehab - Immediate (Hold Head).

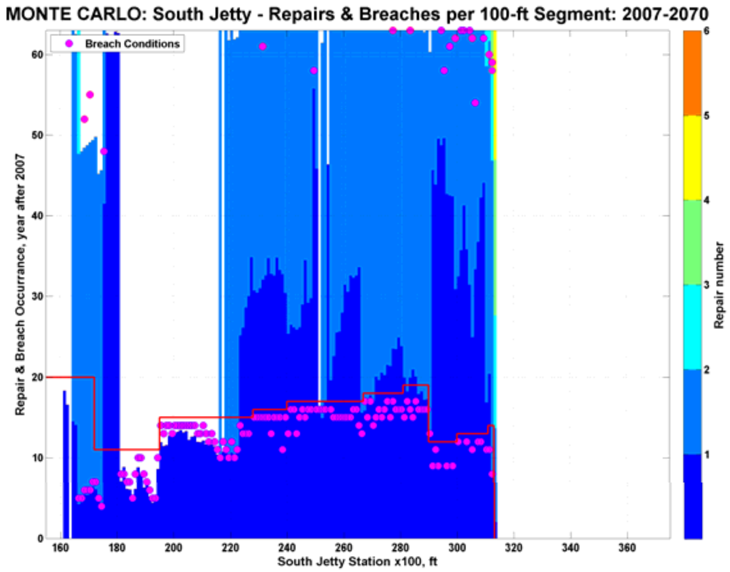

Figure A2-125a. Forecast repair occurrence for MCR South Jetty, shown for each 100 ft jetty segment. Composite 1 Large Rehab - Immediate (Hold Head). RED line marks time of REHAB phase implementation

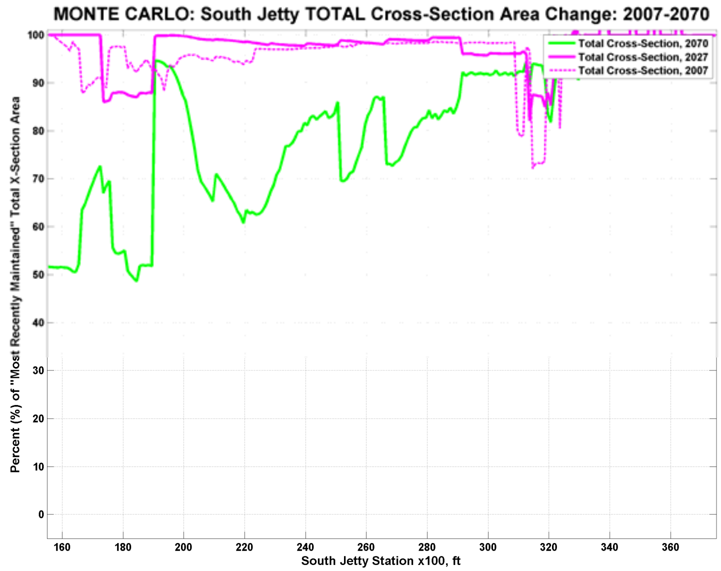

Figure A2-125b. Variation in total cross-section area along MCR South Jetty during forecast period. Composite 1 Large Rehab - Immediate (Hold Head).RED line marks time of REHAB phase implementation

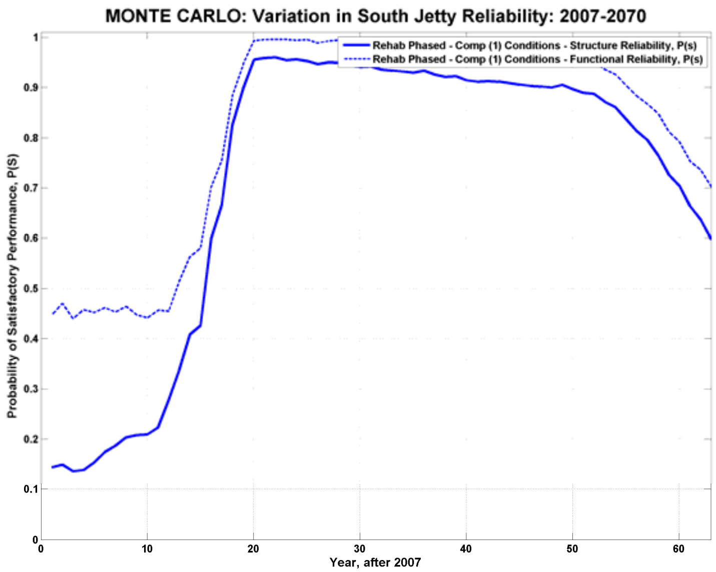

Figure A2-125c. Forecast reliability for MCR South Jetty. Composite 1 Large Rehab - Immediate (Hold Head).

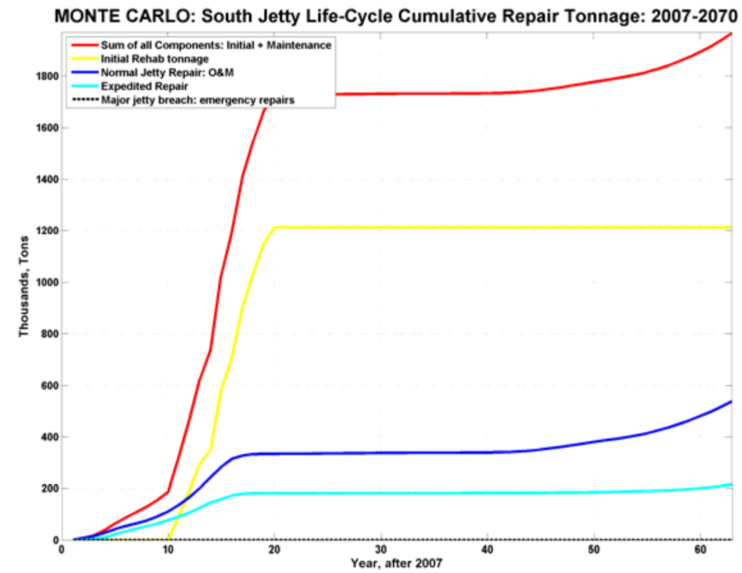

Figure A2-125d. Life-cycle cumulative repair tonnage for MCR South Jetty. Composite 1 Large Rehab - Immediate (Hold Head).

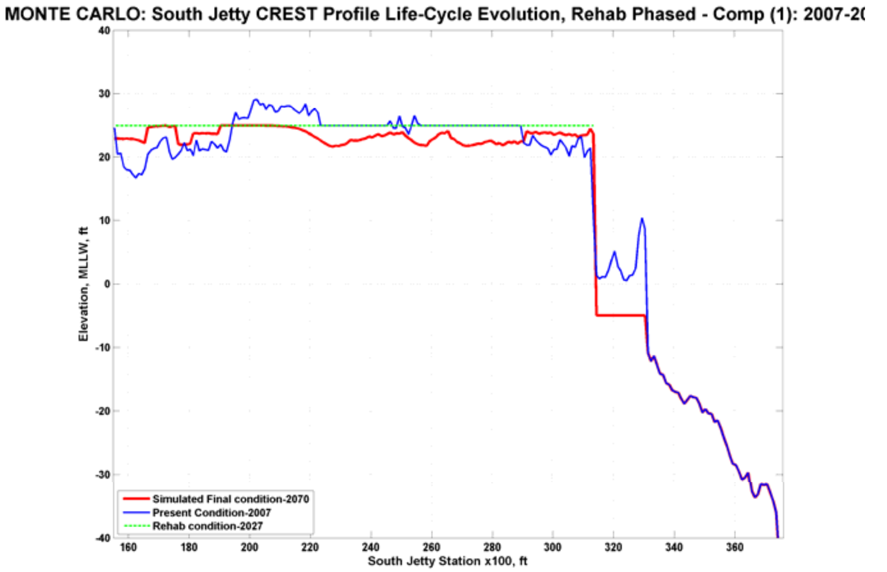

Figure A2-125e. Centerline profile for MCR South Jetty. Composite 1 Large Rehab - Immediate (Hold Head).

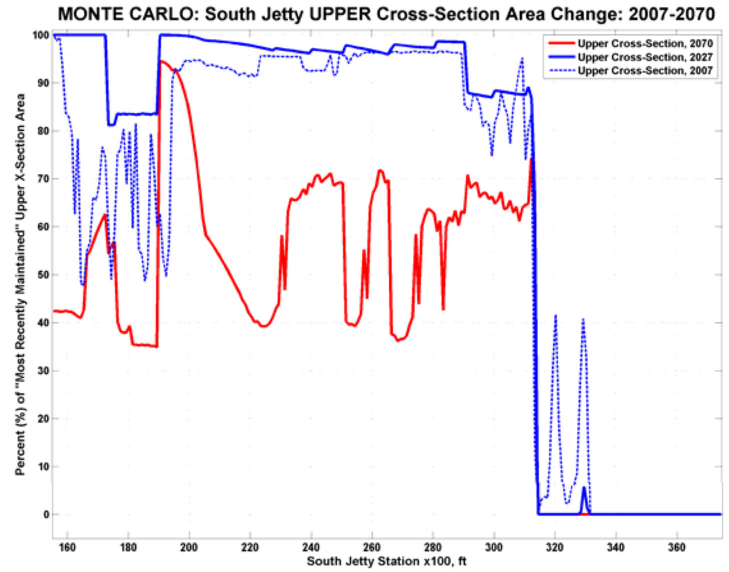

Figure A2-125f. Variation of upper cross-section area for given station of MCR South Jetty. Composite 1 Large Rehab - Immediate (Hold Head).

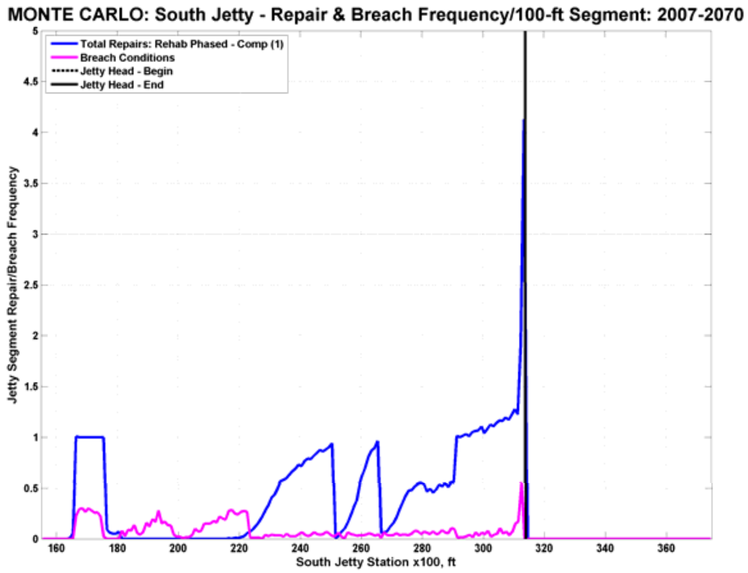

Figure A2-125g. Frequency and location of repairs and breaches for MCR South Jetty. Composite 1 Large Rehab - Immediate (Hold Head).

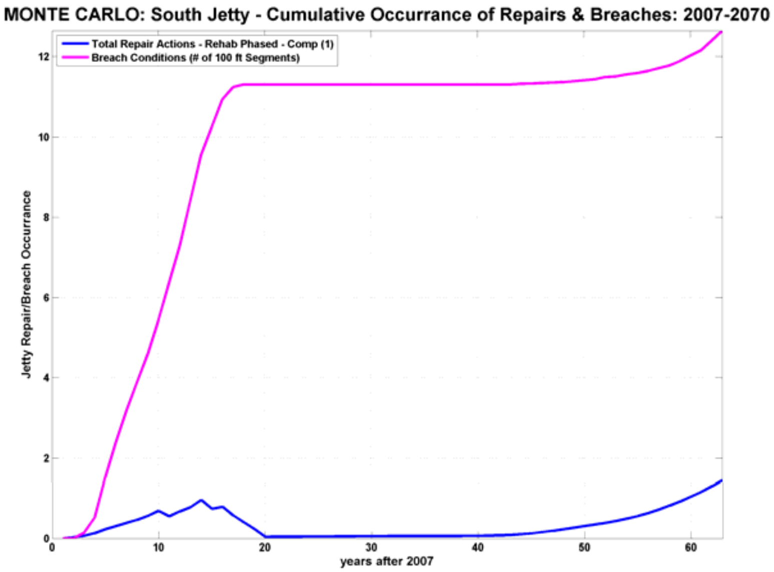

Figure A2-125h. Cumulative occurrence of repairs and breach conditions for MCR South Jetty. Composite 1 Large Rehab - Immediate (Hold Head).

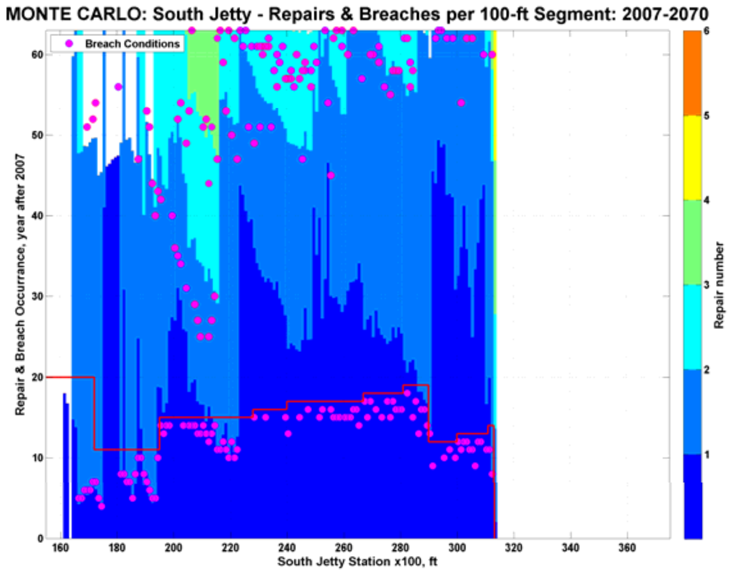

Figure A2-126a. Forecast repair occurrence for MCR South Jetty, shown for each 100 ft jetty segment. Composite 5 Modified 2 Rehab - Immediate (Hold Head). RED line marks time of REHAB phase implementation

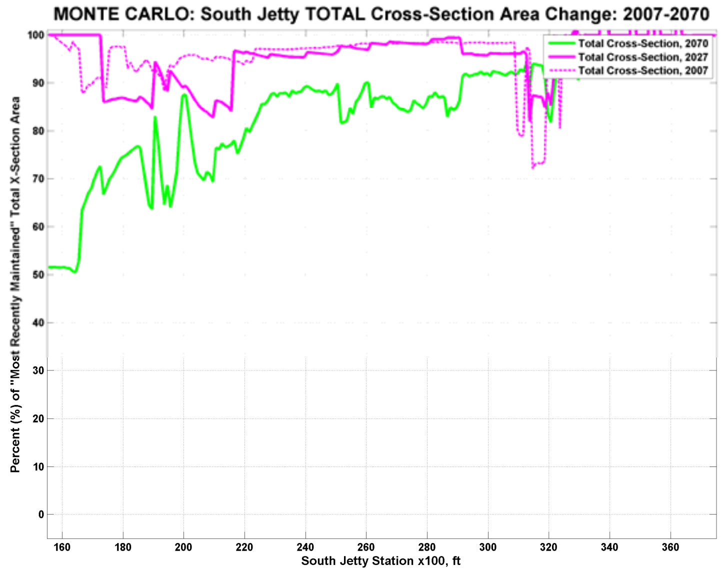

Figure A2-126b. Variation in total cross-section area along MCR South Jetty during forecast period. Composite 5 Modified 2 Rehab - Immediate (Hold Head).RED line marks time of REHAB phase implementation

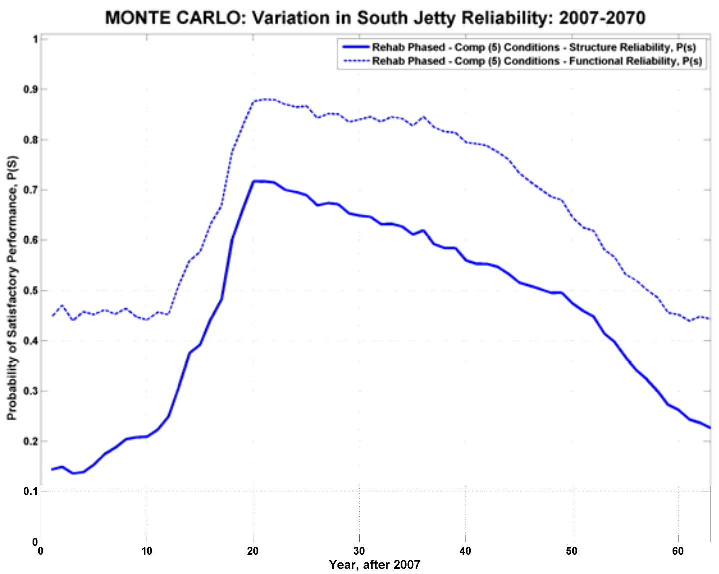

Figure A2-126c. Forecast reliability for MCR South Jetty. Composite 5 Modified 2 Rehab - Immediate (Hold Head).

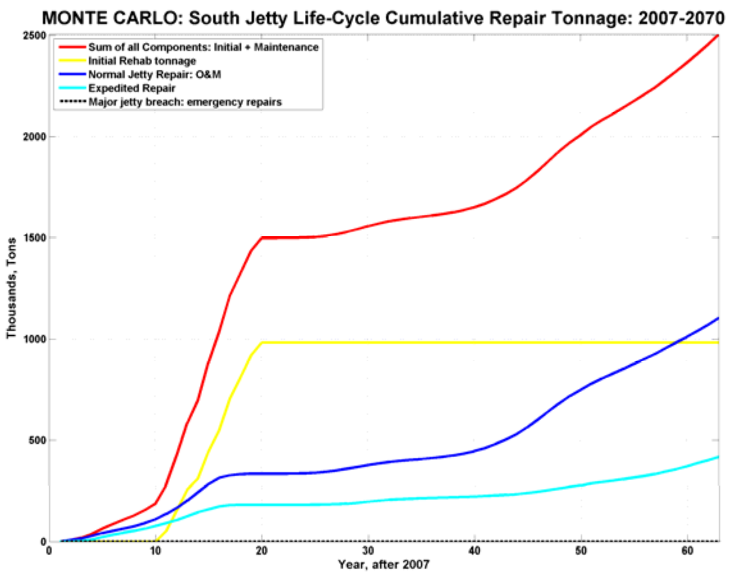

Figure A2-126d. Life-cycle cumulative repair tonnage for MCR South Jetty. Composite 5 Modified 2 Rehab - Immediate (Hold Head).

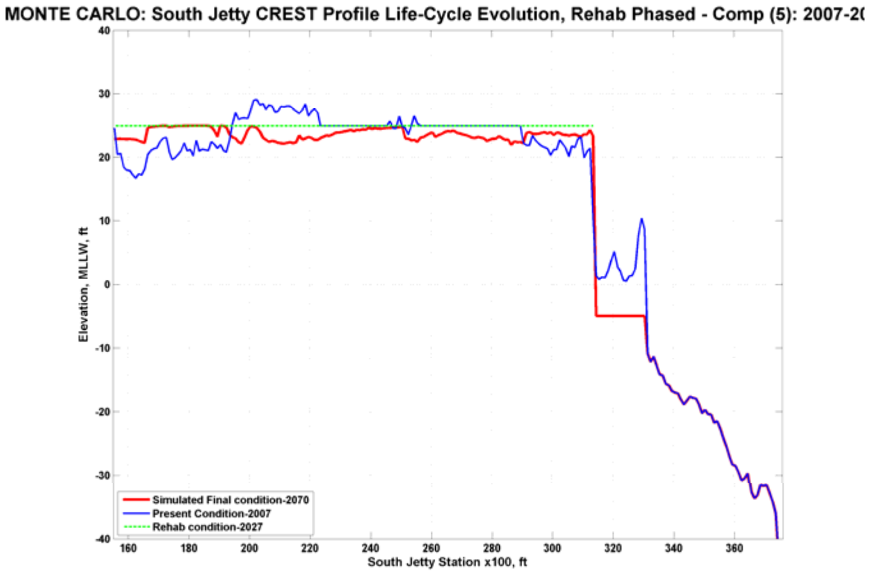

Figure A2-126e. Centerline profile for MCR South Jetty. Composite 5 Modified 2 Rehab - Immediate (Hold Head).

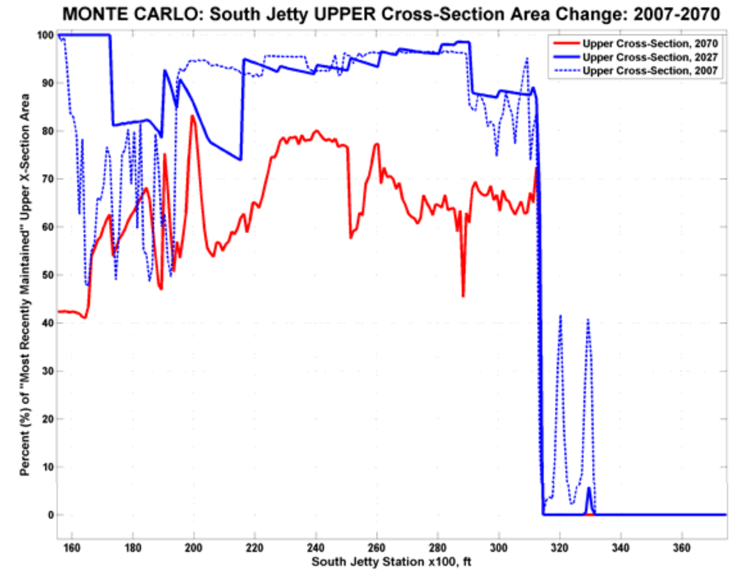

Figure A2-126f. Variation of upper cross-section area for given station of MCR South Jetty. Composite 5 Modified 2 Rehab - Immediate (Hold Head).

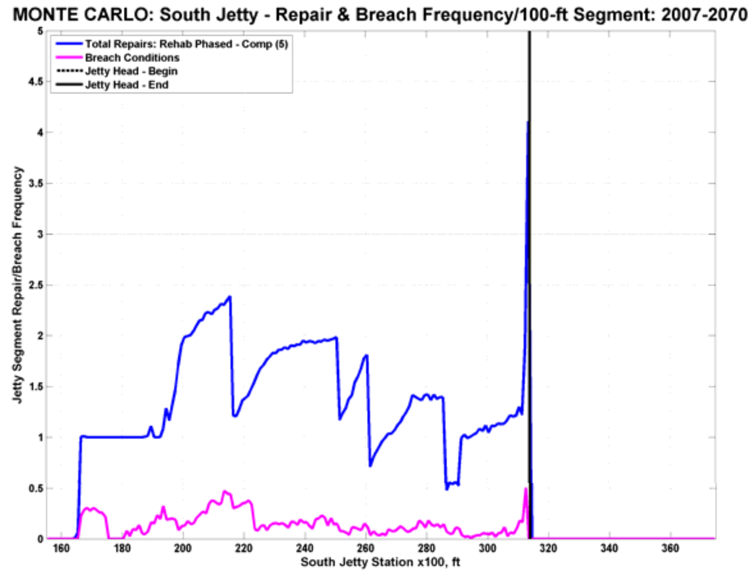

Figure A2-126g. Frequency and location of repairs and breaches for MCR South Jetty. Composite 5 Modified 2 Rehab - Immediate (Hold Head).

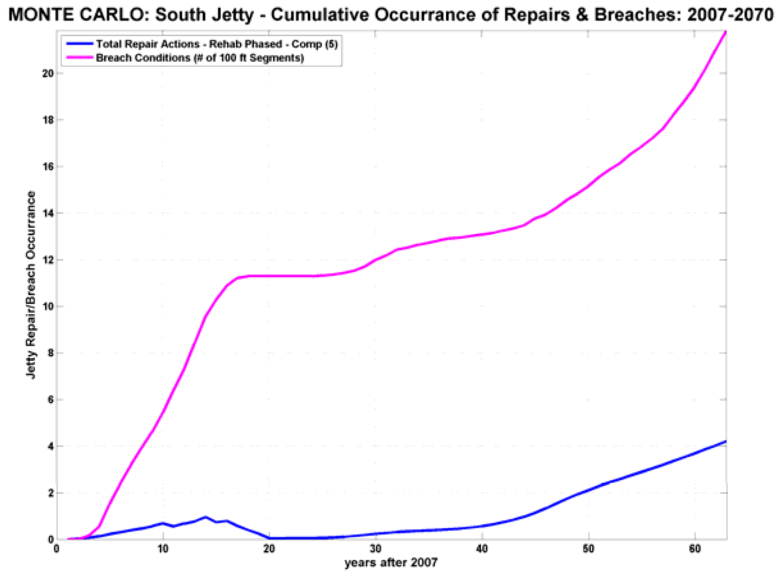

Figure A2-126h. Cumulative occurrence of repairs and breach conditions for MCR South Jetty. Composite 5 Modified 2 Rehab - Immediate (Hold Head).

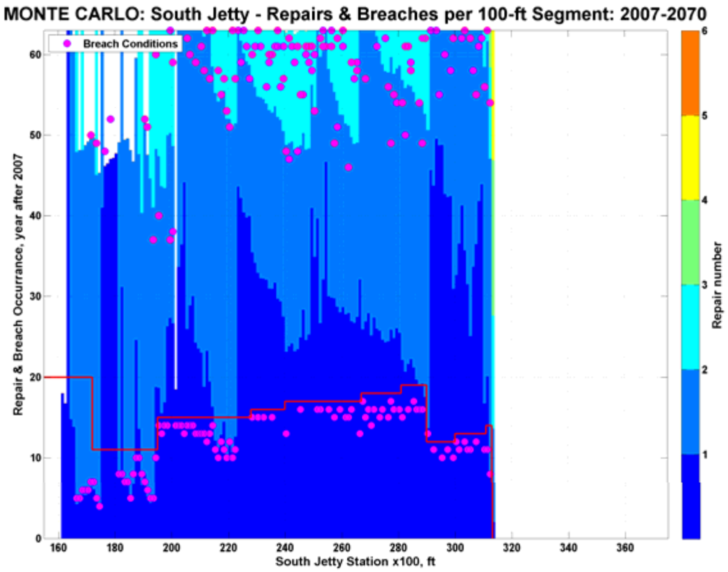

Figure A2-127a. Forecast repair occurrence for MCR South Jetty, shown for each 100 ft jetty segment. Composite 2 Modified 1 Rehab - Immediate (Hold Head). RED line marks time of REHAB phase implementation

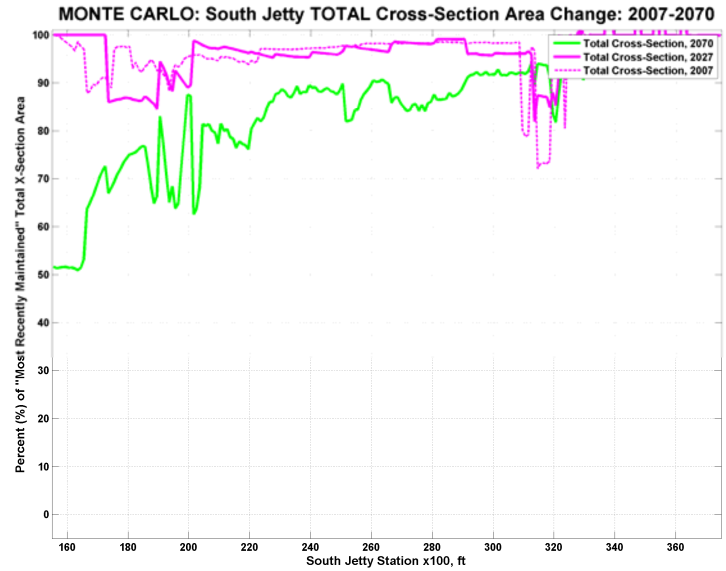

Figure A2-127b. Variation in total cross-section area along MCR South Jetty during forecast period. Composite 2 Modified 1 Rehab - Immediate (Hold Head).RED line marks time of REHAB phase implementation

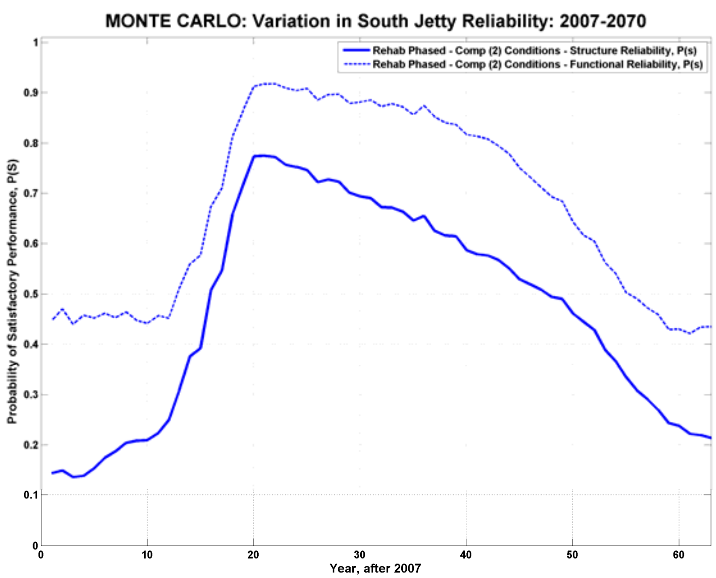

Figure A2-127c. Forecast reliability for MCR South Jetty. Composite 2 Modified 1 Rehab - Immediate (Hold Head).

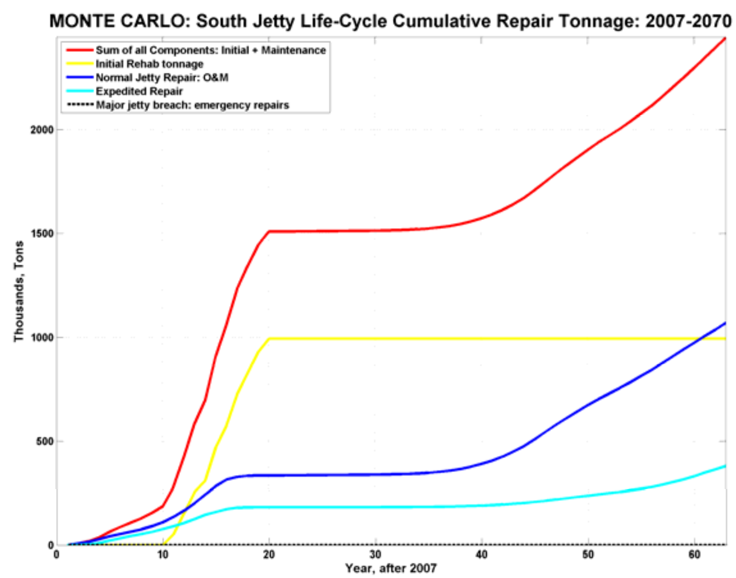

Figure A2-127d. Life-cycle cumulative repair tonnage for MCR South Jetty. Composite 2 Modified 1 Rehab - Immediate (Hold Head).

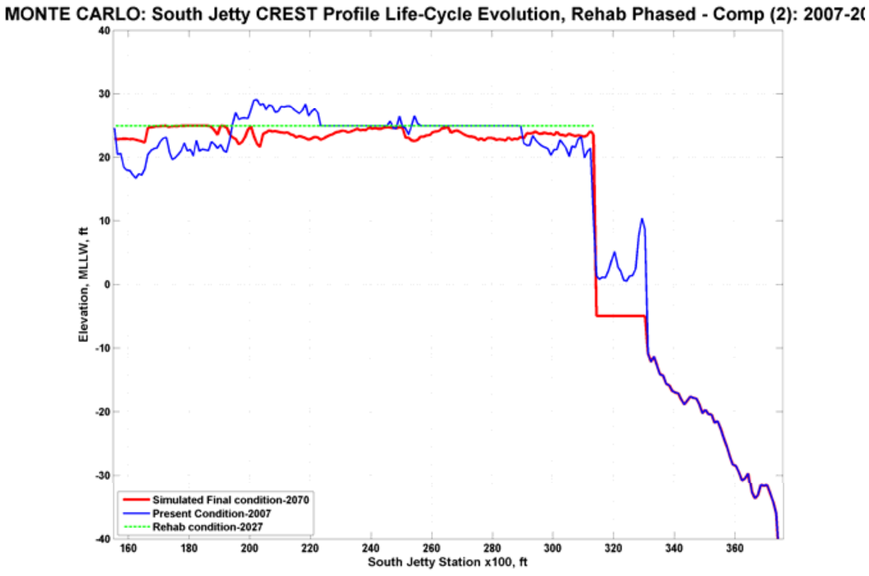

Figure A2-127e. Centerline profile for MCR South Jetty. Composite 2 Modified 1 Rehab - Immediate (Hold Head).

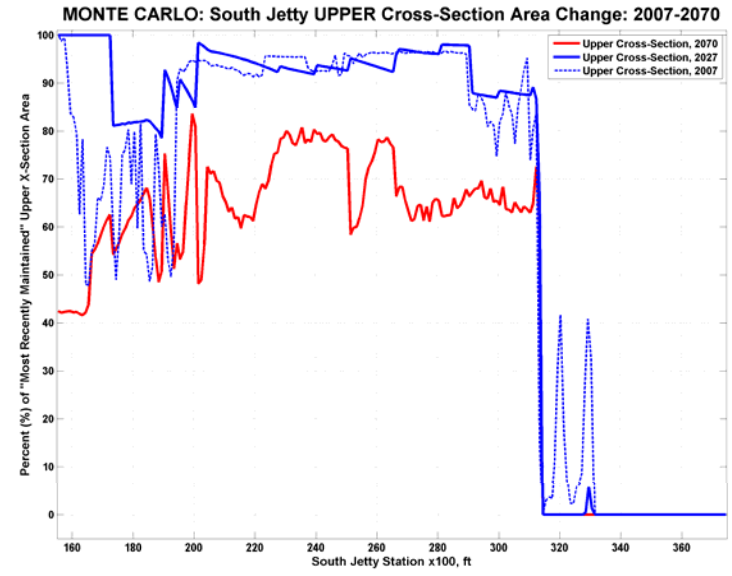

Figure A2-127f. Variation of upper cross-section area for given station of MCR South Jetty. Composite 2 Modified 1 Rehab - Immediate (Hold Head).

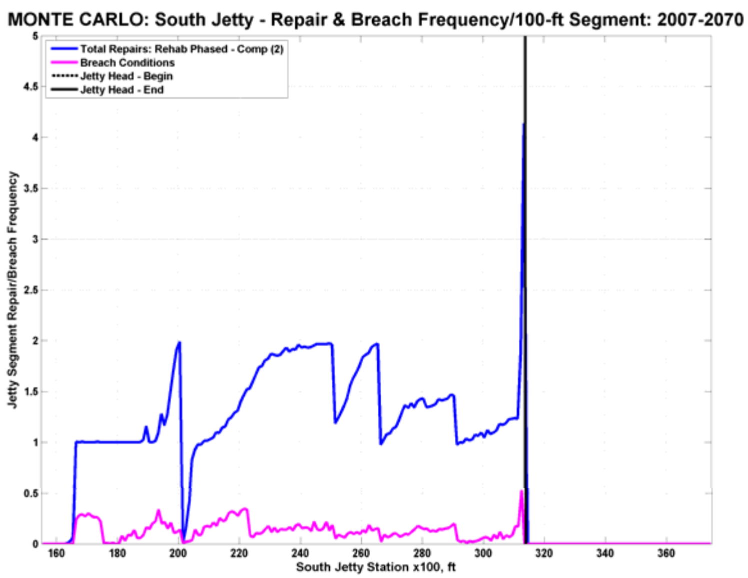

Figure A2-127g. Frequency and location of repairs and breaches for MCR South Jetty. Composite 2 Modified 1 Rehab - Immediate (Hold Head).

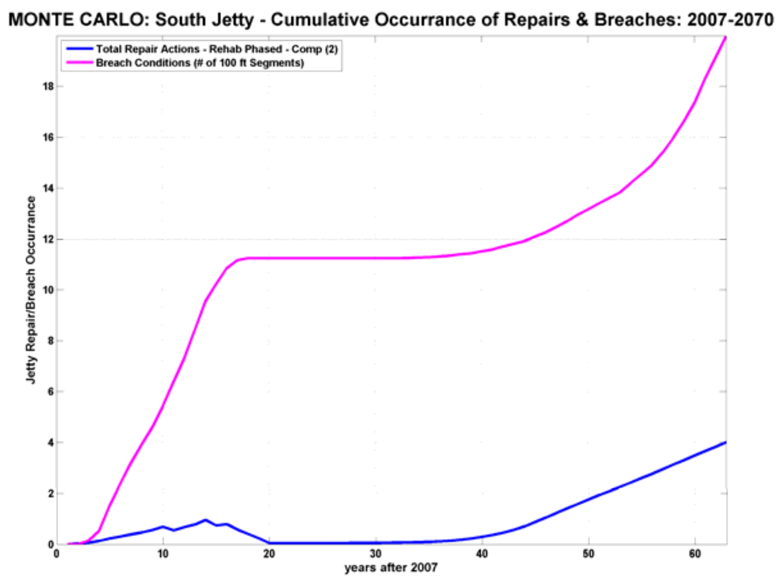

Figure A2-127h. Cumulative occurrence of repairs and breach conditions for MCR South Jetty. Composite 2 Modified 1 Rehab - Immediate (Hold Head).

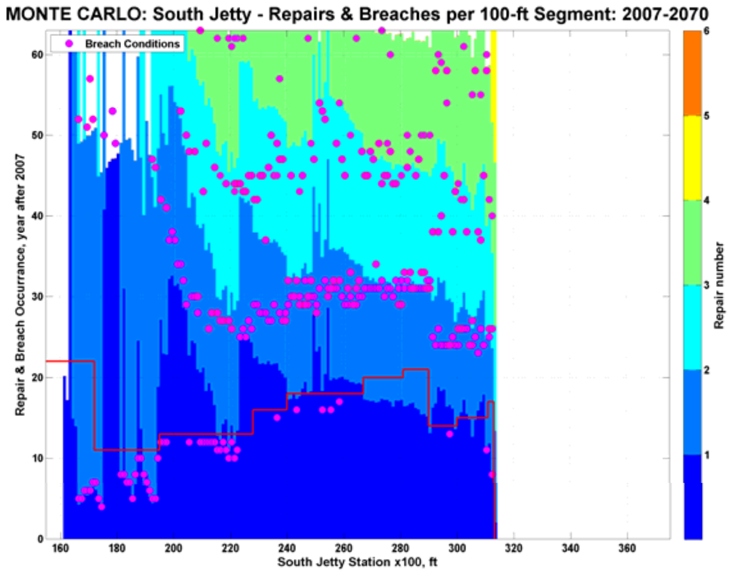

Figure A2-128a. Forecast repair occurrence for MCR South Jetty, shown for each 100 ft jetty segment. Minimum Template Rehab - Scheduled (Hold Head). RED line marks time of REHAB phase implementation

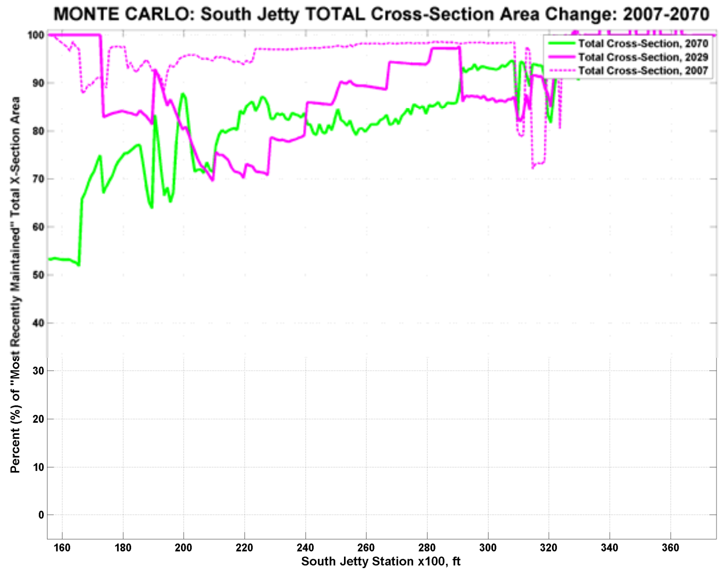

Figure A2-128b. Variation in total cross-section area along MCR South Jetty during forecast period. Minimum Template Rehab - Scheduled (Hold Head).RED line marks time of REHAB phase implementation

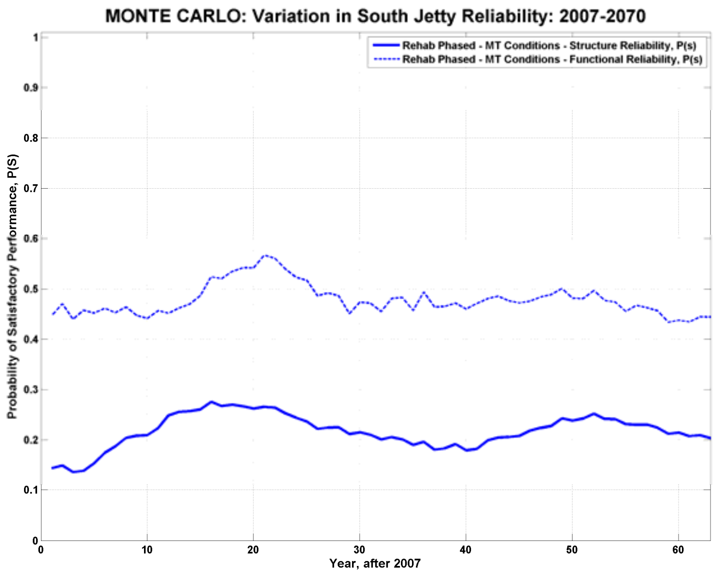

Figure A2-128c. Forecast reliability for MCR South Jetty. Minimum Template Rehab - Scheduled (Hold Head).

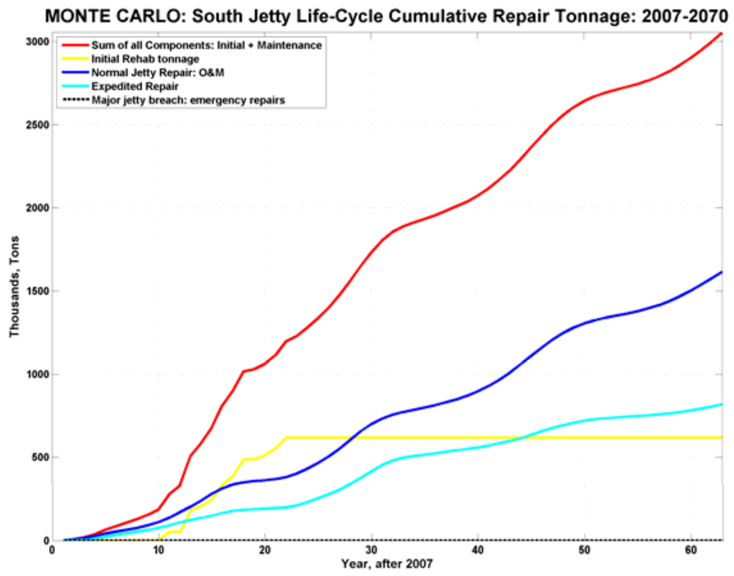

Figure A2-128d. Life-cycle cumulative repair tonnage for MCR South Jetty. Minimum Template Rehab - Scheduled (Hold Head).

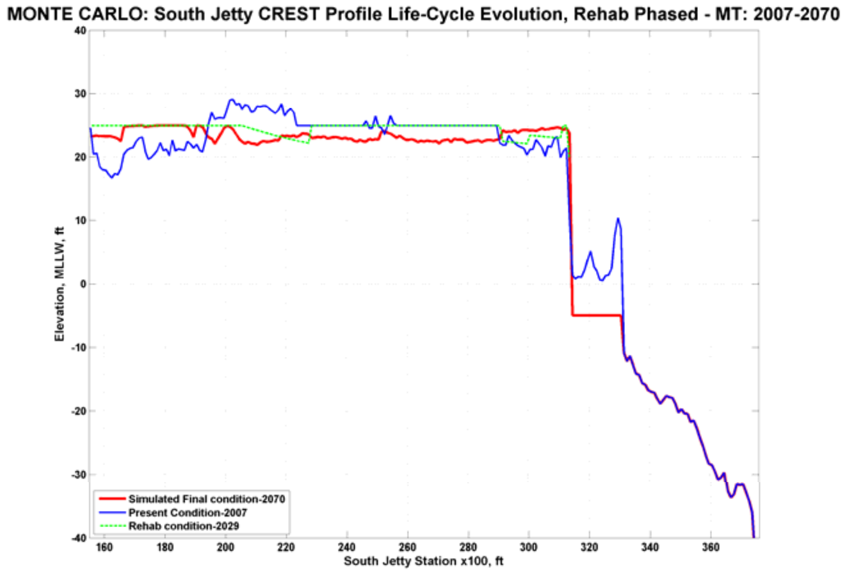

Figure A2-128e. Centerline profile for MCR South Jetty. Minimum Template Rehab - Scheduled (Hold Head).

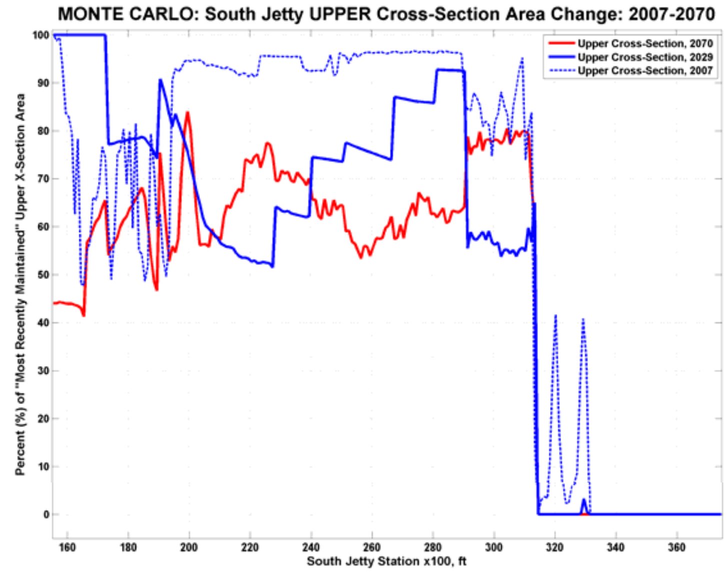

Figure A2-128f. Variation of upper cross-section area for given station of MCR South Jetty. Minimum Template Rehab - Scheduled (Hold Head).

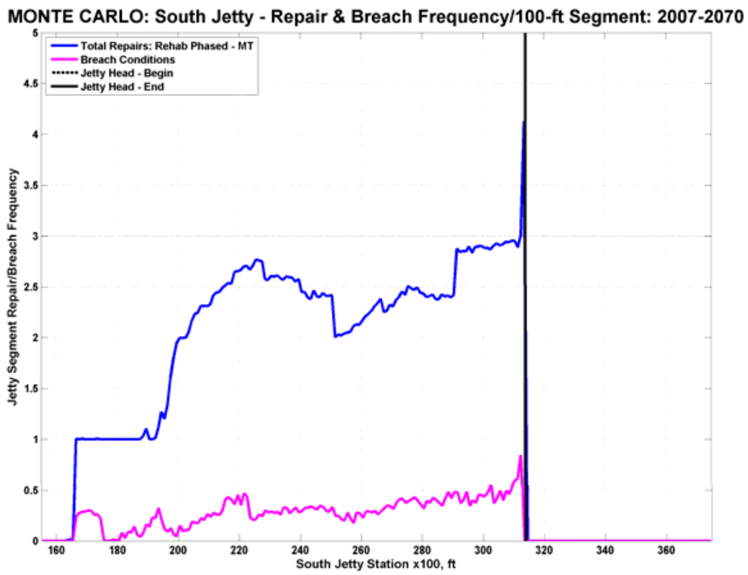

Figure A2-128g. Frequency and location of repairs and breaches for MCR South Jetty. Minimum Template Rehab - Scheduled (Hold Head).

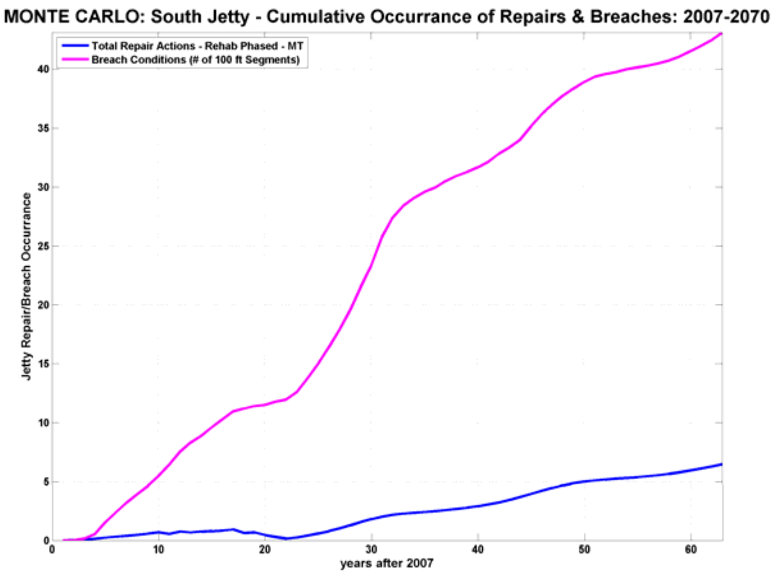

Figure A2-128h. Cumulative occurrence of repairs and breach conditions for MCR South Jetty. Minimum Template Rehab - Scheduled (Hold Head).

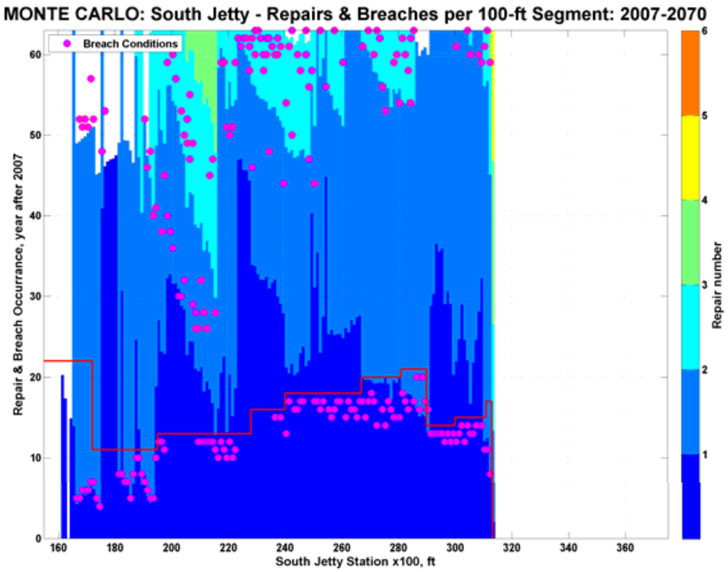

Figure A2-129a. Forecast repair occurrence for MCR South Jetty, shown for each 100 ft jetty segment. Composite 5 Modified 2 Rehab - Scheduled (Hold Head). RED line marks time of REHAB phase implementation

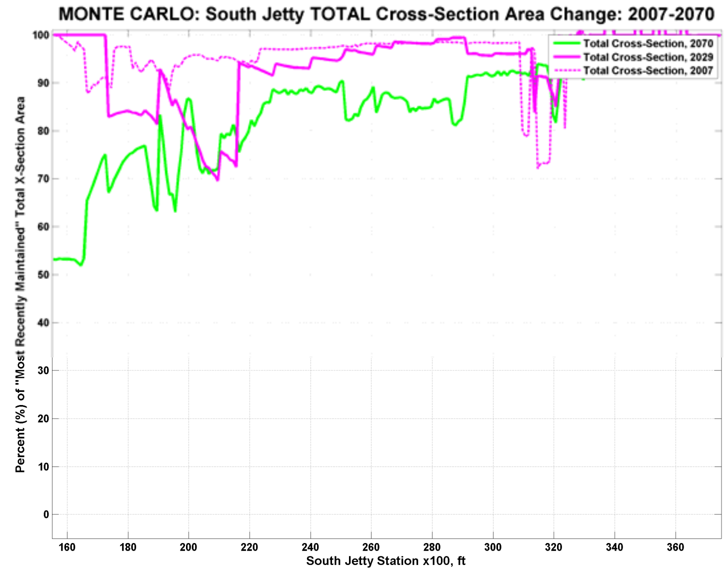

Figure A2-129b. Variation in total cross-section area along MCR South Jetty during forecast period. Composite 5 Modified 2 Rehab - Scheduled (Hold Head).RED line marks time of REHAB phase implementation

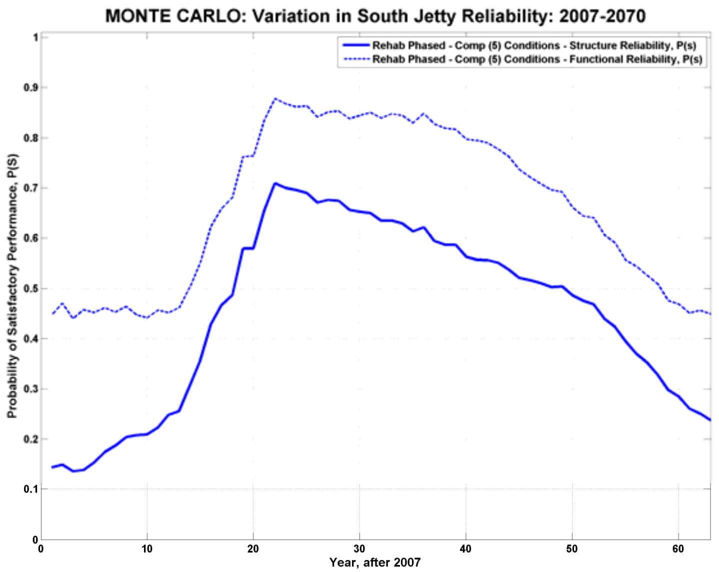

Figure A2-129c. Forecast reliability for MCR South Jetty. Composite 5 Modified 2 Rehab - Scheduled (Hold Head).

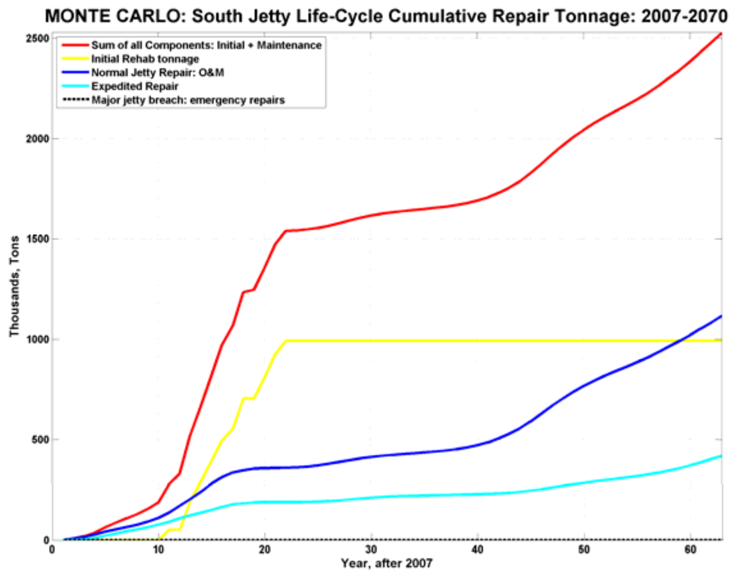

Figure A2-129d. Life-cycle cumulative repair tonnage for MCR South Jetty. Composite 5 Modified 2 Rehab - Scheduled (Hold Head).

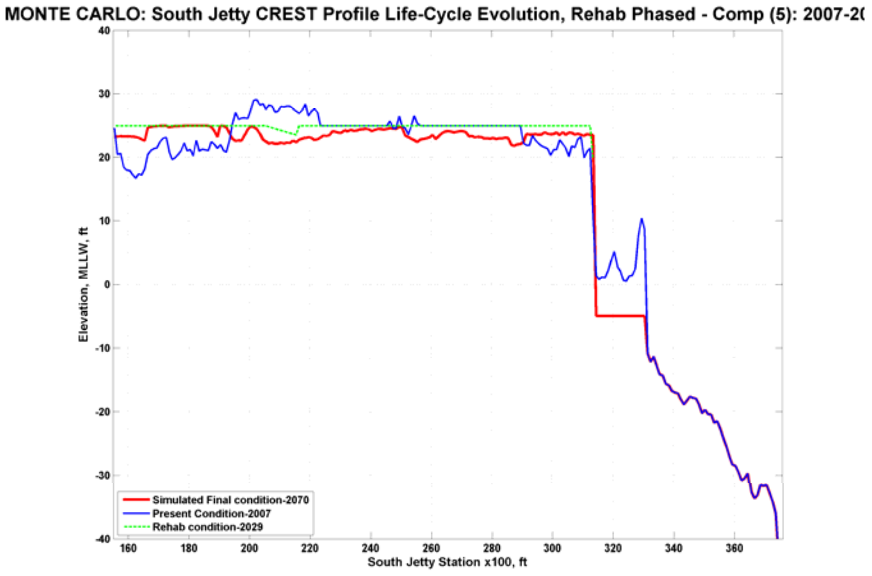

Figure A2-129e. Centerline profile for MCR South Jetty. Composite 5 Modified 2 Rehab - Scheduled (Hold Head).

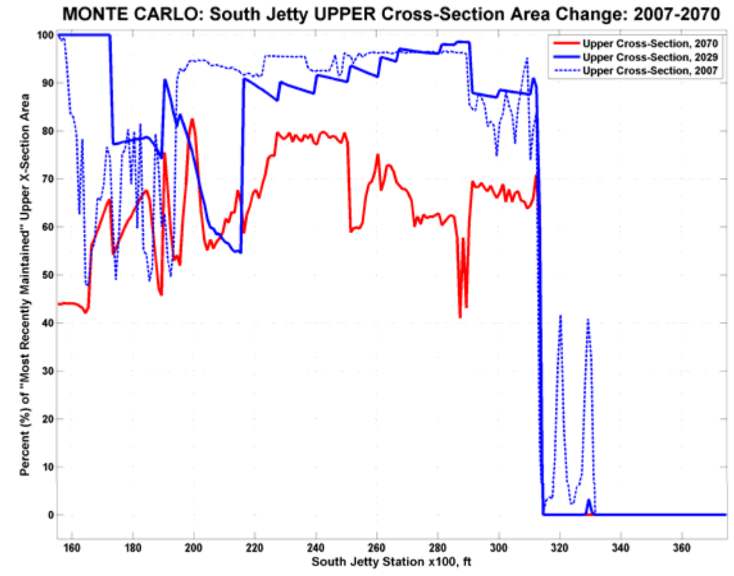

Figure A2-129f. Variation of upper cross-section area for given station of MCR South Jetty. Composite 5 Modified 2 Rehab - Scheduled (Hold Head).

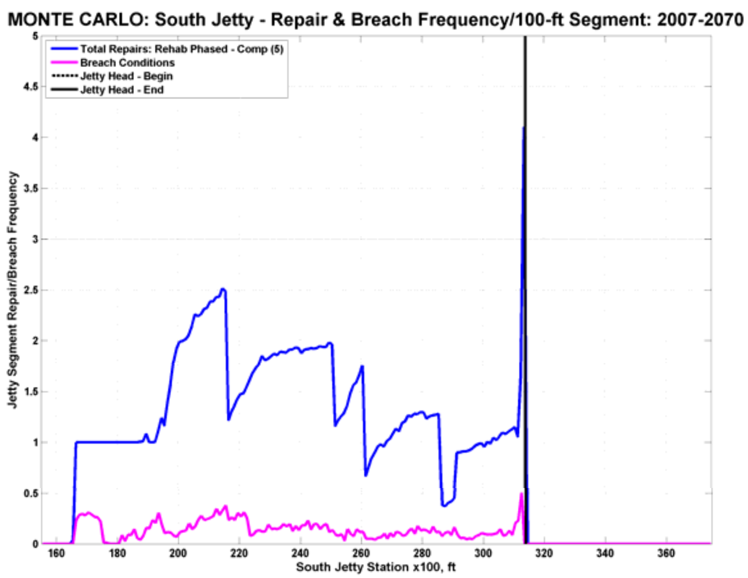

Figure A2-129g. Frequency and location of repairs and breaches for MCR South Jetty. Composite 5 Modified 2 Rehab - Scheduled (Hold Head).

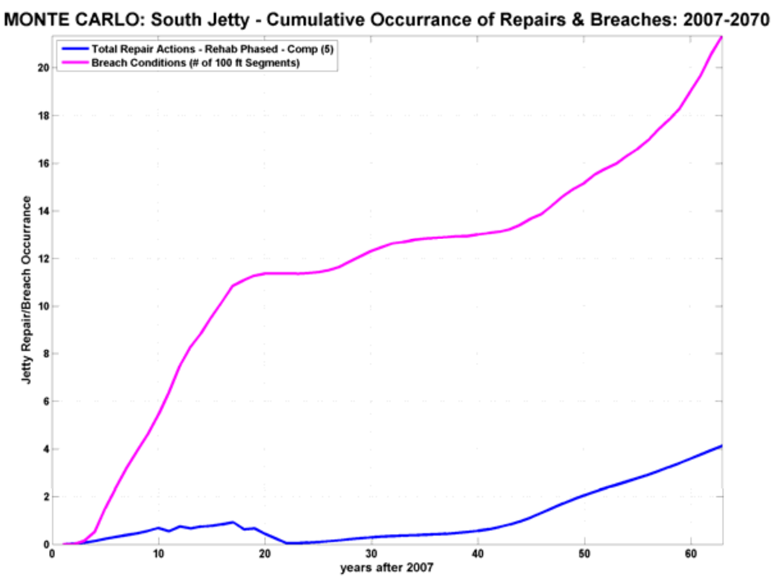

Figure A2-129h. Cumulative occurrence of repairs and breach conditions for MCR South Jetty. Composite 5 Modified 2 Rehab - Scheduled (Hold Head)

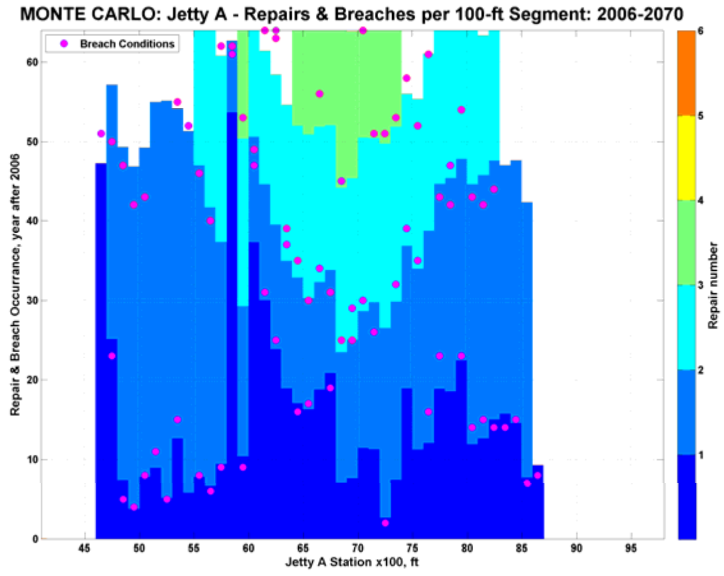

Figure A2-130a. Forecast repair occurrence for MCR Jetty "A", shown for each 100 ft jetty segment. Fix-as-Fail Repair.

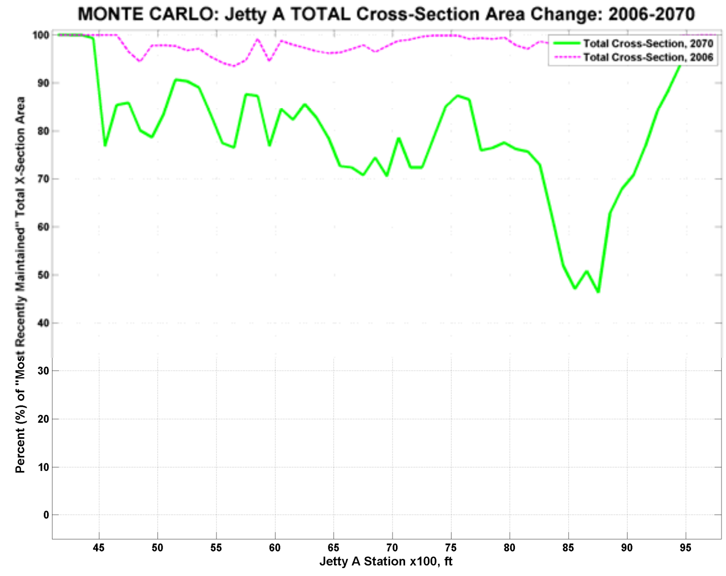

Figure A2-130b. Variation in total cross-section area along MCR Jetty "A" during forecast period. Fix-as-Fail Repair.

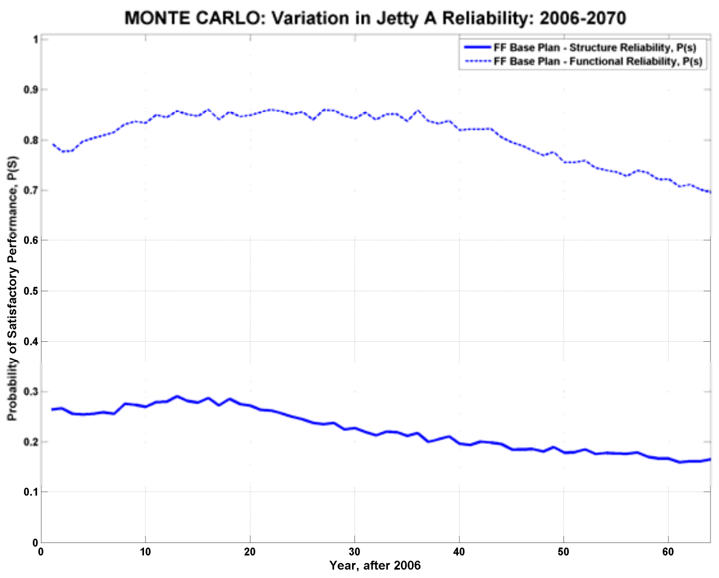

Figure A2-130c. Forecast reliability for MCR Jetty "A". Fix-as-Fail Repair.

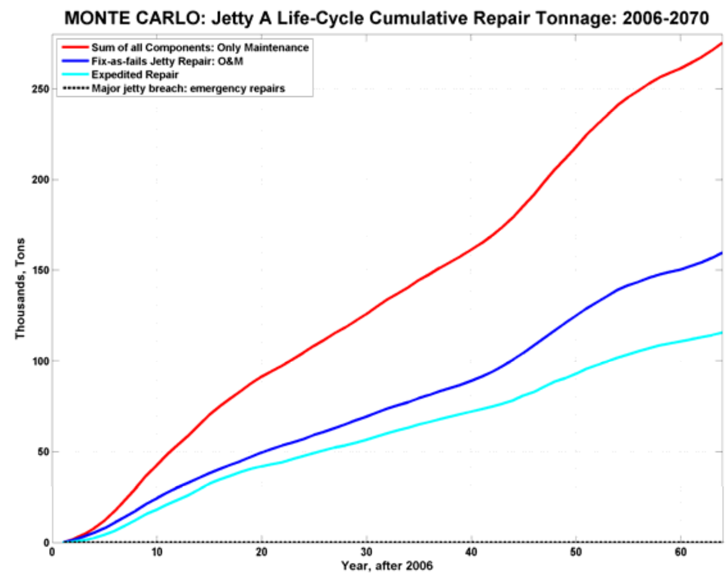

Figure A2-130d. Life-cycle cumulative repair tonnage for MCR Jetty "A". Fix-as-Fail Repair.

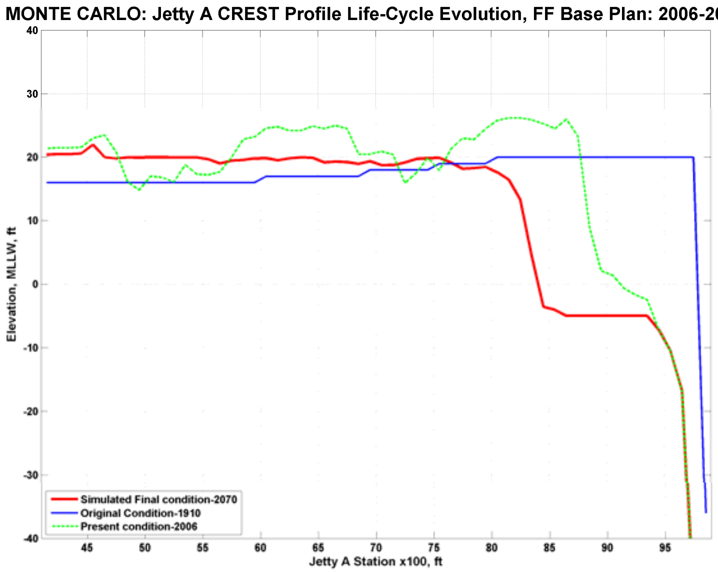

Figure A2-130e. Centerline profile for MCR Jetty "A". Fix-as-Fail Repair.

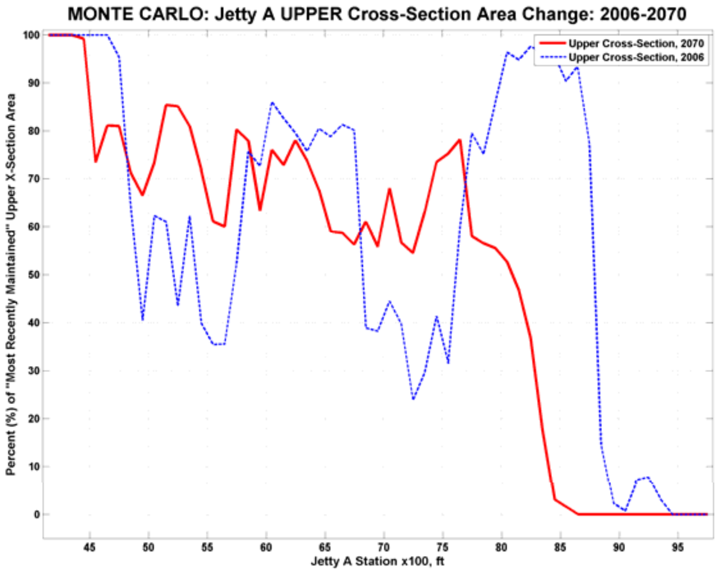

Figure A2-130f. Variation of upper cross-section area for given station of MCR Jetty "A". Fix-as-Fail Repair.

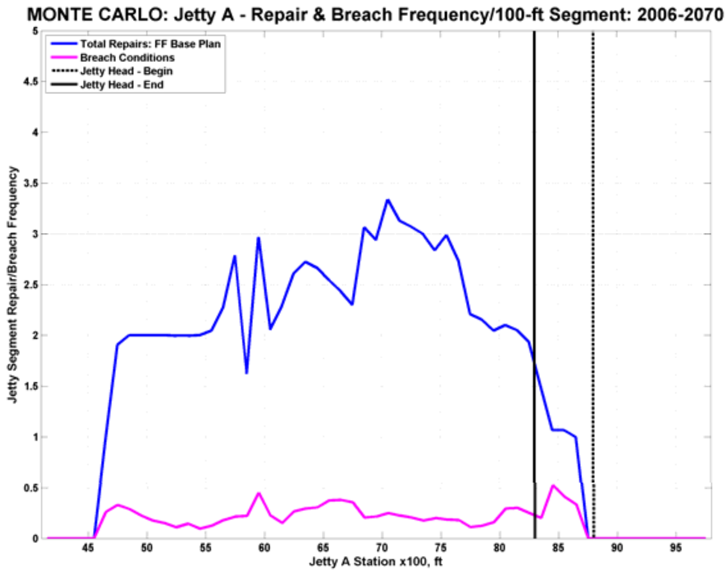

Figure A2-130g. Frequency and location of repairs and breaches for MCR Jetty "A". Fix-as-Fail Repair.

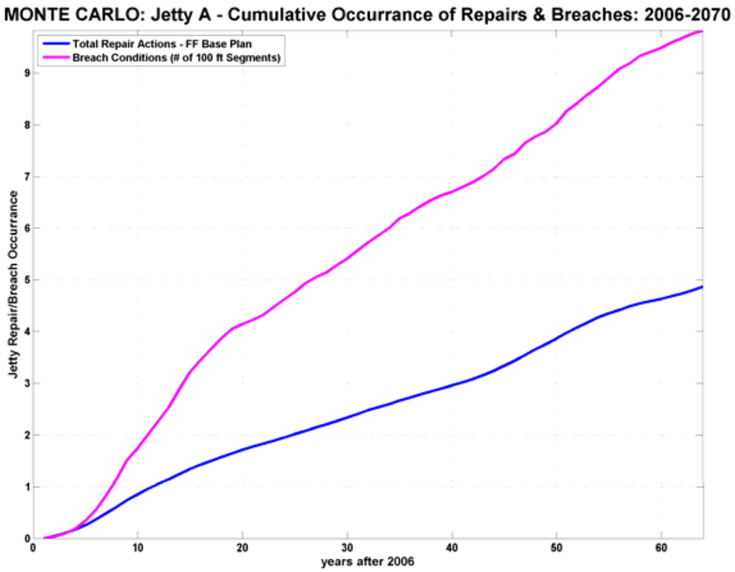

Figure A2-130h. Cumulative occurrence of repairs and breach conditions for MCR Jetty "A". Fix-as-Fail Repair.

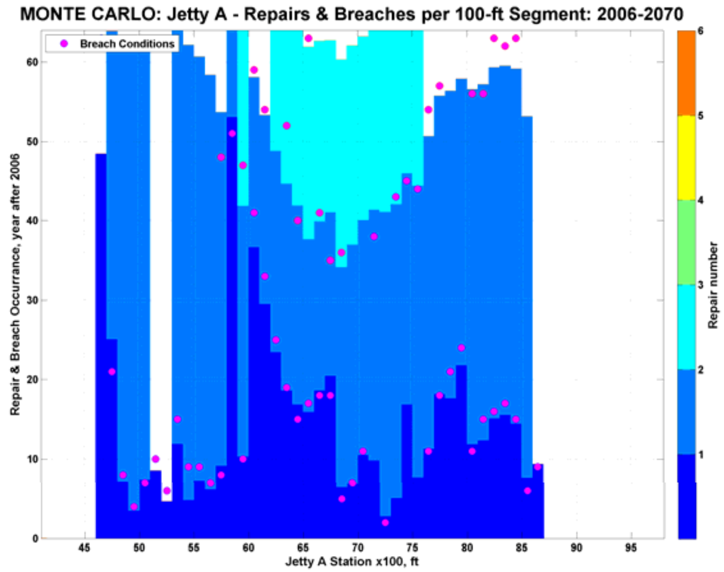

Figure A2-131a. Forecast repair occurrence for MCR Jetty "A", shown for each 100 ft jetty segment. Base Condition.

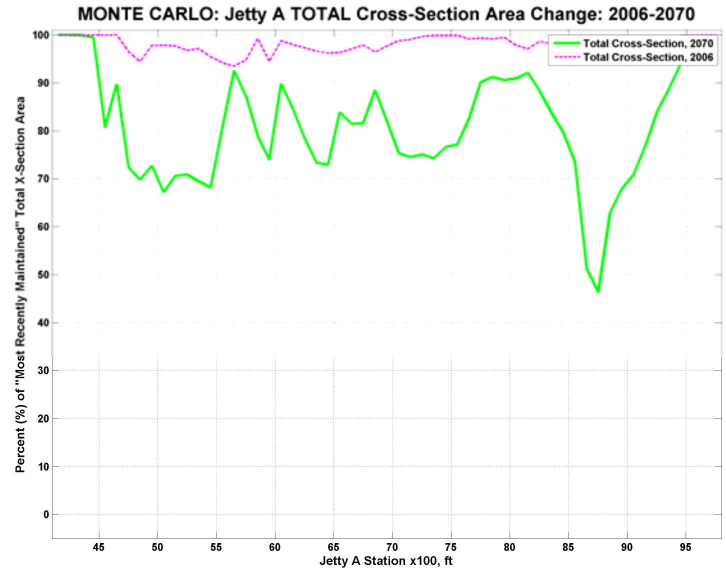

Figure A2-131b. Variation in total cross-section area along MCR Jetty "A" during forecast period. Base Condition.

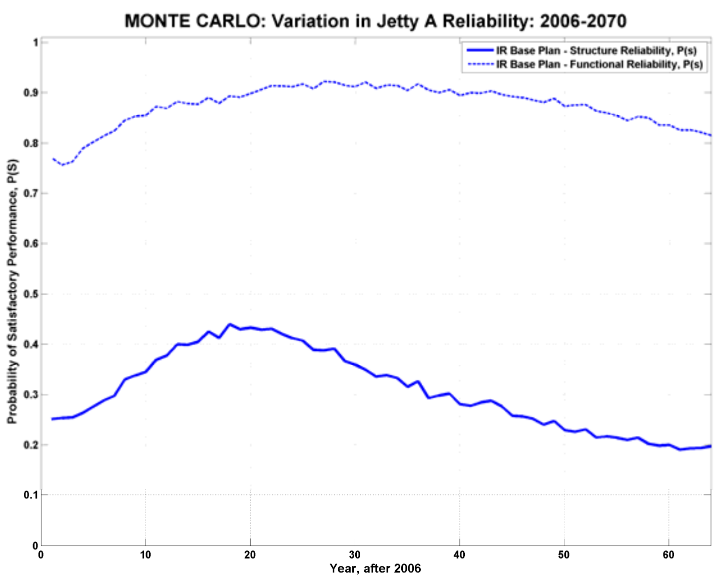

Figure A2-131c. Forecast reliability for MCR Jetty "A". Base Condition.

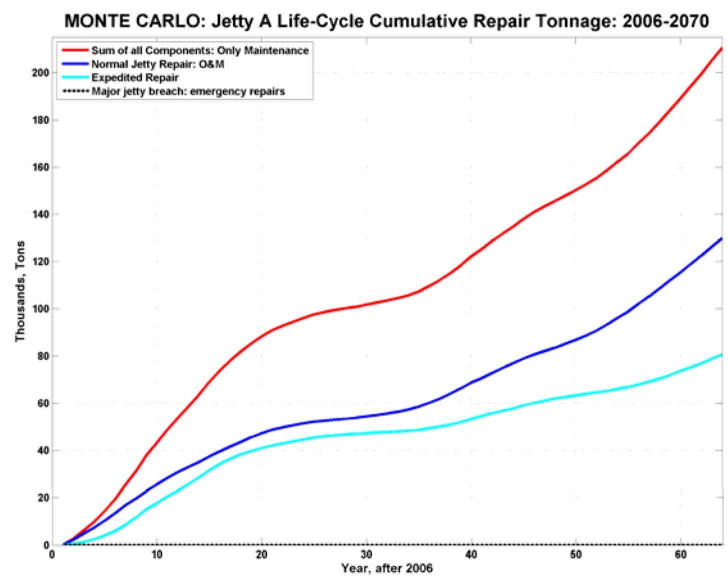

Figure A2-131d. Life-cycle cumulative repair tonnage for MCR Jetty "A". Base Condition.

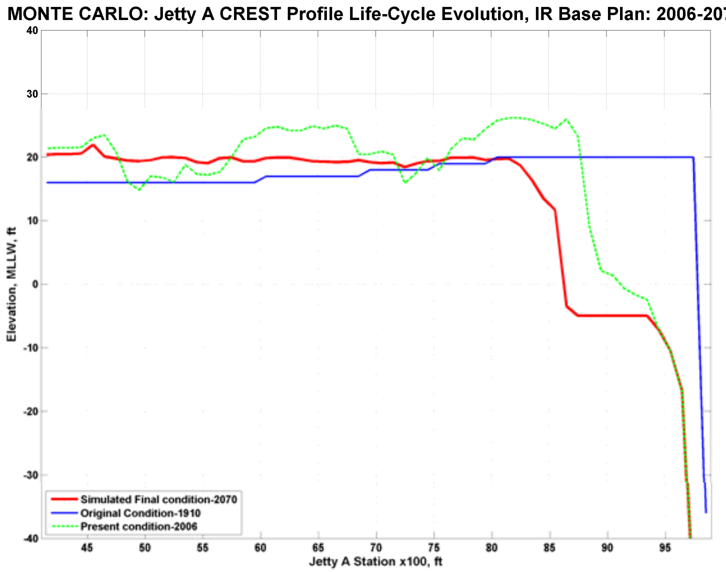

Figure A2-131e. Centerline profile for MCR Jetty "A". Base Condition.

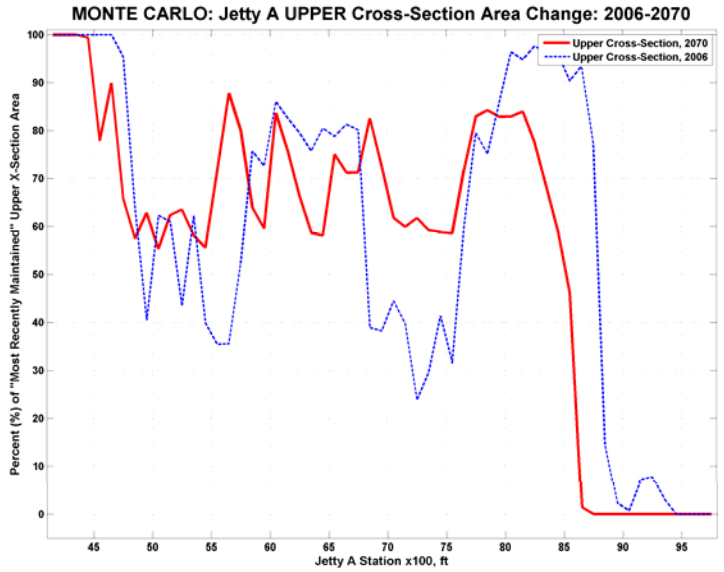

Figure A2-131f. Variation of upper cross-section area for given station of MCR Jetty "A". Base Condition.

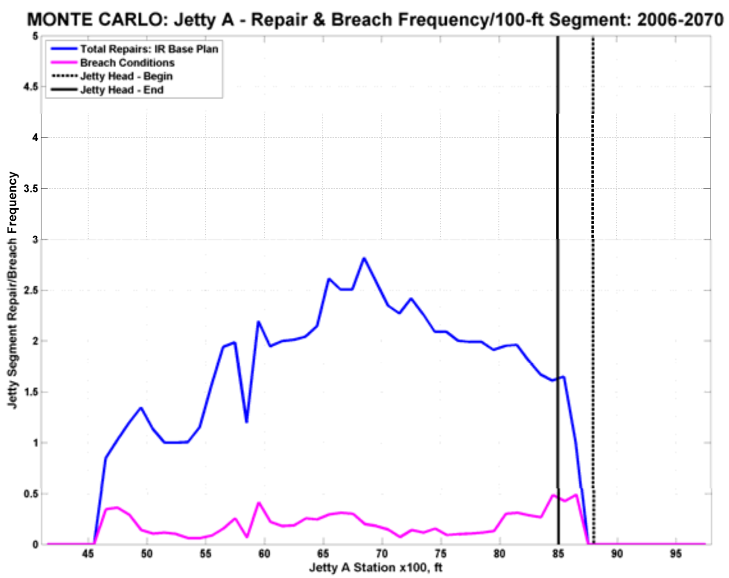

Figure A2-131g. Frequency and location of repairs and breaches for MCR Jetty "A". Base Condition.

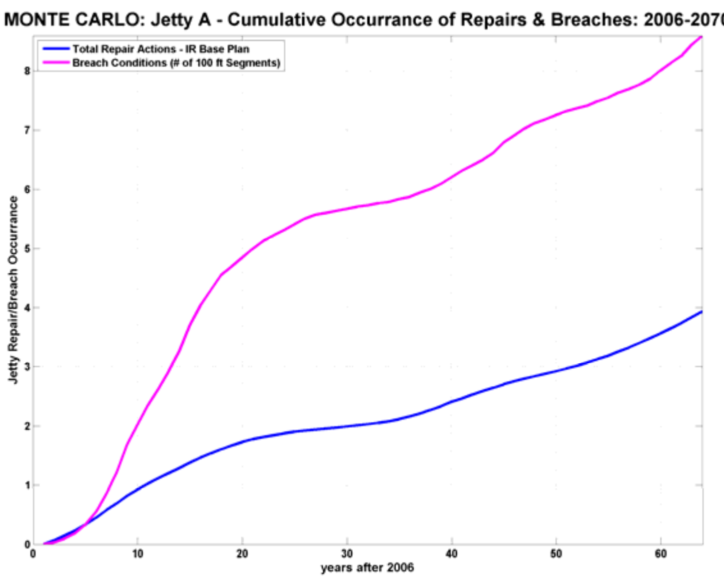

Figure A2-131h. Cumulative occurrence of repairs and breach conditions for MCR Jetty "A". Base Condition.

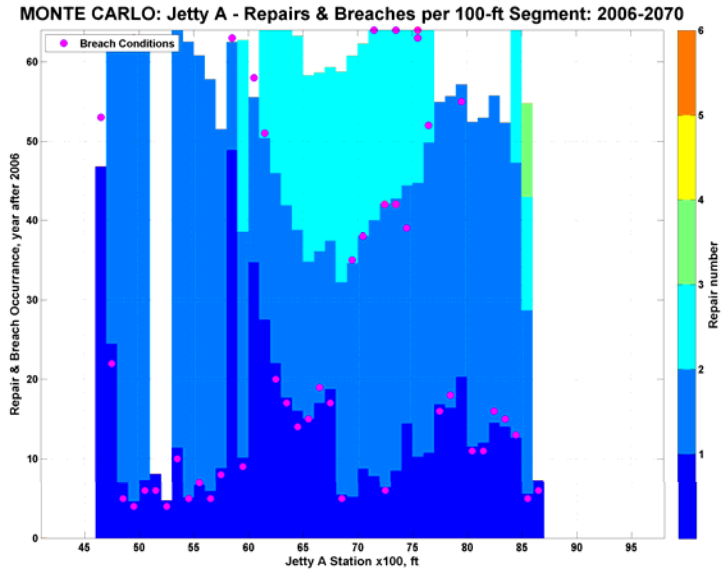

Figure A2-132a. Forecast repair occurrence for MCR Jetty "A", shown for each 100 ft jetty segment. Scheduled Repair.

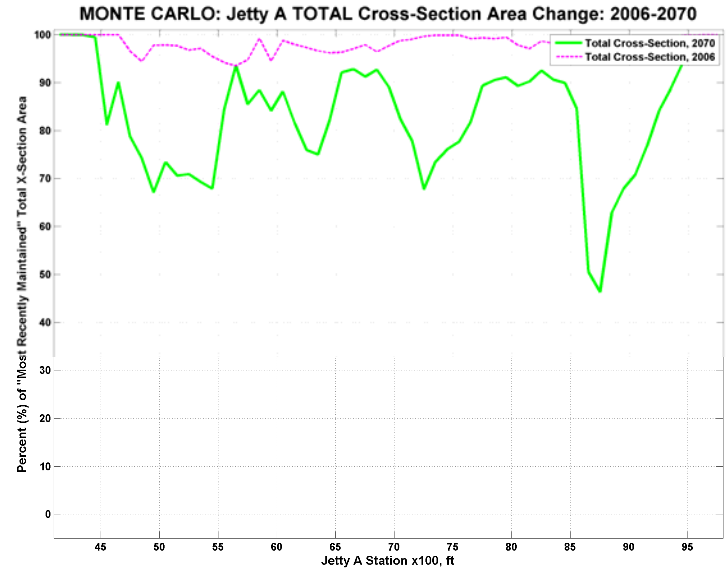

Figure A2-132b. Variation in total cross-section area along MCR Jetty "A" during forecast period. Scheduled Repair.

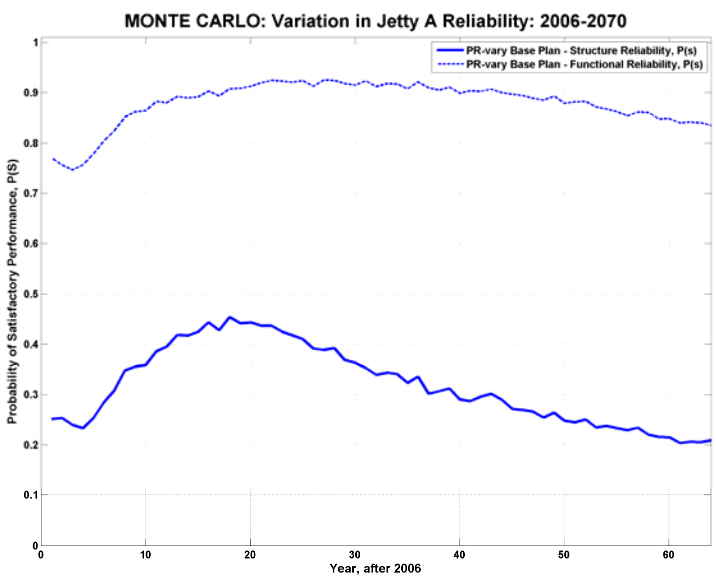

Figure A2-132c. Forecast reliability for MCR Jetty "A". Scheduled Repair.

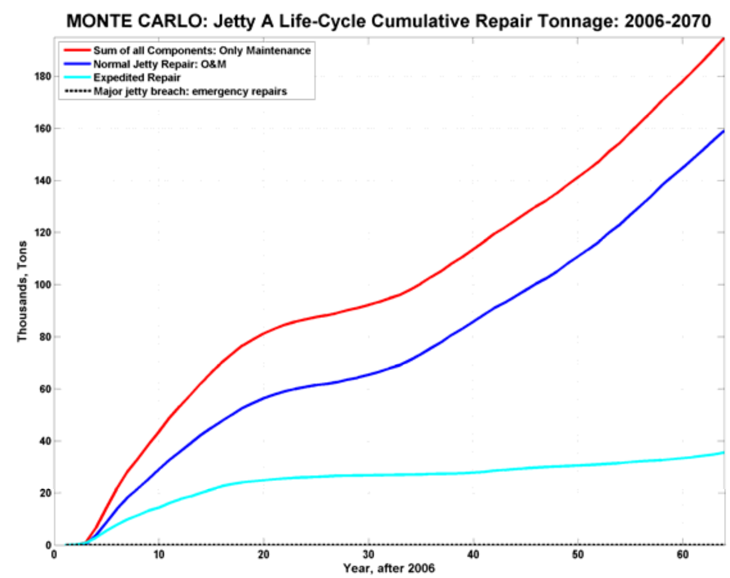

Figure A2-132d. Life-cycle cumulative repair tonnage for MCR Jetty "A". Scheduled Repair.

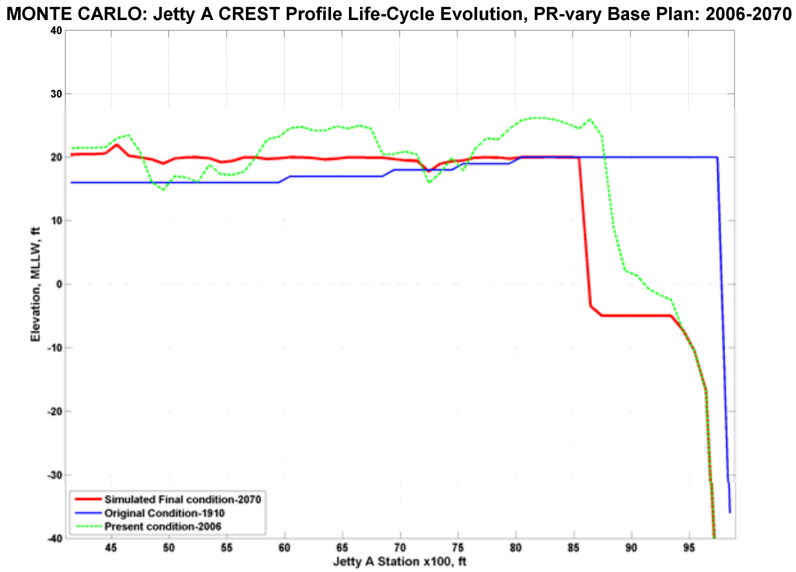

Figure A2-132e. Centerline profile for MCR Jetty "A". Scheduled Repair.

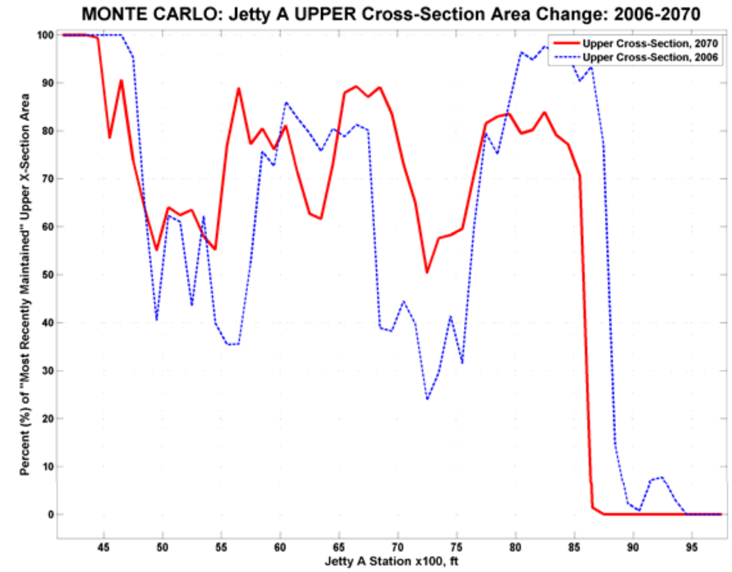

Figure A2-132f. Variation of upper cross-section area for given station of MCR Jetty "A". Scheduled Repair.

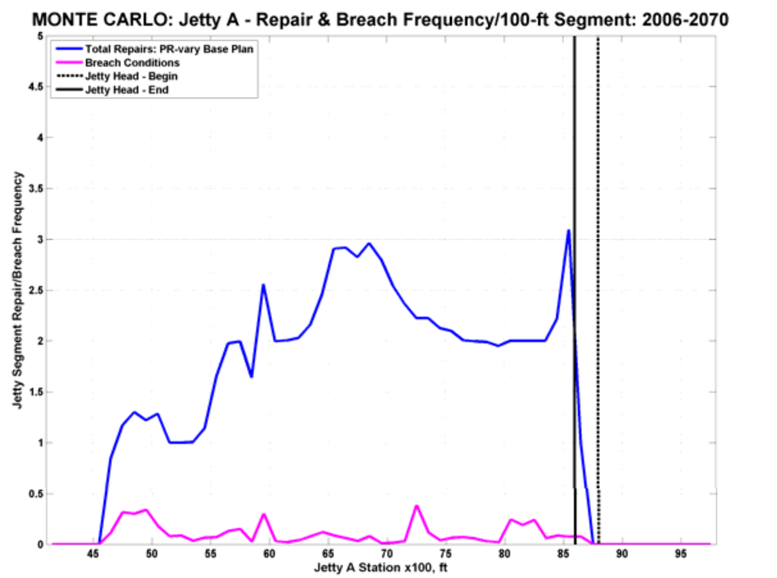

Figure A2-132g. Frequency and location of repairs and breaches for MCR Jetty "A". Scheduled Repair.

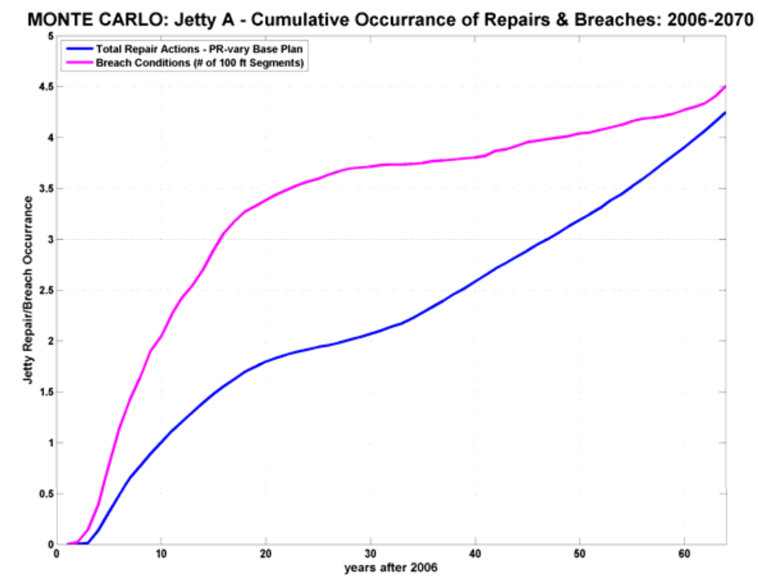

Figure A2-132h. Cumulative occurrence of repairs and breach conditions for MCR Jetty "A". Scheduled Repair.

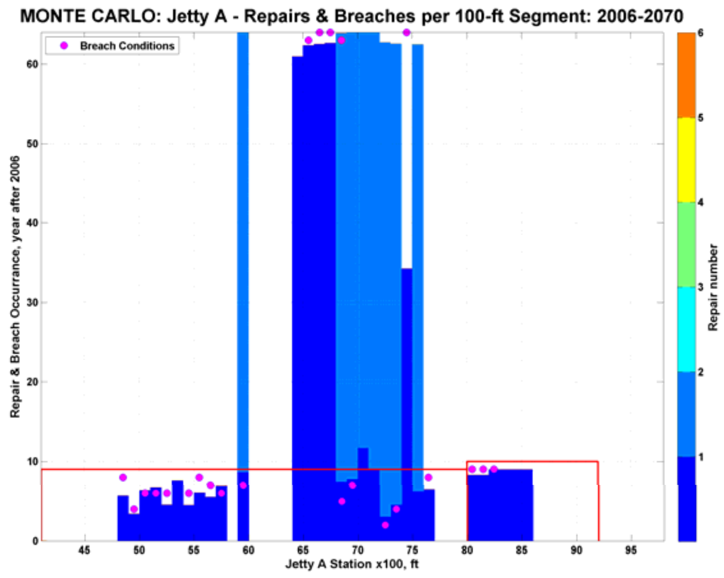

Figure A2-133a. Forecast repair occurrence for MCR Jetty "A", shown for each 100 ft jetty segment. Small Template Rehab (Plan A) - Immediate. RED line marks time of REHAB phase implementation

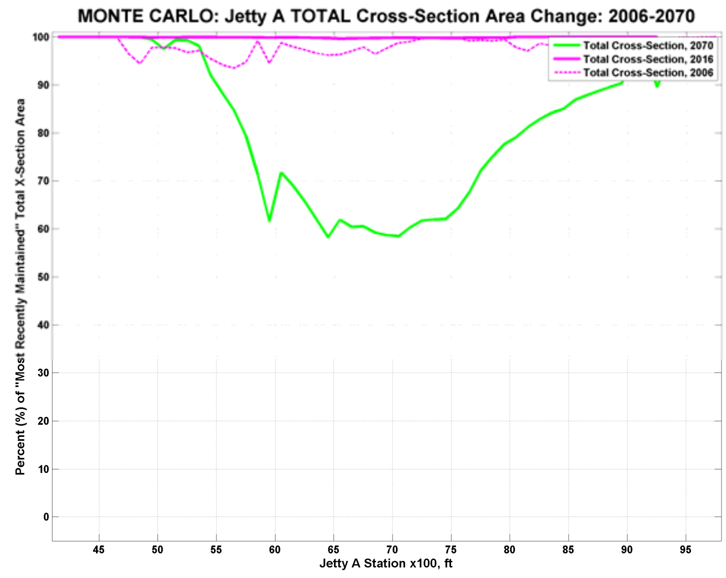

Figure A2-133b. Variation in total cross-section area along MCR Jetty "A" during forecast period. Small Template Rehab (Plan A) - Immediate.RED line marks time of REHAB phase implementation

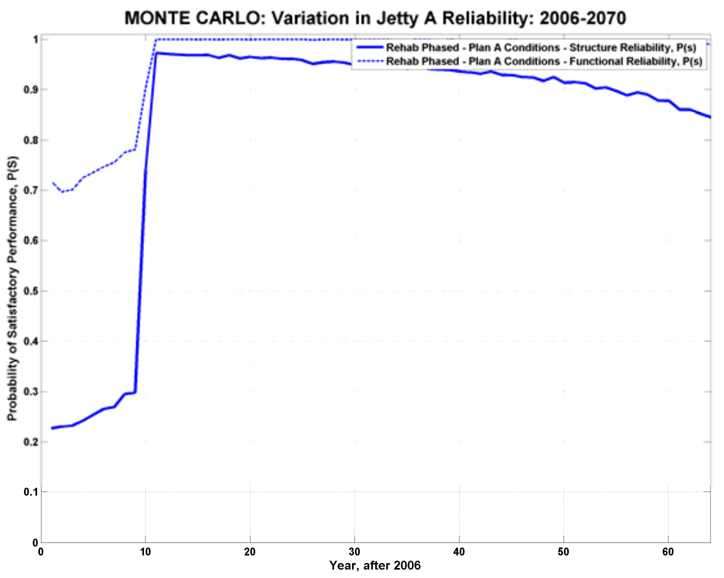

Figure A2-133c. Forecast reliability for MCR Jetty "A". Small Template Rehab (Plan A) - Immediate.

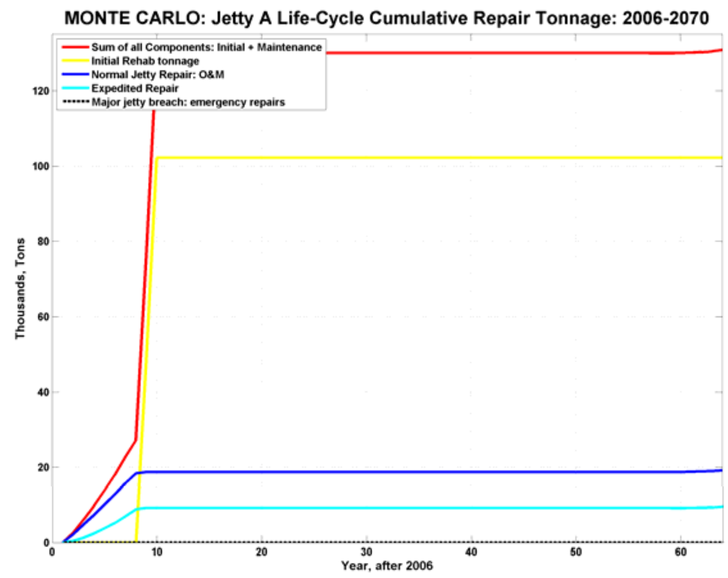

Figure A2-133d. Life-cycle cumulative repair tonnage for MCR Jetty "A". Small Template Rehab (Plan A) - Immediate.

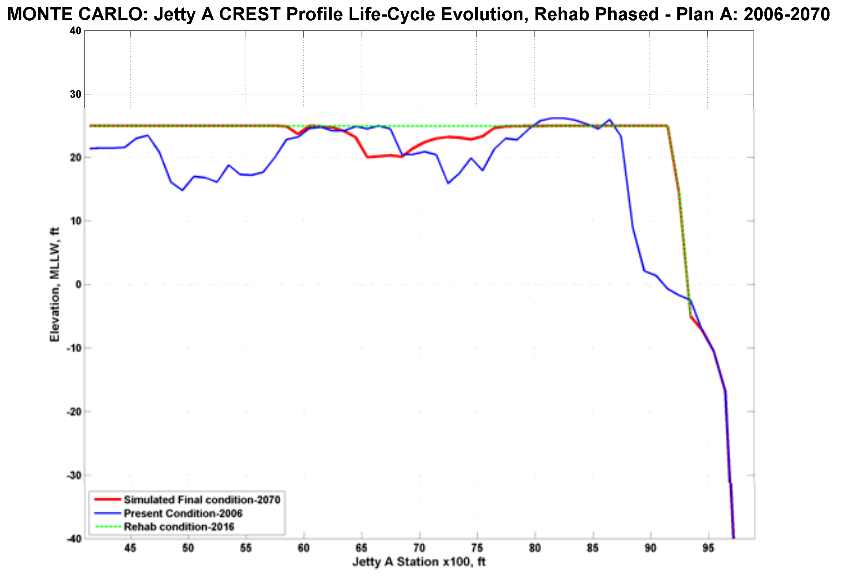

Figure A2-133e. Centerline profile for MCR Jetty "A". Small Template Rehab (Plan A) - Immediate.

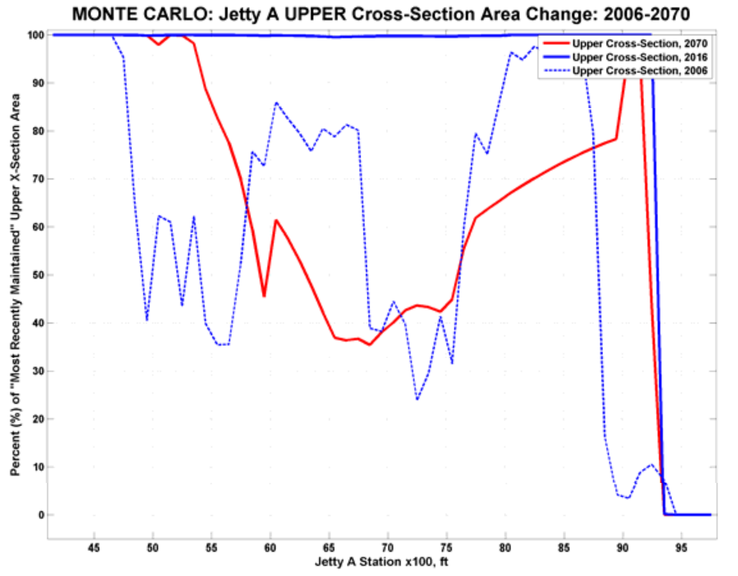

Figure A2-133f. Variation of upper cross-section area for given station of MCR Jetty "A". Small Template Rehab (Plan A) - Immediate.

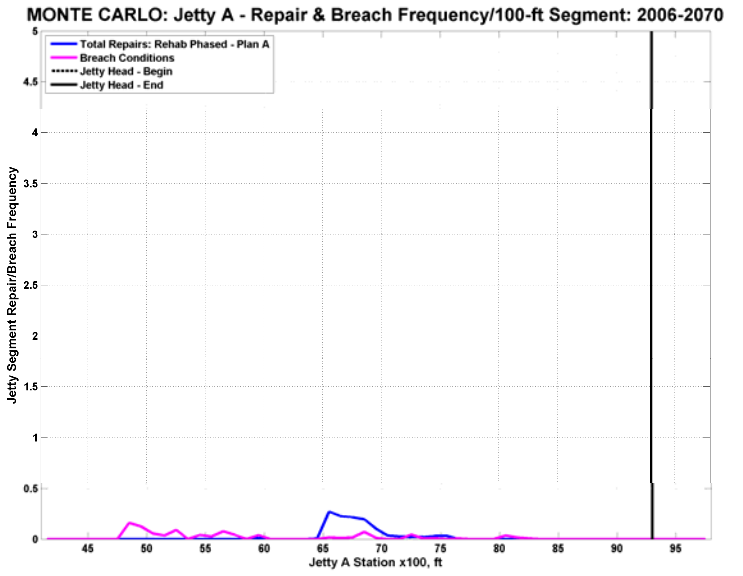

Figure A2-133g. Frequency and location of repairs and breaches for MCR Jetty "A". Small Template Rehab (Plan A) - Immediate.

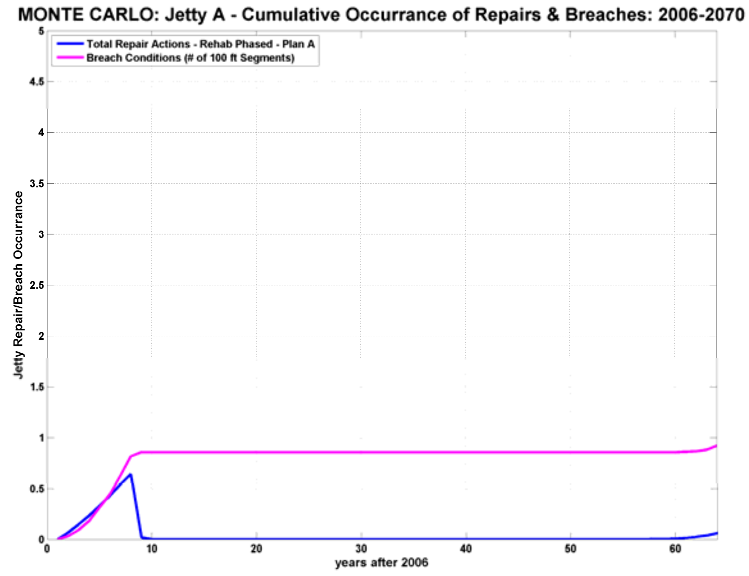

Figure A2-133h. Cumulative occurrence of repairs and breach conditions for MCR Jetty "A". Small Template Rehab (Plan A) - Immediate.

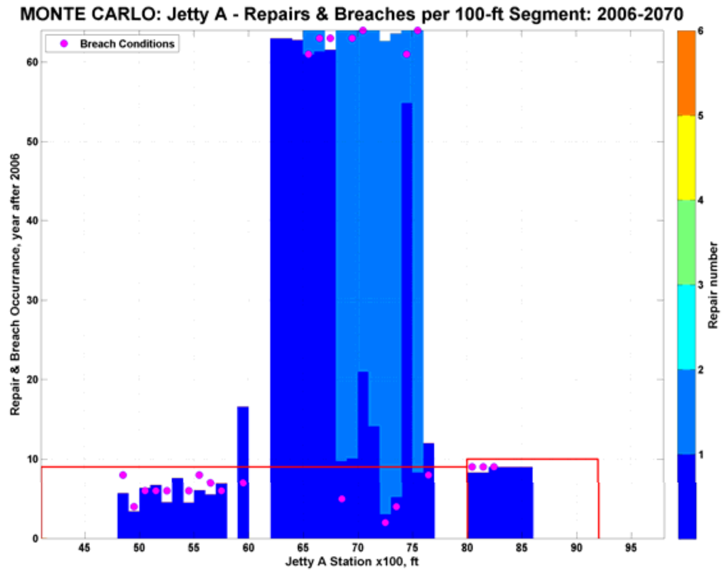

Figure A2-134a. Forecast repair occurrence for MCR Jetty "A", shown for each 100 ft jetty segment. Small Template Rehab (Plan B) - Immediate. RED line marks time of REHAB phase implementation

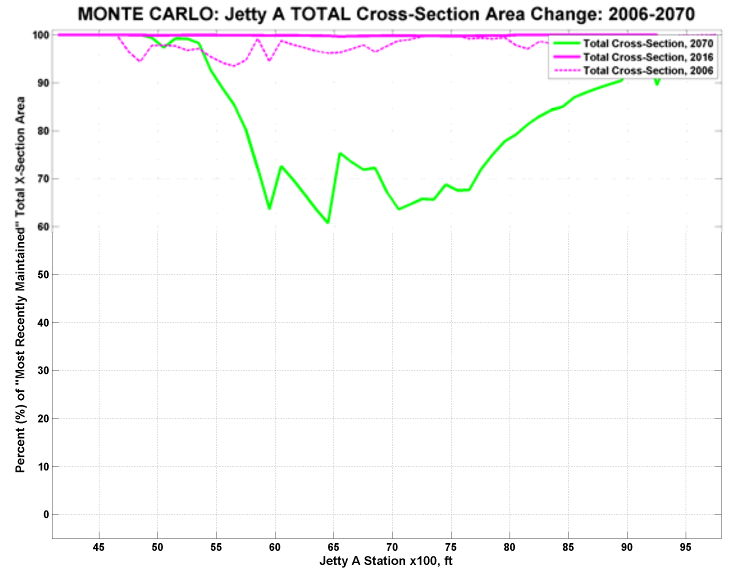

Figure A2-134b. Variation in total cross-section area along MCR Jetty "A" during forecast period. Small Template Rehab (Plan B) - Immediate.RED line marks time of REHAB phase implementation

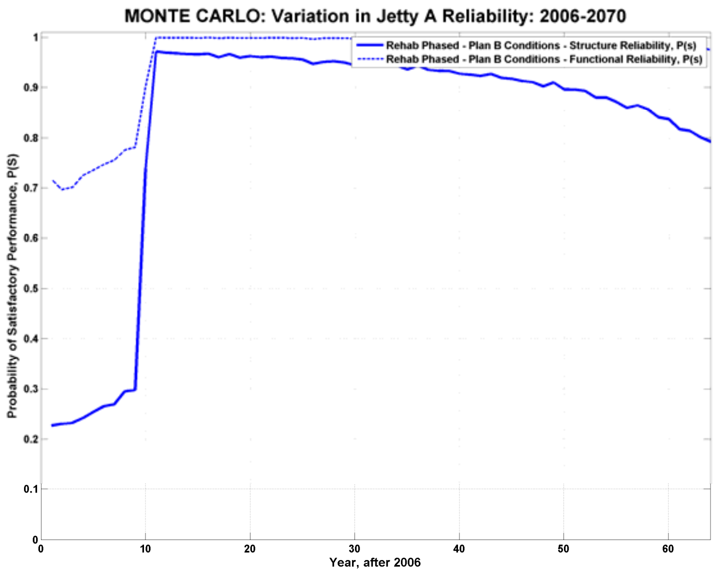

Figure A2-134c. Forecast reliability for MCR Jetty "A". Small Template Rehab (Plan B) - Immediate.

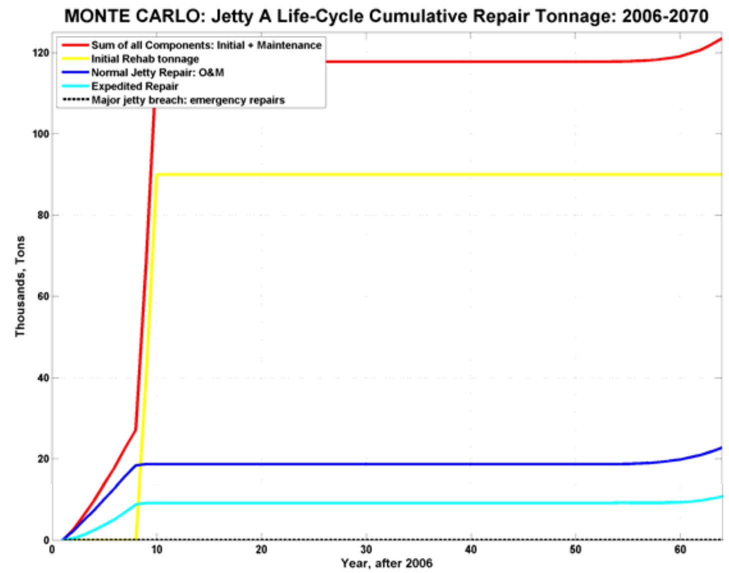

Figure A2-134d. Life-cycle cumulative repair tonnage for MCR Jetty "A". Small Template Rehab (Plan B) - Immediate.

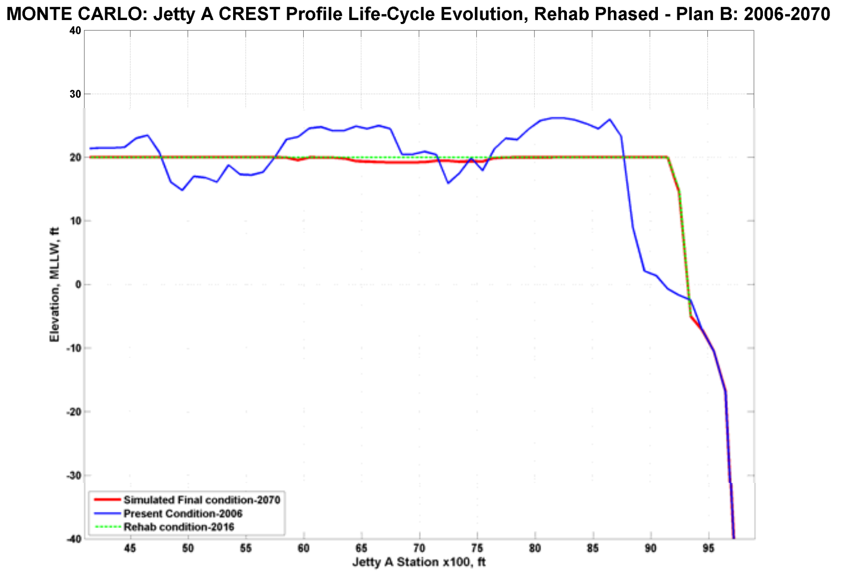

Figure A2-134e. Centerline profile for MCR Jetty "A". Small Template Rehab (Plan B) - Immediate.

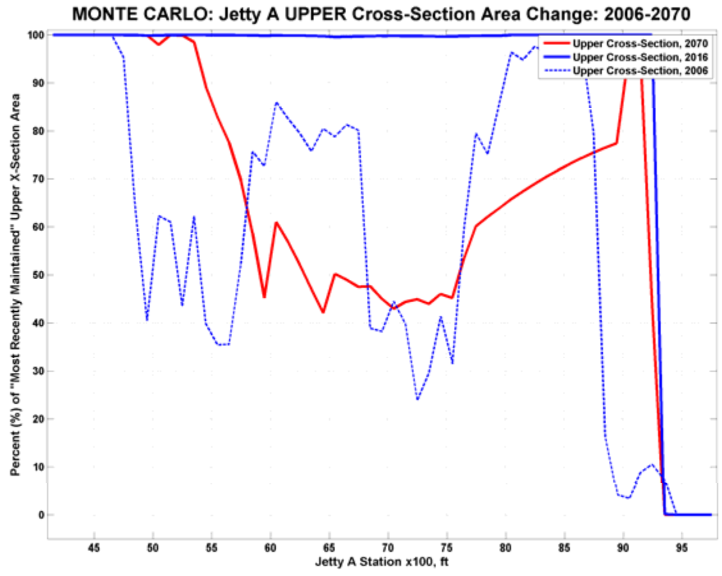

Figure A2-134f. Variation of upper cross-section area for given station of MCR Jetty "A". Small Template Rehab (Plan B) - Immediate.

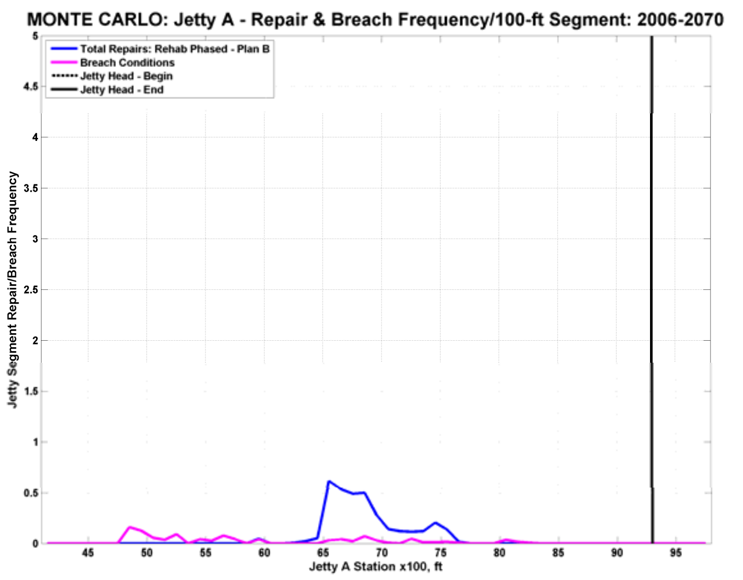

Figure A2-134g. Frequency and location of repairs and breaches for MCR Jetty "A". Small Template Rehab (Plan B) - Immediate.

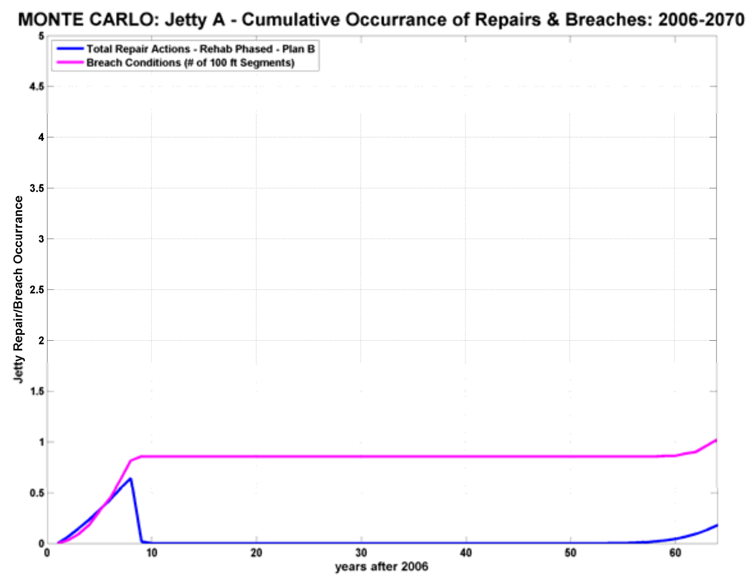

Figure A2-134h. Cumulative occurrence of repairs and breach conditions for MCR Jetty "A". Small Template Rehab (Plan B) - Immediate.

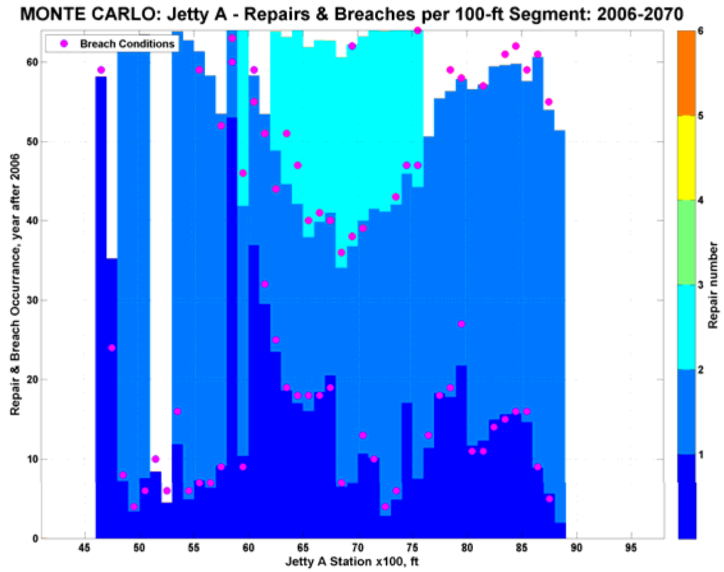

Figure A2-135a. Forecast repair occurrence for MCR Jetty "A", shown for each 100 ft jetty segment. Base Condition (Hold Head).

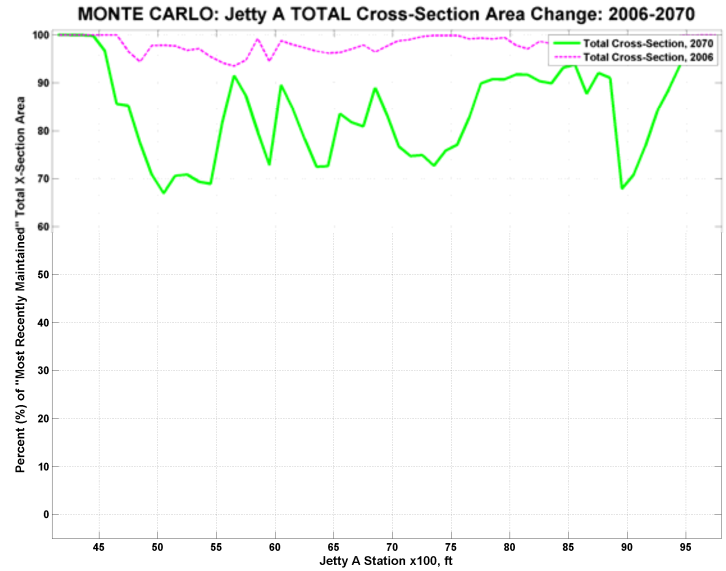

Figure A2-135b. Variation in total cross-section area along MCR Jetty "A" during forecast period. Base Condition (Hold Head).

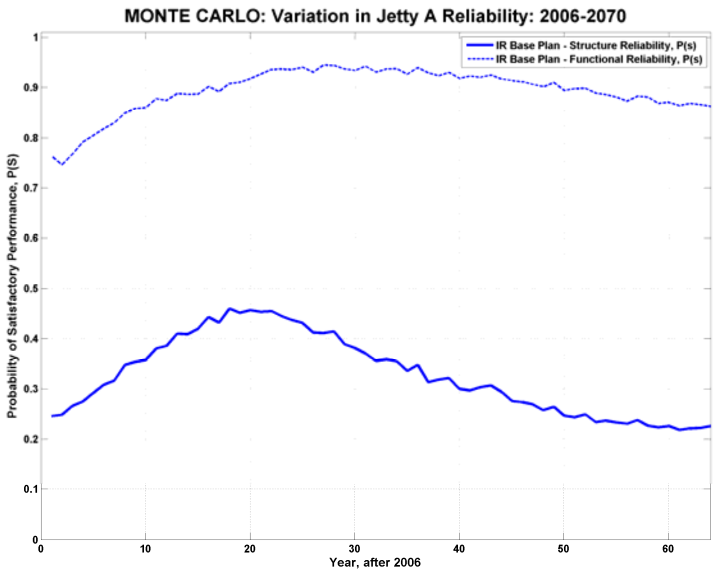

Figure A2-135c. Forecast reliability for MCR Jetty "A". Base Condition (Hold Head).

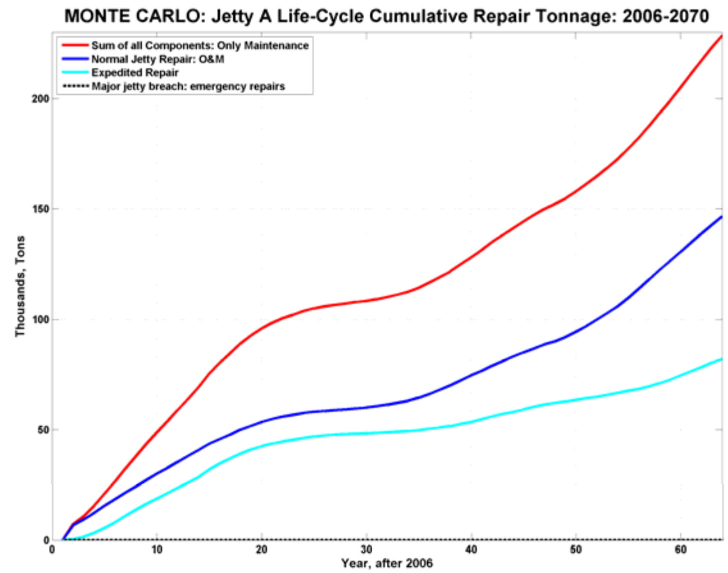

Figure A2-135d. Life-cycle cumulative repair tonnage for MCR Jetty "A". Base Condition (Hold Head).

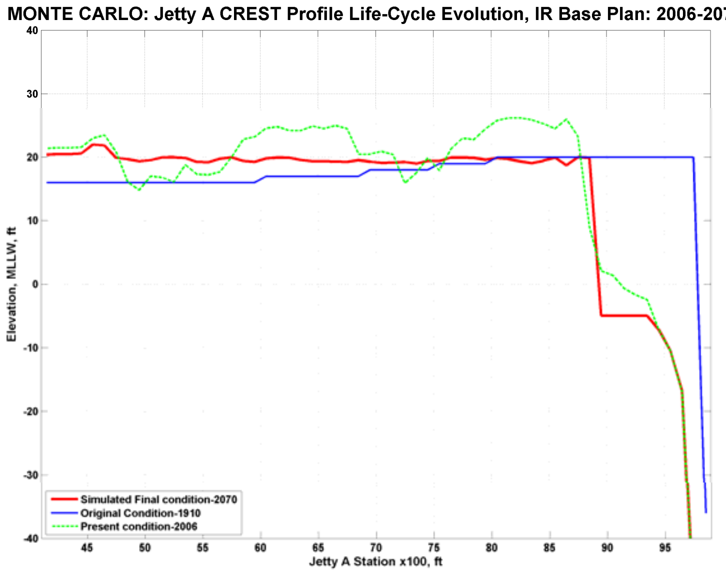

Figure A2-135e. Centerline profile for MCR Jetty "A". Base Condition (Hold Head).

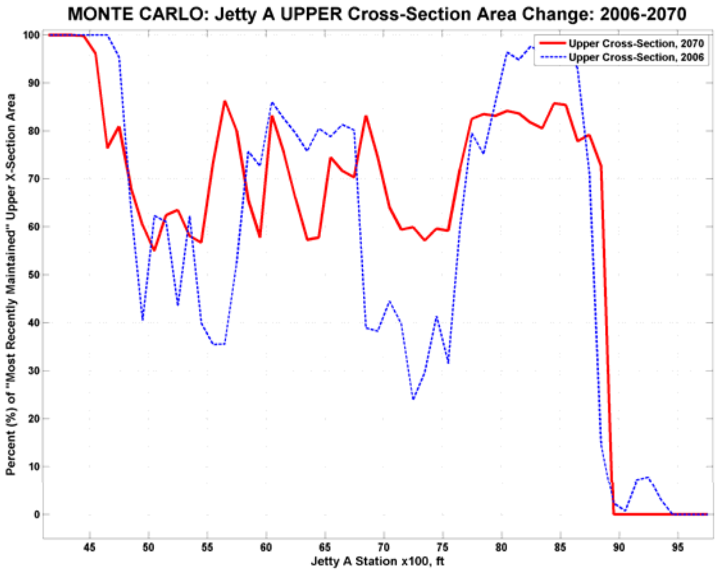

Figure A2-135f. Variation of upper cross-section area for given station of MCR Jetty "A". Base Condition (Hold Head).

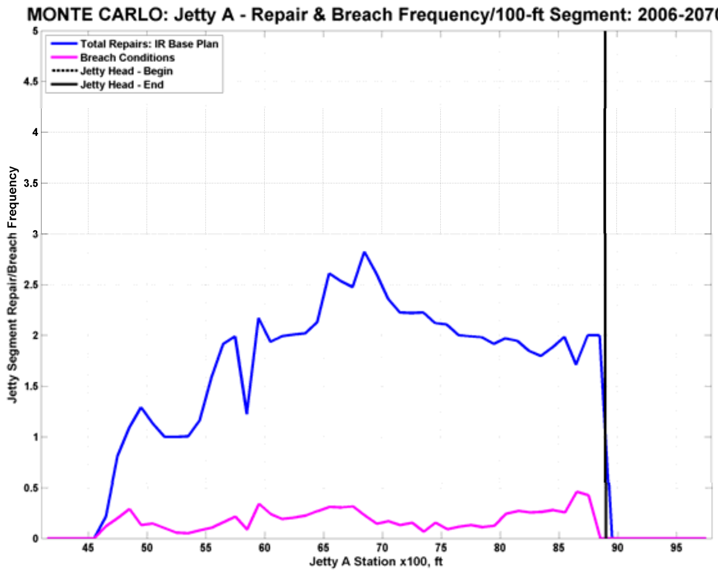

Figure A2-135g. Frequency and location of repairs and breaches for MCR Jetty "A". Base Condition (Hold Head).

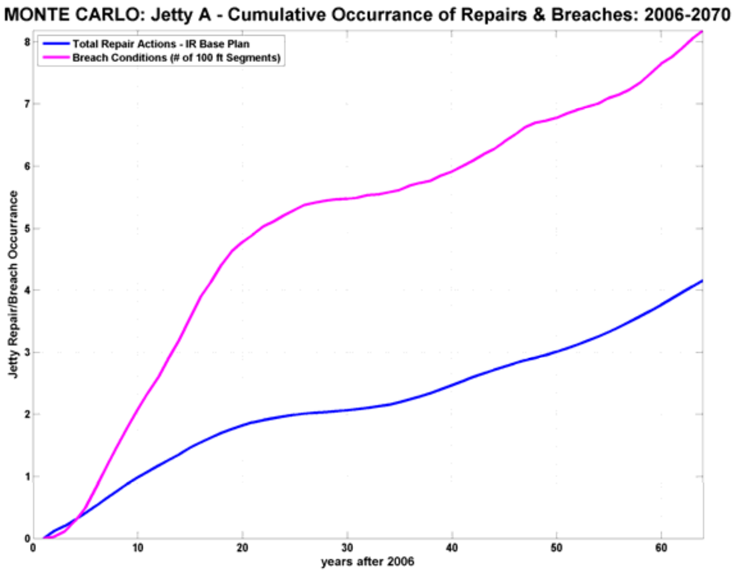

Figure A2-135h. Cumulative occurrence of repairs and breach conditions for MCR Jetty "A". Base Condition (Hold Head).

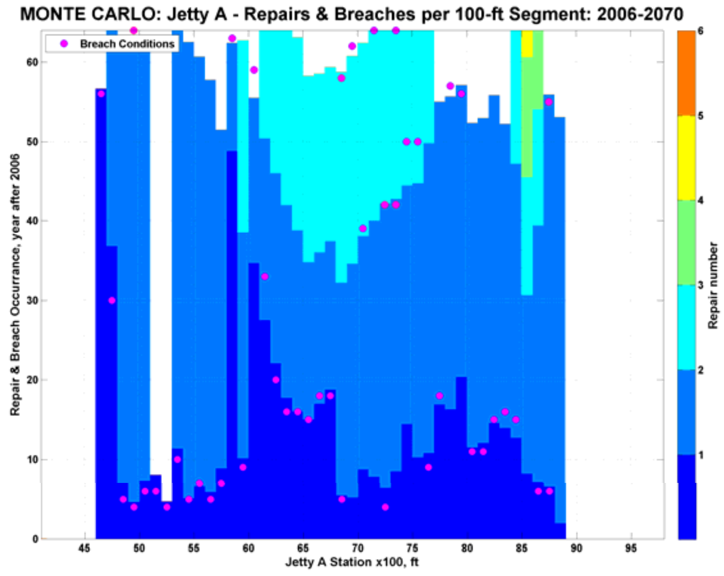

Figure A2-136a. Forecast repair occurrence for MCR Jetty "A", shown for each 100 ft jetty segment. Scheduled Repair (Hold Head).

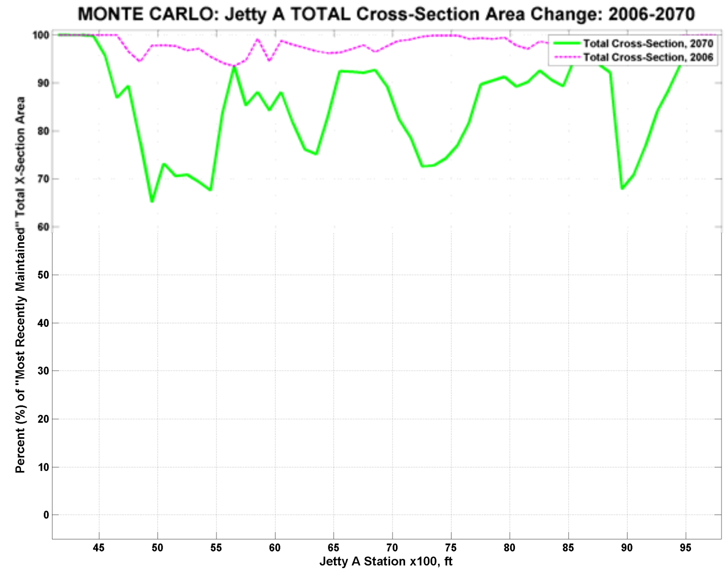

Figure A2-136b. Variation in total cross-section area along MCR Jetty "A" during forecast period. Scheduled Repair (Hold Head).

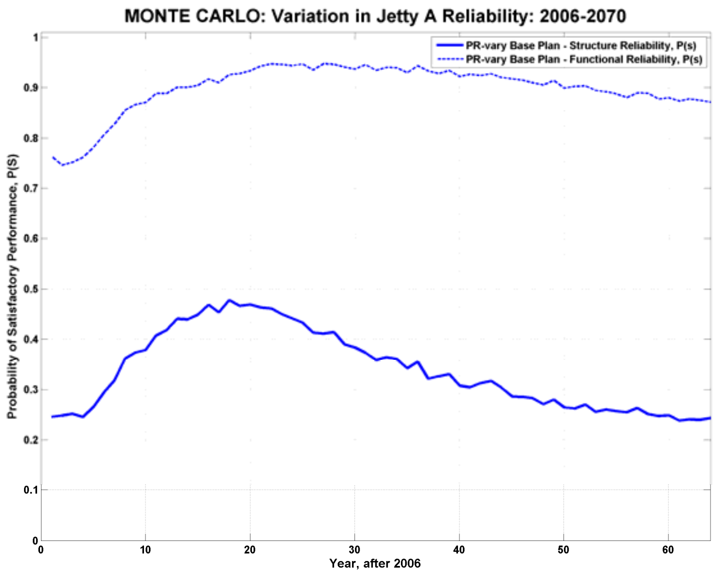

Figure A2-136c. Forecast reliability for MCR Jetty "A". Scheduled Repair (Hold Head).

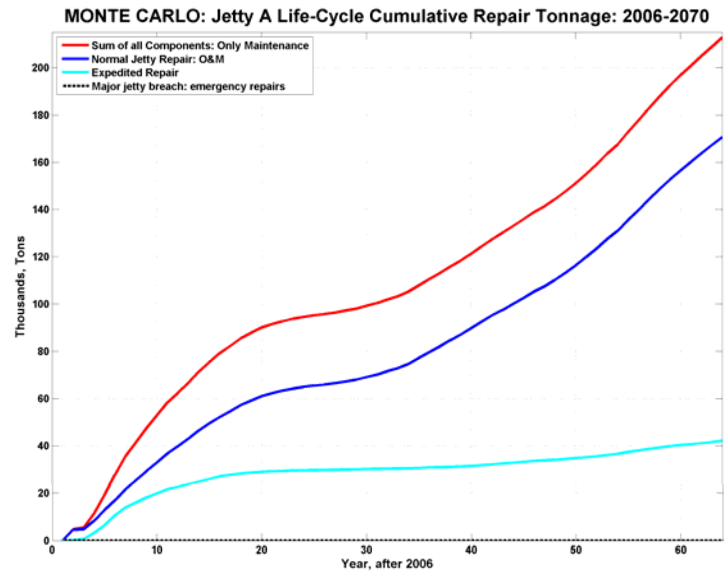

Figure A2-136d. Life-cycle cumulative repair tonnage for MCR Jetty "A". Scheduled Repair (Hold Head).

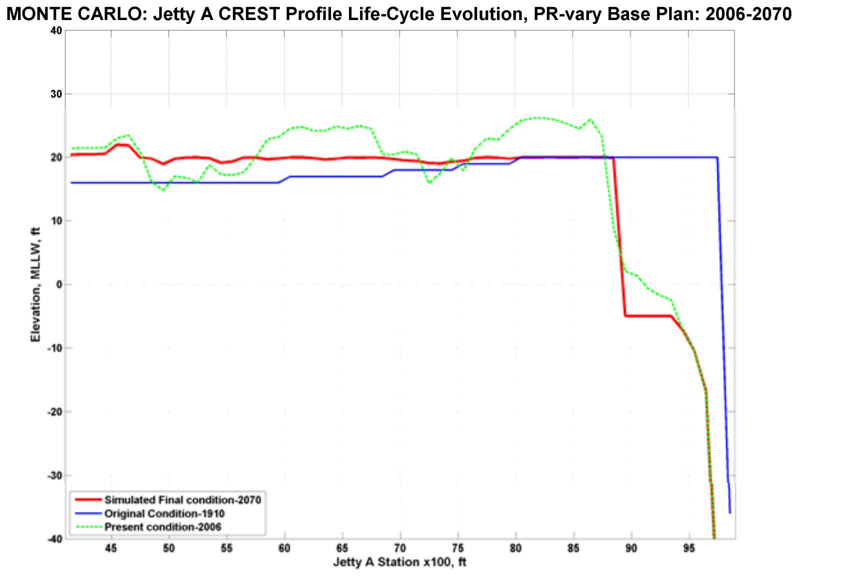

Figure A2-136e. Centerline profile for MCR Jetty "A". Scheduled Repair (Hold Head).

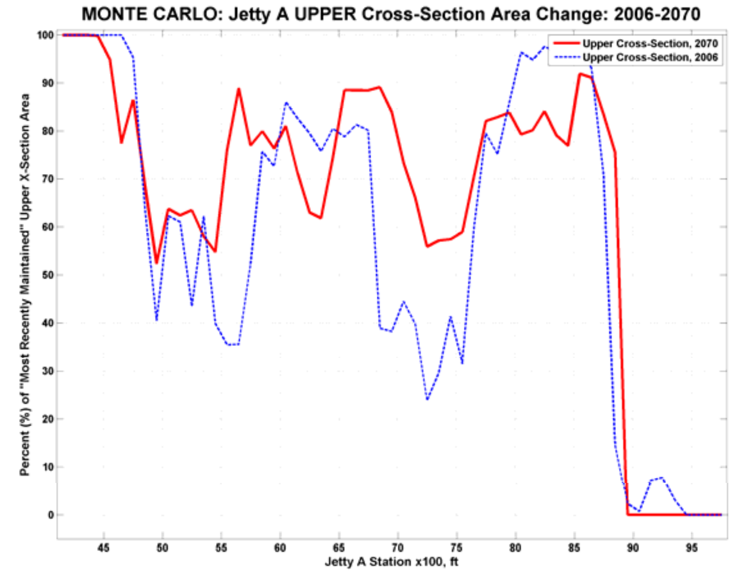

Figure A2-136f. Variation of upper cross-section area for given station of MCR Jetty "A". Scheduled Repair (Hold Head).

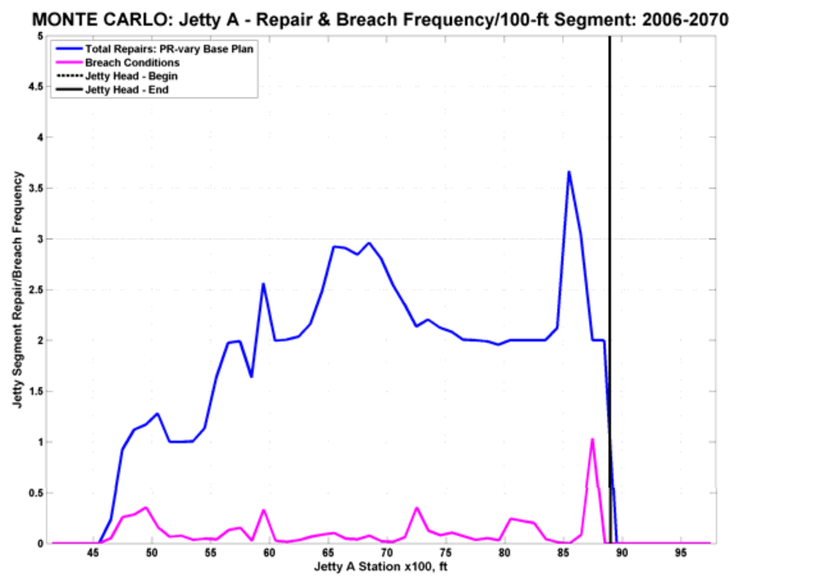

Figure A2-136g. Frequency and location of repairs and breaches for MCR Jetty "A". Scheduled Repair (Hold Head).

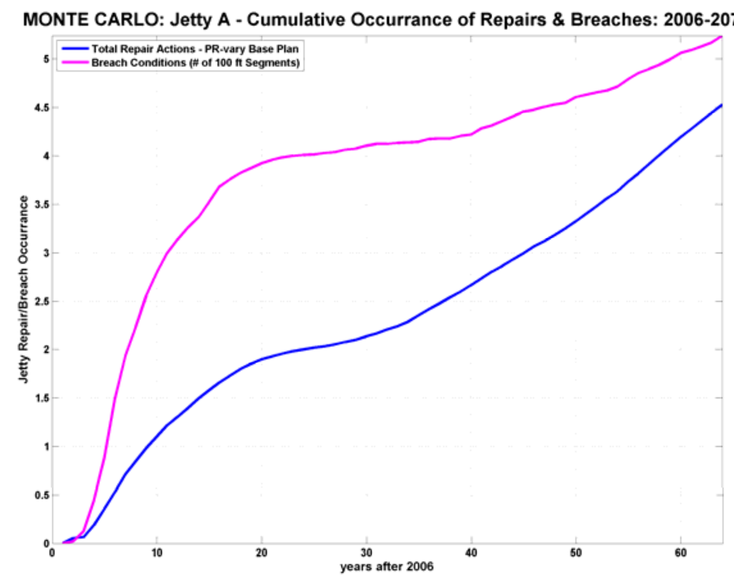

Figure A2-136h. Cumulative occurrence of repairs and breach conditions for MCR Jetty "A". Scheduled Repair (Hold Head).

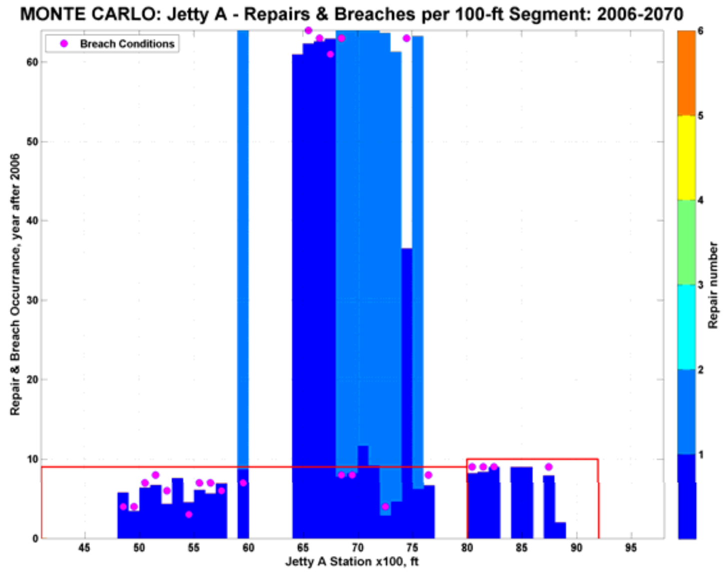

Figure A2-137a. Forecast repair occurrence for MCR Jetty "A", shown for each 100 ft jetty segment. Small Template Rehab (Plan A) - Immediate (Hold Head). RED line marks time of REHAB phase implementation

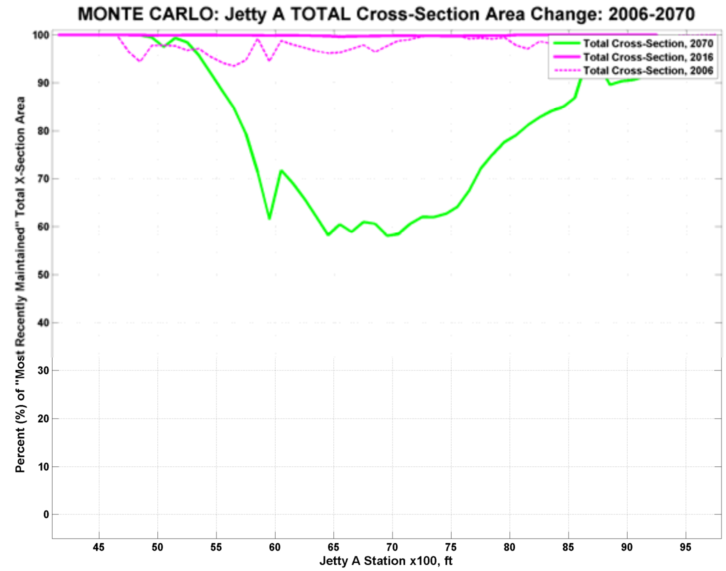

Figure A2-137b. Variation in total cross-section area along MCR Jetty "A" during forecast period. Small Template Rehab (Plan A) - Immediate (Hold Head).RED line marks time of REHAB phase implementation

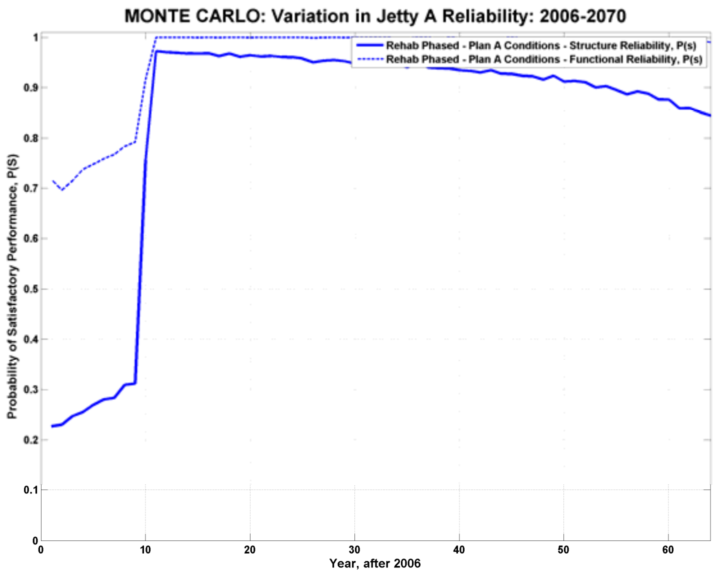

Figure A2-137c. Forecast reliability for MCR Jetty "A". Small Template Rehab (Plan A) - Immediate (Hold Head).

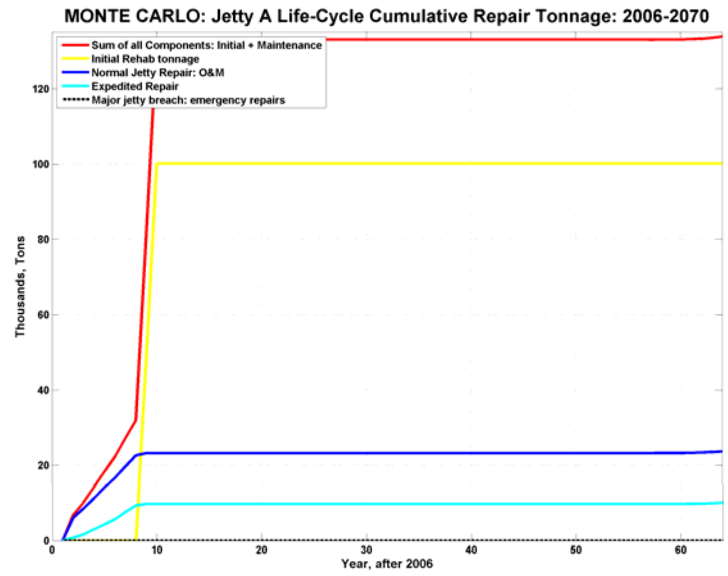

Figure A2-137d. Life-cycle cumulative repair tonnage for MCR Jetty "A". Small Template Rehab (Plan A) - Immediate (Hold Head).

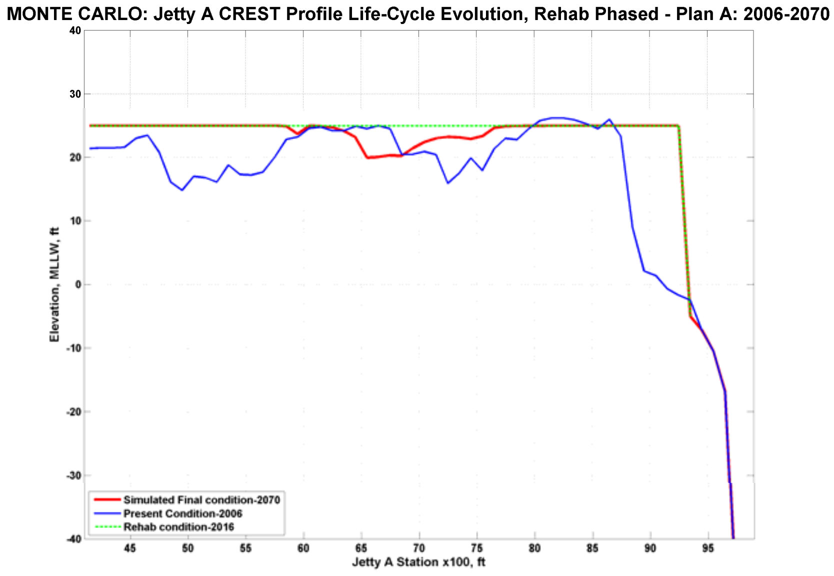

Figure A2-137e. Centerline profile for MCR Jetty "A". Small Template Rehab (Plan A) - Immediate (Hold Head).

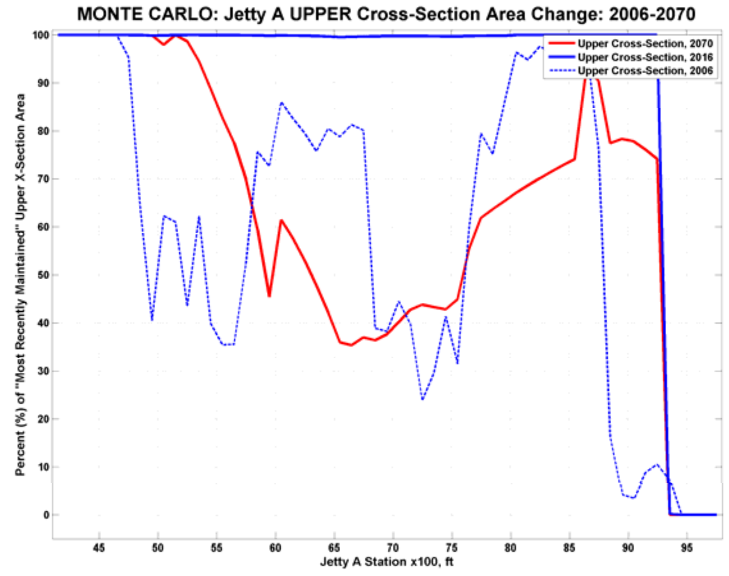

Figure A2-137f. Variation of upper cross-section area for given station of MCR Jetty "A". Small Template Rehab (Plan A) - Immediate (Hold Head).

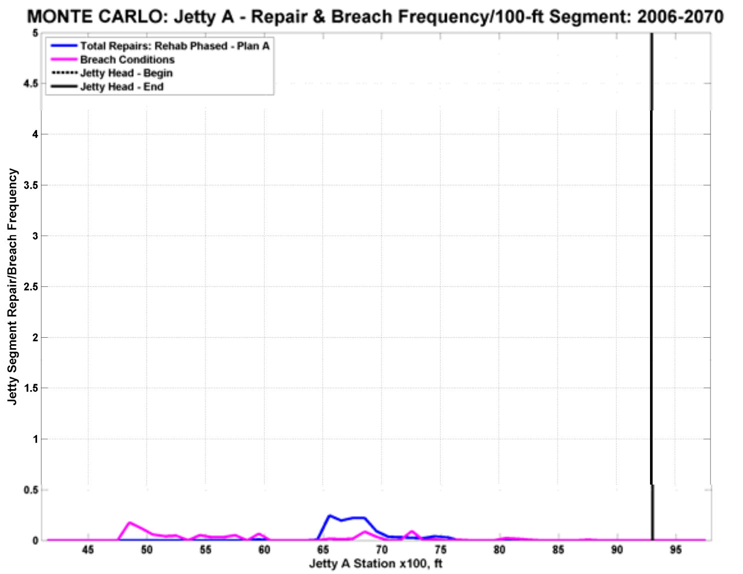

Figure A2-137g. Frequency and location of repairs and breaches for MCR Jetty "A". Small Template Rehab (Plan A) - Immediate (Hold Head).

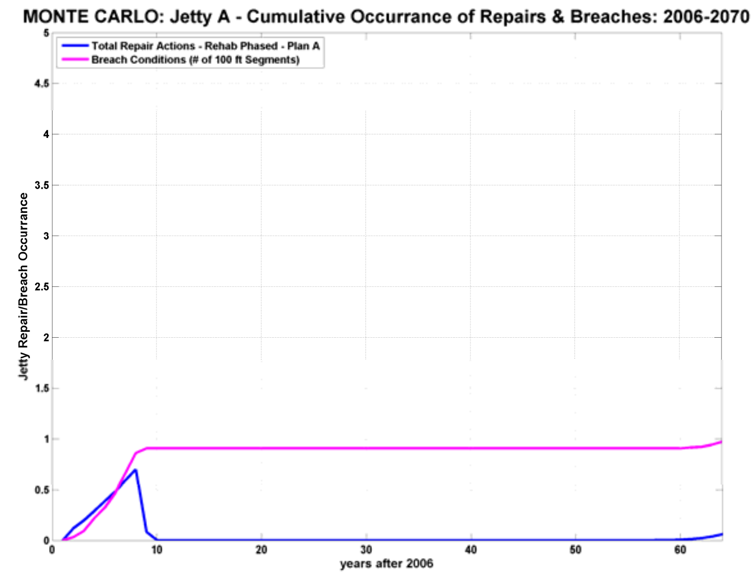

Figure A2-137h. Cumulative occurrence of repairs and breach conditions for MCR Jetty "A". Small Template Rehab (Plan A) - Immediate (Hold Head).

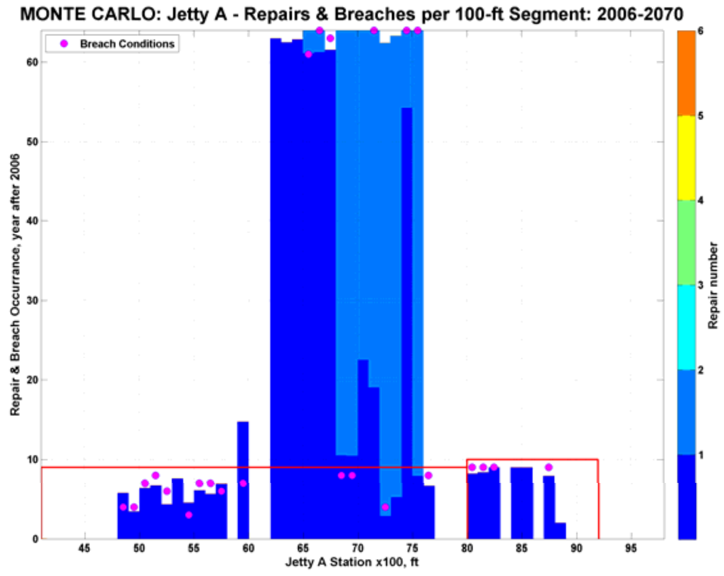

Figure A2-138a. Forecast repair occurrence for MCR Jetty "A", shown for each 100 ft jetty segment. Small Template Rehab (Plan B) - Immediate (Hold Head). RED line marks time of REHAB phase implementation

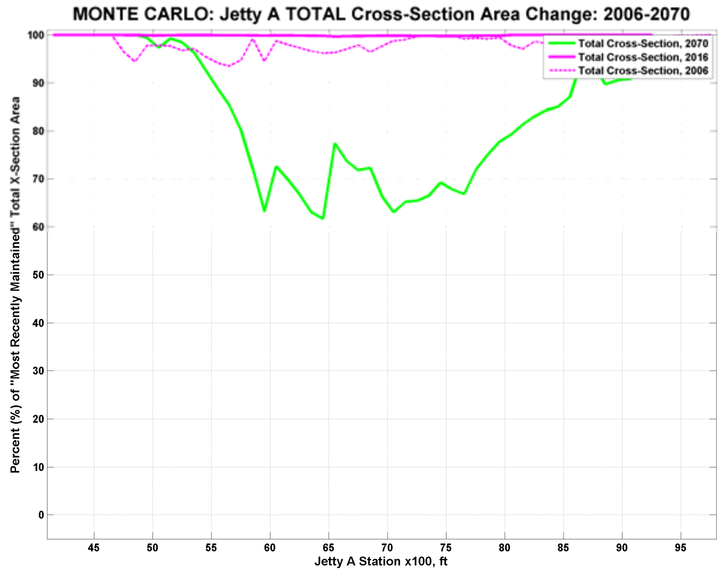

Figure A2-138b. Variation in total cross-section area along MCR Jetty "A" during forecast period. Small Template Rehab (Plan B) - Immediate (Hold Head).RED line marks time of REHAB phase implementation

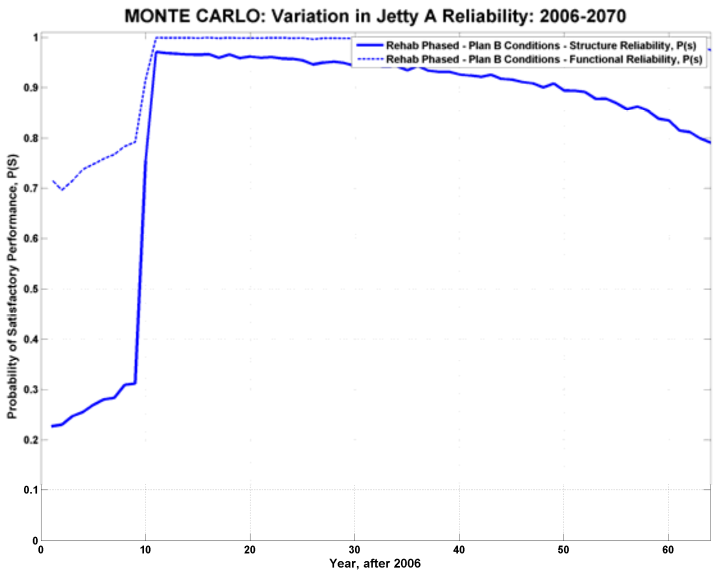

Figure A2-138c. Forecast reliability for MCR Jetty "A". Small Template Rehab (Plan B) - Immediate (Hold Head).

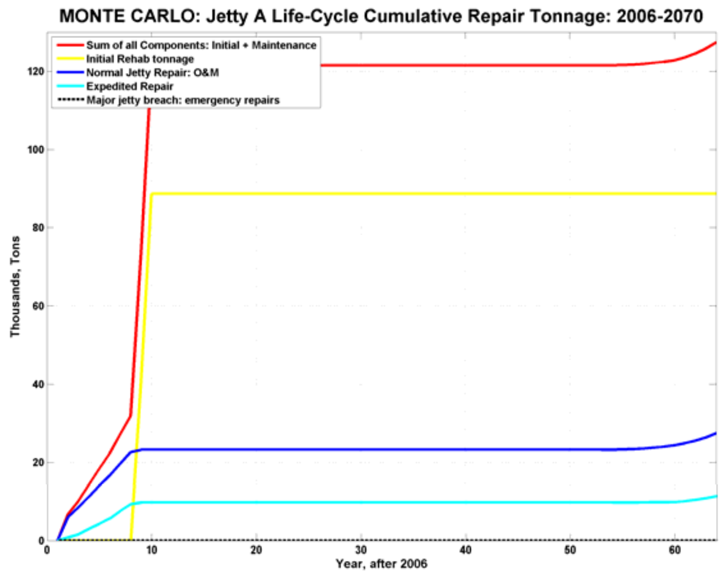

Figure A2-138d. Life-cycle cumulative repair tonnage for MCR Jetty "A". Small Template Rehab (Plan B) - Immediate (Hold Head).

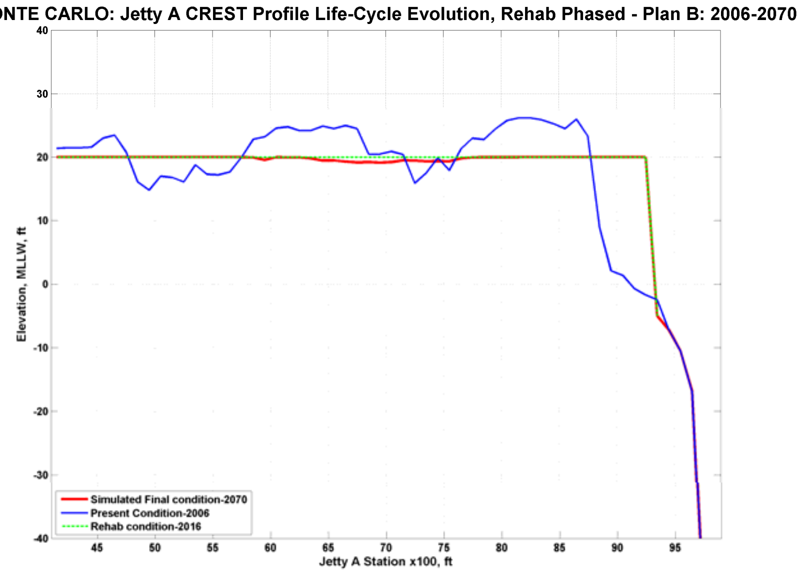

Figure A2-138e. Centerline profile for MCR Jetty "A". Small Template Rehab (Plan B) - Immediate (Hold Head).

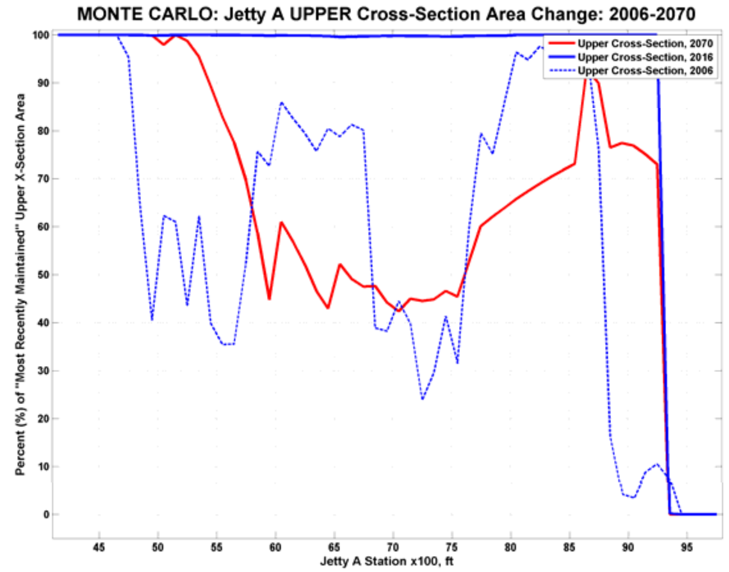

Figure A2-138f. Variation of upper cross-section area for given station of MCR Jetty "A". Small Template Rehab (Plan B) - Immediate (Hold Head).

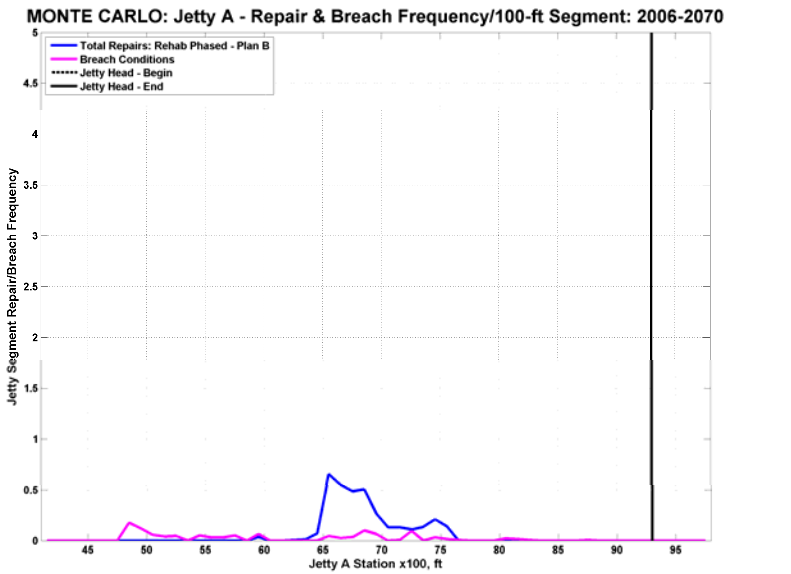

Figure A2-138g. Frequency and location of repairs and breaches for MCR Jetty "A". Small Template Rehab (Plan B) - Immediate (Hold Head).

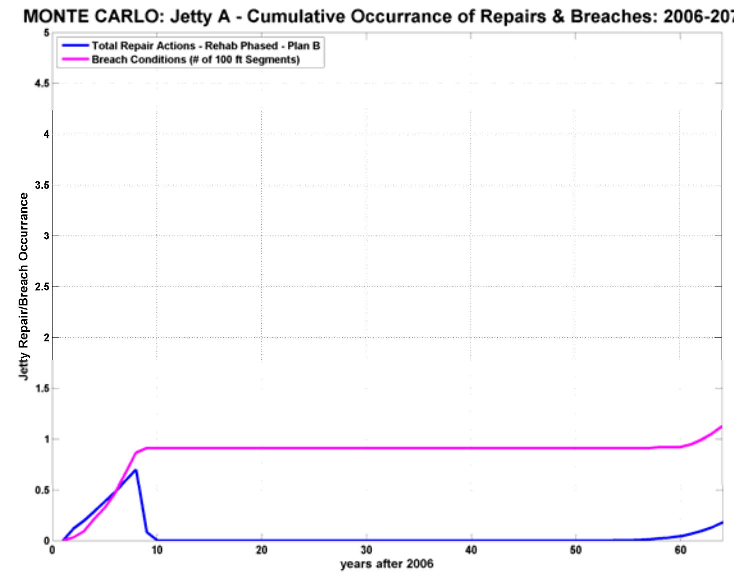

Figure A2-138h. Cumulative occurrence of repairs and breach conditions for MCR Jetty "A". Small Template Rehab (Plan B) - Immediate (Hold Head).

MCR Jetty System Major Rehabilitation Evaluation Report

Appendix A3

SRB Model User's Manual

Preface

This User's Manual contains a description of how to apply the Stochastic Reliability-Based (SRB) Model for evaluating future maintenance alternatives for the Mouth of the Columbia River (MCR) jetty systems. This User's Manual and the SRB model have been modified/improved to address review comments from the U.S. Army Corps of Engineers Headquarters (HQUSACE) and an Independent Engineering Peer Review (IEPR) team. This manual replaces the previous *Model Documentation Report* (USACE, 2010).

In order to address the IEPR team's unresolved comments, CENWP retained the assistance of Moffatt and Nichol, via a two-phase task order. Phase I of the task order was to review the model, associated documentation, and engineering regulations to identify specific changes that needed to be made in the model code and Phase II was to assist CENWP in making those changes. Phase I produced a letter report evaluating the functionality of the MCR SRB model and identified nine specific improvements to the model that addressed the outstanding concerns. All nine of the recommendations were adopted by the PDT and were then developed and implemented in Phase II. Among the specific improvements are: an improved user interface, a detailed user's manual, changes to the SRB model structure (including the use of one model for all three MCR jetties), changes to how costs are evaluated, and other modifications which were recommended by HQUSACE. The table on the following page lists the nine required improvements, how the improvements were implemented, and the related sections of this User's Manual.

A significant new aspect of the SRB model is the input interface. The model user is able to define and modify input parameters from a convenient Excel worksheet. A description of this input interface is included as an appendix to this manual, as well as within the main body of the manual.

It should be noted that the SRB model does not develop design criteria for the alternative plans. The alternative design process is performed external from the SRB model and the alternative design parameters are then input into the SRB model by the user in the form of an Excel file. Other input parameters include damage functions, storm events and wave heights, initial jetty geometry, and other simulation control variables such as the desired duration of the lifecycle model. Various alternatives can be evaluated by the SRB model by changing the input parameters to the SRB model.

The cost analysis is performed separately from the structural calculations and is further described in the *MCR Major Rehabilitation Evaluation Report* (USACE, 2012). The structural analysis is performed first, via the SRB model, resulting in calculations of jetty degradation and repair (e.g. life-cycle material quantities) for each repair alternative. The output files from this SRB model analysis are then used as inputs to the Excel spreadsheet-based cost analysis to estimate life-cycle costs and other parameters for each alternative.

This User's Manual starts with an overview of the MCR SRB model operation in order to facilitate basic understanding. Additional sections provide details of the specific model input procedures, output options, variables definitions, model subroutines, a narrative of how the model handles a typical jetty section, and a discussion of the model calibration approach and results. Appendix B of the manual provides a comparison of results between the original model and the new model.

Required Improvement	Model Improvement Completed	Related Section of This Manual
1. Modularize the model code using the existing approaches where they are appropriate. Specifically, separate parts of the code related to the following: Setup of global variables, setup of MC simulation, specification of alternatives, calculation of damage functions, geometry adjustment after damage, creation of output and plotting.	Separate scripts created for these and other parts of the model code.	Sections 3.5 – *Input Setup* and 3.7 – *Running the Model* – Table 5
2. a) Validate independent modules based on available literature and previous experience with the MCR jetties. b) Alternative formulations of the damage functions used in the model should be provided for comparison of model results with alternative published analytical formulations.	a) Model applied in hindcast mode and compared to historical records of MCR jetty maintenance. b) Damage functions were developed through detailed physical model studies conducted at ERDC, featuring MCR jetty cross-section attributes.	a) Section 6 – *Model Calibration* b) 5.3 – *Damage Quantification / Function*
3. Calibration results for the model need to be clearly documented. To accomplish this, the calibration process and parameters must be clearly documented within the model and in the model output and reporting.	Calibration was completed for hindcast conditions. The results are shown in the figures in Section 6.	Section 6 – *Model Calibration*
4. During the process of modularizing the existing model, the structure should be changed to allow a single model code capable of evaluating alternatives for all three jetties.	A single model code is used for all three jetties. Information for each specific jetty is input to the single model and MC simulations are run for each specific jetty.	Sections 3.5 – *Input Setup* and 3.7 – *Running the Model*
5. Improvements are required in the user interface to allow the user to easily review all input and output parameters. Existing hard-coded parameters should be removed from the model code to provide greater transparency.	The input parameters can be specified in an Excel file. The Excel file provides a convenient interface for editing the input parameters.	Sections 3 – *Model Input Interface* and 4 –*Model Output*
6. A well-documented user's manual needs to be prepared to allow qualified modelers to apply the model to evaluate alternatives.	A User's Manual (this document) has been created. This manual replaces the previous *Model Documentation Report* (USACE 2010).	Entire manual.
7. The economic and structural analyses should be separated into independent routines. The economic analysis calculations would be based on the output from structural simulations with an interface between the two models. This approach also permits the use of different economic analysis approaches for a single structural simulation.	The cost analysis is separate from the structural analysis. The structural calculations of jetty degradation and repairs are first performed and results are saved into output files. These output files are the inputs to the separate cost analysis.	Section 2.1- *Intent*. The cost analysis is described in the Evaluation Report
8. Additional metrics for evaluating alternatives can be output from the model to assist in the economic evaluation of the alternatives. These include structural and functional reliabilities, and stone volumes which were lost, placed, or moved. A facility can be created to easily calculate and output new metrics as needed.	Additional metrics, in the form of model output files, include these parameters.	Sections 2.6 – *Reliability* and 4 –*Model Output*
9. Shoaling related to jetty breaching should be eliminated while the repair requirements to the jetty section should be retained for the breaching.	The shoaling related to jetty breaching was eliminated. Breach occurrences and frequency are output files.	Section 4 – *Model Output*

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1. INTRODUCTION

This User's Manual contains a description of how to apply the Stochastic Reliability-Based (SRB) Model for evaluating future maintenance alternatives for the Mouth of the Columbia River (MCR) jetty systems. Further background on the model formulation is available in Appendix A1: Coastal Engineering and Appendix A2: Reliability Analysis, Event Tree Formulation and Life-Cycle Analysis of the *MCR Jetty System Major Rehabilitation Evaluation Report* (USACE 2012), (a separate document from this user's manual).

1.1. BACKGROUND

The U.S. Army Corps of Engineers-Portland District coastal engineers have developed a stochastic SRB model to evaluate future jetty repair and rehabilitation alternatives for the MCR jetty systems.

Three jetties presently control the dynamic morphology of the MCR inlet (North Jetty, South Jetty and Jetty 'A'), each of which is in a varied state of deterioration. The jetties each provide an important individual function which contributes to the ultimate objective of securing and maintaining the configuration of the authorized navigation channel through the MCR inlet. Initial construction of the South Jetty began in the late 1800's; North Jetty construction began in 1917. The jetties were designed to minimize navigation channel maintenance and provide a safe entrance to the inlet. Over time, the channel thalweg migrated north, in proximity of the North Jetty. Jetty 'A' was constructed in 1939 to direct river (and ebb tide) currents away from the North Jetty, minimizing the potential for scour along the North Jetty foundation. The North and South Jetties have been repaired several times since original construction; the latest repairs occurred in 2005 on the North Jetty and 2006-2007 on the South Jetty (Jetty 'A' has only been repaired once since initial construction, in 1965). The recent repairs on the North and South Jetties were interim repairs designed to maintain jetty functionality until a longer-term maintenance and repair plan was designed.

The MCR SRB model described in this manual is intended to be a statistical tool that assists engineers and project managers in determining the most cost-effective and reliable method of maintaining and repairing the jetties in the future. The jetties have been functioning for over 70 years (South Jetty for over 100 years) and the SRB model is being implemented to determine the best repair and maintenance plan so that the jetties can continue to provide reliable function into the future.

1.2. RECENT MODEL DEVELOPMENTS

The MCR SRB model has been developed over several years and was subjected to an Agency Technical Review (ATR). After incorporating the ATR comments, the model was evaluated during the Independent Engineering Peer Review (IEPR) of the MCR Major Rehabilitation Study.

This User's Manual and the SRB model have been modified/improved to address the review comments from the IEPR team and HQUSACE. Among the specific changes are: an improved user interface, a detailed user's manual, changes to the SRB model structure (including the use of one model for all three MCR jetties), changes to how costs are evaluated, and other modifications. These improvements allow CENWP personnel to more easily evaluate various modifications to the alternatives analysis. This manual replaces the previous *Model Documentation Report* (USACE, 2010).

This User's Manual contains a description of how to apply the SRB Model for evaluating future maintenance alternatives for the MCR jetty systems. The MCR SRB model is intended to be operated by a person with some general knowledge about the model flow and implications of selecting alternative values for variables.

2. MODEL OPERATION OVERVIEW

2.1. INTENT

The general intent of the MCR SRB model is to provide data to predict the lifecycle costs of MCR jetty repair and maintenance alternatives. The ultimate objective is to utilize the predicted lifecycle cost ranges computed for each plan to select the option with the minimum cost. One of the basic assumptions of the model application is that the functional performance of the MCR jetties, in terms of stabilizing the navigation channel, will be not be compromised. Therefore, jetty reliability becomes less important relative to maintenance costs. At the foundation of the model is a Monte Carlo (MC) simulation which comprises numerous model runs (often in the thousands), each with varying random parameter values. The model, therefore, relies heavily on replicating stochastic processes that affect jetty life-cycle performance. The cost analysis is performed separately from the MRB model structural analysis and is described further in Chapter 2 and Appendix C of the *MCR Jetty System Major Rehabilitation Evaluation Report* (USACE 2012).

Random variation of specific parameters is necessary due to the uncertainty involved in predicting the future demand on, and resultant response of, the jetty structures. Random hydrodynamic effects (waves and currents), structural instabilities (improper interlocking of stones, poor foundation, etc.) and an uncertain future climate are just a few examples of the factors that will affect jetty structural performance. These uncertainties and others, however, will impact the total lifecycle cost of repairing and rehabilitating the jetties in the future. The degree of impact each parameter will have in the future is unknown.

Implementing a MC simulation in this model provides a means to estimate ranges of expected future jetty lifecycle performance metrics for different repair alternatives; these ranges are akin to confidence limits in a statistical analysis. Through this analysis, it is possible to observe the parameters that are most sensitive to random variation and have the largest impacts on lifecycle costs and/or reliability. If the impacts of these parameters are understood and their variation can be controlled to a certain degree, it should follow that the lifecycle costs can likewise be managed to a similar degree.

2.2. OPERATION

The SRB model is considered to be an engineering model and was developed based on USACE guidance for major rehabilitation evaluation and life-cycle analysis. Table 1 summarizes the physical processes that affect jetty life-cycle performance versus how those processes are addressed in the SRB model.

The MCR SRB model was built on the MATLAB® platform, a high-level language and interactive environment that enables performing computationally intensive tasks faster than with traditional programming languages such as C, C++, or FORTRAN. The model is constructed of a master routine that calls other subroutines throughout model execution.

The SRB model can be operated in two distinct manners: as a *hindcast* model typically used for calibration of critical model parameters or a *forecast* model. The hindcast mode for each jetty incorporates historical jetty geometries (e.g., cross-sectional elevations and widths), and other relevant information from the actual repairs that occurred to each structure since original construction (or since a specified historical date in the case of the South Jetty). Generally, if there is good agreement between modeled and historically measured data, then the model has good skill (predictability) and is deemed performing well. In calibrating the SRB model, historical repair schedules are compared to modeled schedules. Based on a qualitative assessment (i.e., observing plots of repair schedules), the hindcast predictions for the MCR jetties appear to have good model skill. The model calibration utilizing the hindcast mode will be discussed in a later section of this User's Manual.

Table 1: Physical Processes and Jetty Responses Emulated within the SRB Model

DEFINE INITIAL CONDITIONS Hindcast or Forecast →	SIMULATE ENVIRONMENTAL FORCING & STRUCTURE RESPONSE →	EVALUATE END STATE
Jetty Segment Attributes	**Environmetal Forcing and Jetty System Response**	**SRB Life-Cycle Performance Metrics**
(mean value, std dev)	(mean value, std dev for each side of jetty)	(mean value, std dev)
toe elevation	time-varying shoreline evolution	time-varying structural reliability
crest elevation	time- and spatially-varying scour rates	time-varying functional reliability
crest width	time- and spatially-varying wave conditions	timing and location of repairs
jetty side slope	time-varying water levels	repair tonnage & shoaling volume
armor stone size	variable jetty root degradation rates	jetty breach occurrence
armor stability number	repair history by jetty segment	components of life cycle cost
stone density	tonnage placed on the jetty	jetty crest elevation change
core stone presence	cost functions for jetty repair scenarios	cross-section evolution
jetty head position	channel shoaling associated with jetty performance*	jetty end state
	cost functions for dredging effect scenarios*	
*** = used for life-cycle cost forecasting**		

The hindcast model results are also used to initialize the model for operation in forecast mode. In forecast mode, the MCR SRB model predicts structural damages (based on randomized storm conditions), implements repairs and rehabilitations, and calculates material quantities involved over an anticipated jetty lifecycle. The jetty repair and rehabilitation responses that occur during forecasting in the SRB model are based on a user-selected repair plan and are activated when computed jetty damages exceed specified thresholds. The forecasting procedure is similar to the hindcast procedure within the SRB model. For simplicity, only the model forecasting procedures will be described below, but the general methods are essentially equivalent.

2.3. ORGANIZATION

Within the SRB model, lifecycle simulations are facilitated as nested loops. 'Nested' indicates that routines are called to run within other routines; in essence, creating loops within loops. This makes it possible to break the model into smaller, more manageable sections while still achieving modeling efficiency (fast computation times). The model can be setup to run for several years (e.g., lifecycles) and damages can be estimated over a range of storms (annual number of storms) on individual jetty segments (100-ft segments).

The model is controlled by the main procedural module, which calls routines as required to perform the specific simulation. Within the main procedural module, the loops are nested in the following order:

- Number of MC simulations to run (currently set to 1,000 simulations)
- Number of years to forecast in the future (jetty dependent, beginning in year 2006; or hindcast)
- Number of jetty segments (broken into 100-ft segments, or Stations)
- Number of storms predicted to occur in each year (randomly determined from a distribution)

In other words, for each MC simulation, and for each year in the forecast, each 100-ft jetty segment is analyzed for damages from each storm predicted to occur in that year. This continues sequentially until all jetty segments have been analyzed for all predicted annual storms in a given year. Subsequently, the model year is incremented and loops through the routines again until a complete lifecycle has been modeled. This process is repeated for each MC simulation (1,000 simulations) until the total number of simulations has been analyzed. Figure 1 graphically depicts the concept.

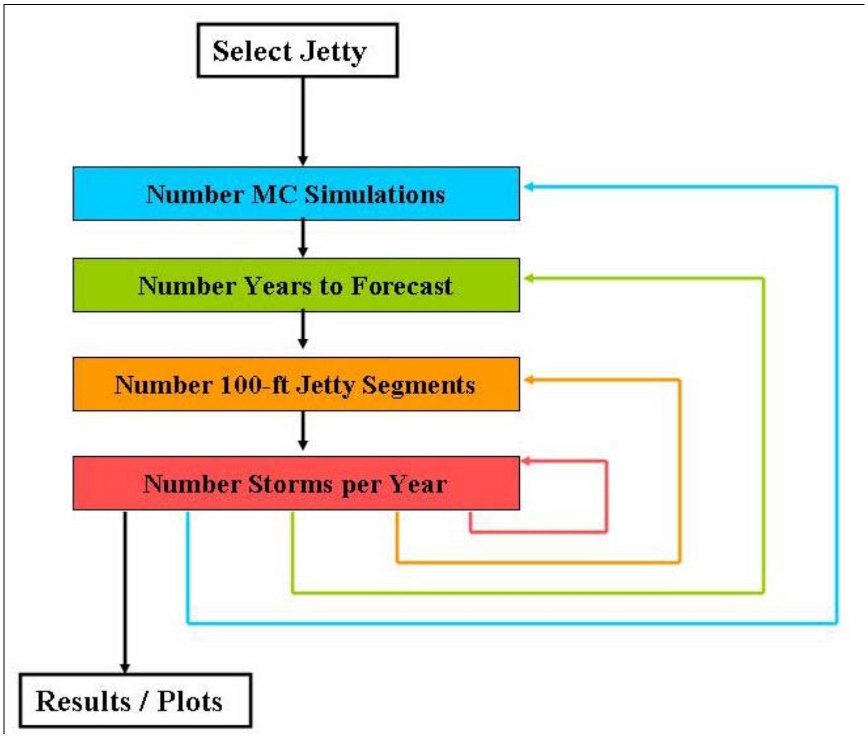


Figure 1: Basic MCR SRB Model Flowchart

2.4. STORM EVENTS

Storm wave heights used in the model are generated utilizing a numerical wave propagation model (STWAVE). STWAVE computes nearshore wave heights, periods, and directions by propagating offshore deepwater wave conditions to the nearshore area adjacent to the jetties. A total of 52 observed storm events were selected as representative events to include in the storm database. These are the largest storm events on record, as measured by offshore observation buoys in proximity to the MCR inlet. Each event has impacted the MCR in the recent past; the potential exists for similar events to occur and impact the structures at the MCR inlet in the future.

The storm database used in the MCR SRB model was created prior to any forecast modeling. It comprised near-jetty wave heights at specific along-jetty locations that were predicted by the STWAVE model. Each near-jetty wave height correlated directly with an offshore storm condition.

In the MCR SRB model, for each storm predicted to occur in any given model year, a storm event was randomly selected from the database of 52 storms. Subsequently, the corresponding near-jetty wave heights for that particular storm event are selected from the storm database. The wave heights are interpolated along the lengths of the jetties, so that wave heights at each 100-ft jetty station are known, and damages calculated at each jetty segment.

2.5. JETTY DAMAGE

In the MCR SRB model, both static and dynamic effects contribute to structural damage of the jetties. Static damage is attributable to toe scour and side slope failure. Toe scour and resulting toe and slope stone settlement typically results from river and tidal currents scouring the foundation sediments away. Side slope failure often occurs subsequently because of foundation settlement, and may also be a result of scour. The damage associated with static effects are estimated based on historical observations of scour and slope failure occurrences which occurred as an aggregate of all relevant processes. Therefore, detailed knowledge of the individual processes is not required. In the SRB model, damages from scour are only applied below the wave elevation surface (defined as the elevation below which wave action does not affect jetty stone).

Dynamic effects are attributable to wave action on the jetty stone (wave breaking and wave overtopping). The damage associated with wave action is computed directly from damage functions resulting from extensive physical modeling of various jetty repair alternative designs. The physical model results, which are specific to the MCR Jetties, are critical for defining the damage functions. The damage functions are simply correlations between wave height and damage. Damage is measured as area damage (square feet [sf]) with respect to the jetty cross-section for a particular 100-ft jetty segment (e.g., for a certain wave height at the jetty, a corresponding amount of damage [in sf] is expected to occur). The damage is combined with any previous damage that has occurred at a particular jetty segment such that cumulative damages are tracked at all stations along a jetty from storm to storm and year to year. The damage thresholds set in the model determines when repairs are implemented and when failures occur.

2.6. RELIABILITY

Jetty reliability is a metric by which to quantify the likelihood of jetty damage occurring. Reliability is considered in two modes in the MCR SRB model: *structural* and *functional*. Structural reliability is a measure of how likely a structure will resist damage during a given time period. Oftentimes, rubble-mound structures can incur damage without affecting the functionality of the structure (because they are not rigid structures). A jetty's ability to incur damage while still performing its function is its resilience. Jetty segments with high resilience can incur a great deal of damage while still performing their intended function. Functional reliability is a measure of how likely a structure will continue to perform its function without failing (e.g. breaching).

Within the MCR SRB model, as jetty segments incur damages, the structural and functional reliabilities are adjusted accordingly (decreased). Likewise, when segments are repaired, reliabilities are increased to reflect the increased structural stability of the repaired segments. If a jetty segment fails (e.g., the functional reliability falls below a certain threshold) emergency repairs may be initiated.

3. MODEL INPUT INTERFACE

3.1. INPUT PARAMETERS

Input parameters utilized within the SRB model include: time-varying shoreline evolution along each side of the jetty; time- and spatially-varying scour rates along each side of the jetty; time and spatially varying wave conditions along each side of the jetty; time-varying water levels; variable jetty root degradation rates; spatially variable and time-varying jetty cross-section attributes (for each side of the jetty). The pre-loaded input files are shown in Table 2 below.

Table 2: Pre-loaded Excel Input Files

Filename	Purpose
SUMMARY_NJ.xls **SUMMARY_SJ.xls** **SUMMARY_JA.xls**	Summary of jetty geometry
50Waves_Verified.xls	Data for 50 preselected representative storm conditions
STWAVE_MCR2008_comps_L.xls	Storm event wave heights and periods for jetty perimeter locations at low water level condition (all 3 jetties)
STWAVE_MCR2008_comps_M.xls	Storm event wave heights and periods for jetty perimeter locations at medium water level condition (all 3 jetties)
STWAVE_MCR2008_comps_H.xls	Storm event wave heights and periods for jetty perimeter locations at high water level condition (all 3 jetties)
Eroded_A_plots_NJ_FINAL_HS.xls **Eroded_A_plots_SJ_FINAL_HS.xls**	Damage functions for North and South Jetty. Damage functions determine the jetty damage that occurs for a storm event of given wave height.

Two stand-alone scripts for each jetty are used to convert Excel-based data into MATLAB MAT files for input to the SRB model. The input data conversion process (from Excel to MATLAB) deals with data that defines the present physical condition of the jetty, STWAVE model output, and wave damage functions. The data file conversion is performed only one time; after which the SRB model reads the input data from the MAT data file every time the SRB model is run. Other data types and SRB model control parameters are specified in the main XML file.

When executing a hindcast SRB simulation, the initial condition geometry, jetty armor/core stone attributes, and jetty foundation scour rates are defined for the entire jetty, on a segment by segment basis. A jetty segment is 100-ft long. The historical repair sequence is defined within the model, to define the number of times segments can be rebuilt, repair cross-section attributes, and the applicable threshold to initiate repairs. Future lifecycle simulations use the ending jetty condition from the hindcast to describe the initial jetty condition (geometry and armor stone characteristics) in the forecast. This means that a calibrated hindcast simulation must be completed (with hindcast MATLAB .mat output files saved), prior to initiating a future lifecycle simulation.

The SRB model does allow for the use of observed geometry data (present jetty survey) to override the simulated end-state jetty geometry obtained from model hindcast. In this case, the SRB model would use "observed" survey data to define the initial forecast condition when conducting future simulations. The "observed" geometry option was used to define the initial condition for jetty geometry for all SRB life-cycle forecasts conducted in this study. Because there is no objective way to estimate the armor layer characteristics for the forecast initial (present day) condition along each jetty, the calibrated SRB hindcast solution was utilized to define initial conditions for armor stone characteristics along each jetty, when forecasts where conducted.

The model requires a certain amount of input information in order to complete a MC simulation for a specific jetty. During a MC simulation, the bulleted items below are loaded into the model workspace from existing user-defined input data files.

- Damage Functions
    - Damage functions are previously created correlations that were obtained from physical modeling of the jetties at Engineer Research and Development Center (ERDC).
    - They are direct relationships of the near-jetty wave heights to the amount of damage the jetty segment is expected to sustain when that wave height occurs at the jetty.
- Storm Events and Wave Heights
    - Storm wave heights at specific locations along the jetties are known from STWAVE modeling for specific storm conditions.
    - Wave heights for three expected water levels were modeled in STWAVE: low, medium and high water levels.
    - The wave heights and water levels create the storm wave database from which storm wave events are selected and used to compute jetty damages.
- Jetty Initial Geometry (Crest Heights and Widths)
    - Geometries for hindcasts are obtained from historical records.
    - Initial geometries for forecasts are either obtained from the most recent surveys of the jetties (2006) or the final hindcast geometries.
- Simulation Control Variables
    - Hindcast or Forecast model mode selection.
    - Repair alternative plan selection for forecast mode (determines what repairs are implemented and when repairs are necessary).
    - Length of lifecycle model (number of years).
    - Engineering feature options (spur groins, head caps, lagoon fill).
    - Switches for various parameters (how to defer repairs, RSM, shoreline positions and shoreline change positions, etc.).

The basic variables that ensure proper setup and operation of the MCR SRB model are indicated below. These variables determine, among other things, the length of the modeling simulation (number of MC simulation model loops), the length of the lifecycle model duration (number of years into the future simulated), and the type of repairs to be implemented as damage occurs.

3.2. Selection of Repair Strategy

The repair strategy variable determines which repair scenario will be modeled during the simulations.

- ***fut***: The value activates specific repair functions and parameters, determining which repair scenario is implemented and when repairs are made. The values of fut for each jetty and corresponding repair scenarios are listed in Table 3.

Table 3: Repair Strategy Selection

fut for NJ	fut for SJ	fut for JA	Repair Alternative
0	**0**	**0**	Hindcast Condition (for calibration and historical analysis)
1	**1**	**1**	Future Condition: No action alternative (a.k.a. base condition)
10	**10**		Future Condition: NON-Rehab, but includes engineering features
11	**11**		Future Condition: Minimum template (MT), immediate rehab
	12	**12**	Future Condition: Rehab plan A, immediate rehab
13	**13**	**13**	Future Condition: Rehab plan B, immediate rehab
14	**14**		Future Condition: Rehab plan C, immediate rehab
20	**20**	**20**	Future Condition: Composite rehab, immediate rehab
21	**21**		Future Condition: Minimum template (MT), scheduled rehab
	22	**22**	Future Condition: Rehab plan A, scheduled rehab
23	**23**	**23**	Future Condition: Rehab plan B, scheduled rehab
24	**24**		Future Condition: Rehab plan C, scheduled rehab
30	**30**	**30**	Future Condition: Composite rehab, scheduled rehab

3.3. Number of MC Simulations

The numbers of MC simulations over which the model will run are determined with this variable. For a thorough analysis, the value should be large (e.g., 200 simulations); however, caution should be employed when selecting this variable due to the high computational time required for this number of simulations (days).

- ***MC_sim***: The variable sets the number of MC simulations over which the model will run.

3.4. Other Modifiable Model Parameters

The files in Table 4 below are only used or created when damage functions need to be updated. The *.mat MATLAB files are used as model input during model execution. In agreement with the statements above, unless the user has adjusted damage function values, there will be no need for adjustment of any of these files. The remaining files are data files that are loaded by the *master* or subroutine scripts as input files during the MC simulations. They incorporate the storm event wave conditions (wave height and wave period) at specific locations around the perimeter of all three jetties, for three different water levels (low, medium and high). The wave conditions are used to directly compute damages resulting from wave attack.

Table 4: Model Code Input Files

Filename	Purpose
NORTH_XLS_new.mat	MATLAB data file created from damage functions given in SUMMARY_NJ.xls
NJ_2006_ARMR.mat **SJ_2007_ARMR.mat** **JA_2006_ARMR.mat**	Armor stone sizes and standard deviations along both sides of each jetty for future condition simulations. Values are the end result of hindcast simulations.
NJ_2006_GEOM.mat **SJ_2007_GEOM.mat** **JA_2006_GEOM.mat**	Cross-section geometry of each jetty for future condition simulations. Values are the end result of hindcast simulations.
PRE_THRESH_XSECT_NJ **PRE_THRESH_XSECT_SJ** **PRE_THRESH_XSECT_JA**	Repair initiation threshold for each segment of the jetty for scheduled repairs. Result of "fix-as-fail" simulation.

It should be noted that there are some other hard-coded variables and data distributions incorporated throughout the code. These variables are not listed in this guide, but the user is referred to the model code to become informed. Environmental data distributions (e.g., wave heights, directions, etc.) were used to randomize storm event characteristics. These distributions best modeled the data at the time the model was created, based on existing offshore measurements. However, these are subject to change based on the user's discretion.

3.5. INPUT SETUP

Most governing parameters are specified in an XML file; a text file which uses a special markup language to store information. The files are easy to read in a text editor. Also, many software programs can work with these files to transfer information. Both MATLAB and Excel support reading and writing XML files, which makes XML a convenient format for model interface.

The input parameters can be modified in an Excel file which is linked to the main XML file. The Excel file provides an interface for editing input parameters. One can also utilize Excel's capabilities to plot relevant inputs for initial visual verification, such as jetty geometry. The steps to create the input files are detailed in Appendix A.

The model requires many parameters to be specified. In an Excel file, the parameters are grouped in separate sheets. "Global" and "Setup" sheets define parameters of model behavior and definitions of alternatives. Specific parameters are used in calculations for a given jetty; they are defined on special sheets. For example, sheet "NJ" contains variables for North Jetty. The "Geometry" sheet defines locations of nodal points along and across the jetty and their elevations. Because each cross-section profile is defined with eight nodes, all eight node elevations should be defined before the simulation starts.

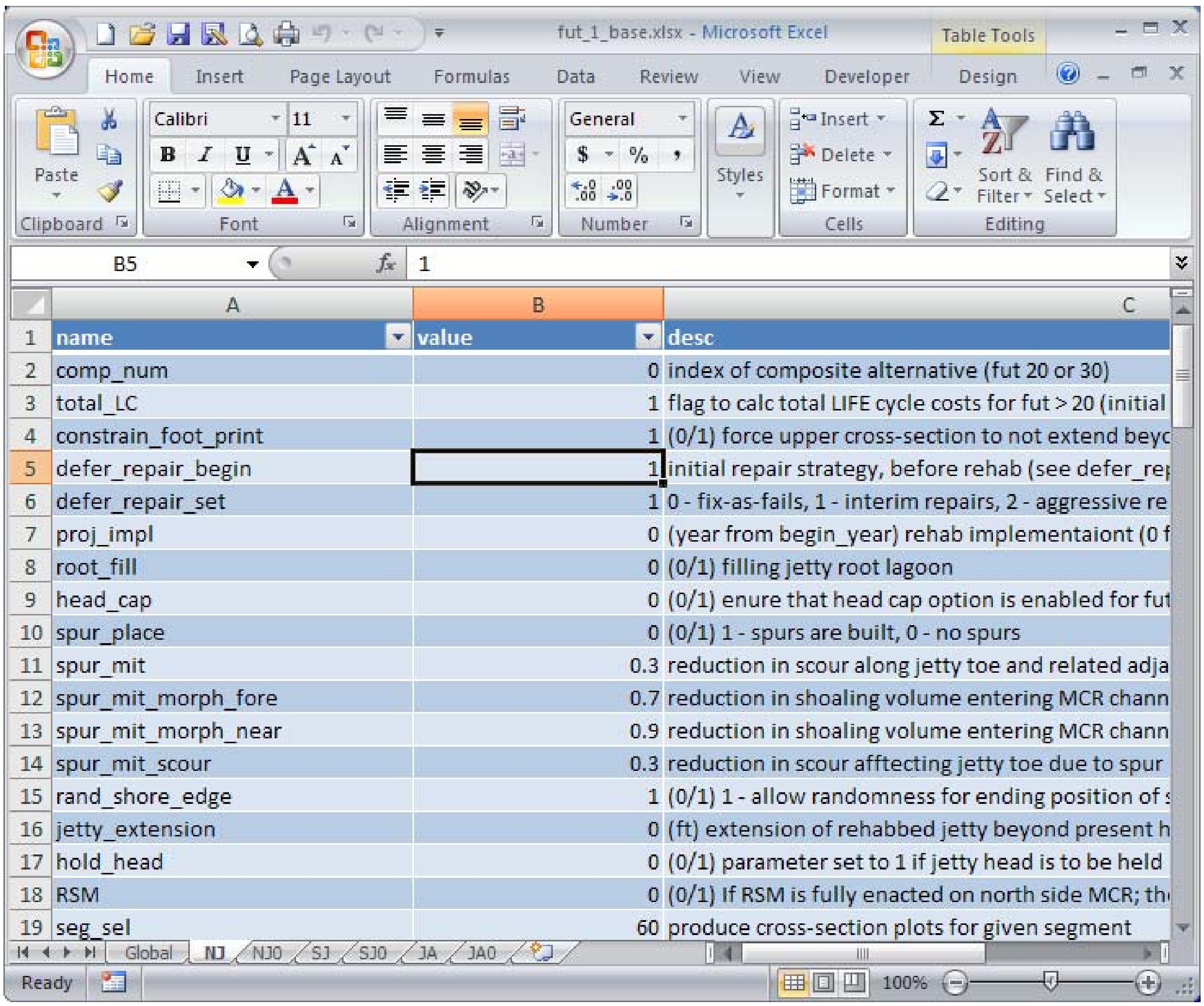
The parameters are defined with their names and values and a description is provided for convenient inline reference. The values can contain strings or numbers. It is also possible to define vector arrays of numbers, for example, "0.1 0.2" defines a variable with two elements.

Because of a large number of parameters, they are grouped in several sheets. "Global" and "Setup" variables define parameters of model behavior and alternative definition. Some specific parameters are used in calculations for given jetty. They are defined on special sheets. For example, sheet "NJ" contains variables for North Jetty. "Geometry" sheet defines locations of nodal points along and across jetty and their elevations. Because each cross-section profile is defined with eight nodes, all eight nodes elevations should be defined before the simulation starts.

After the variables are saved in the Excel file they need to be exported back into the XML file with the XML export command. The resulting XML file is used as an input into the model.

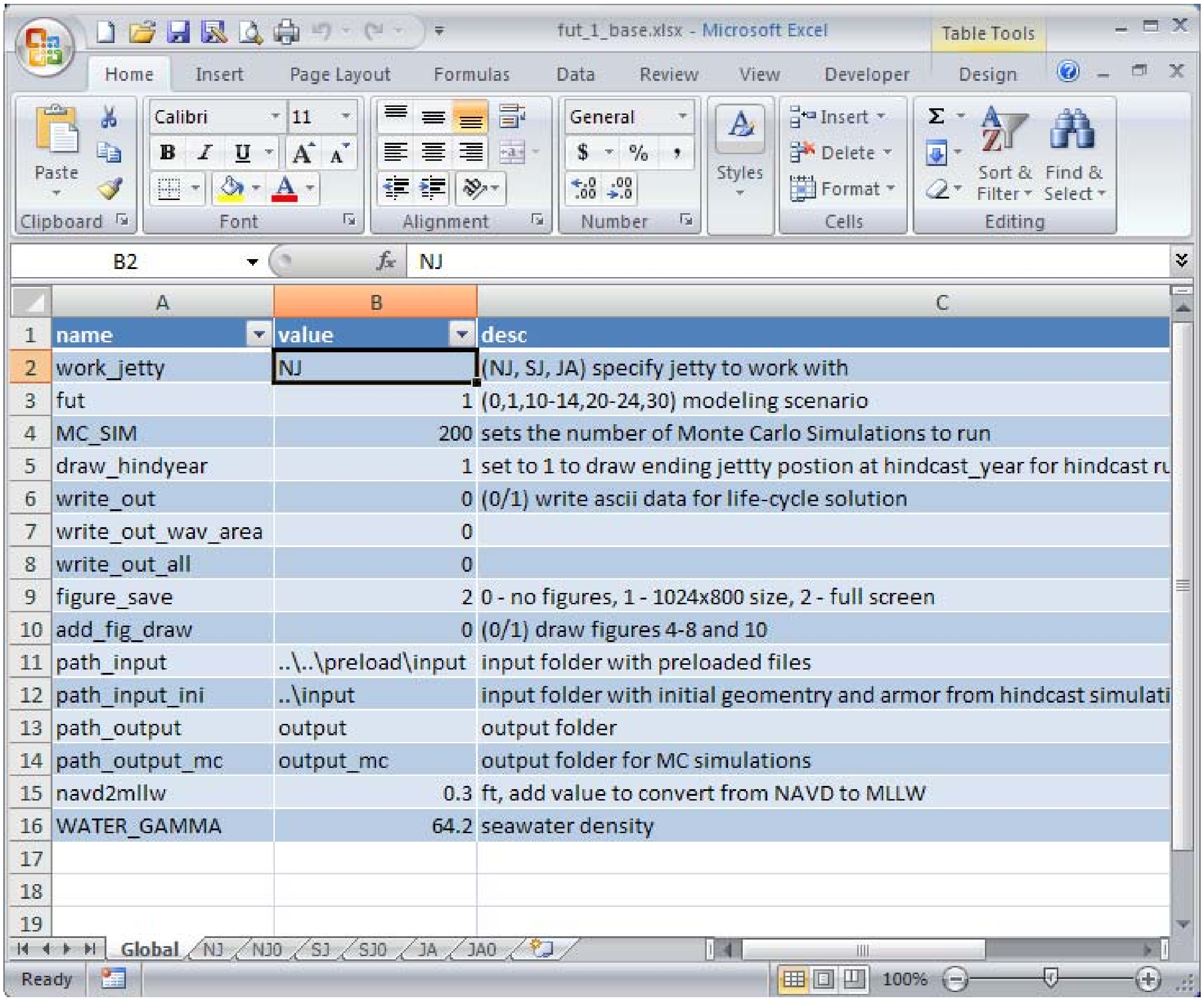
3.6. INPUT FILE SAMPLES

Figures 2 – 5 show examples of input file editing using Excel. The input Excel file is linked to an XML file, which stores all parameters. The Excel file provides a convenient interface for editing the input parameters. It is also possible to use plotting capabilities for initial data validation.



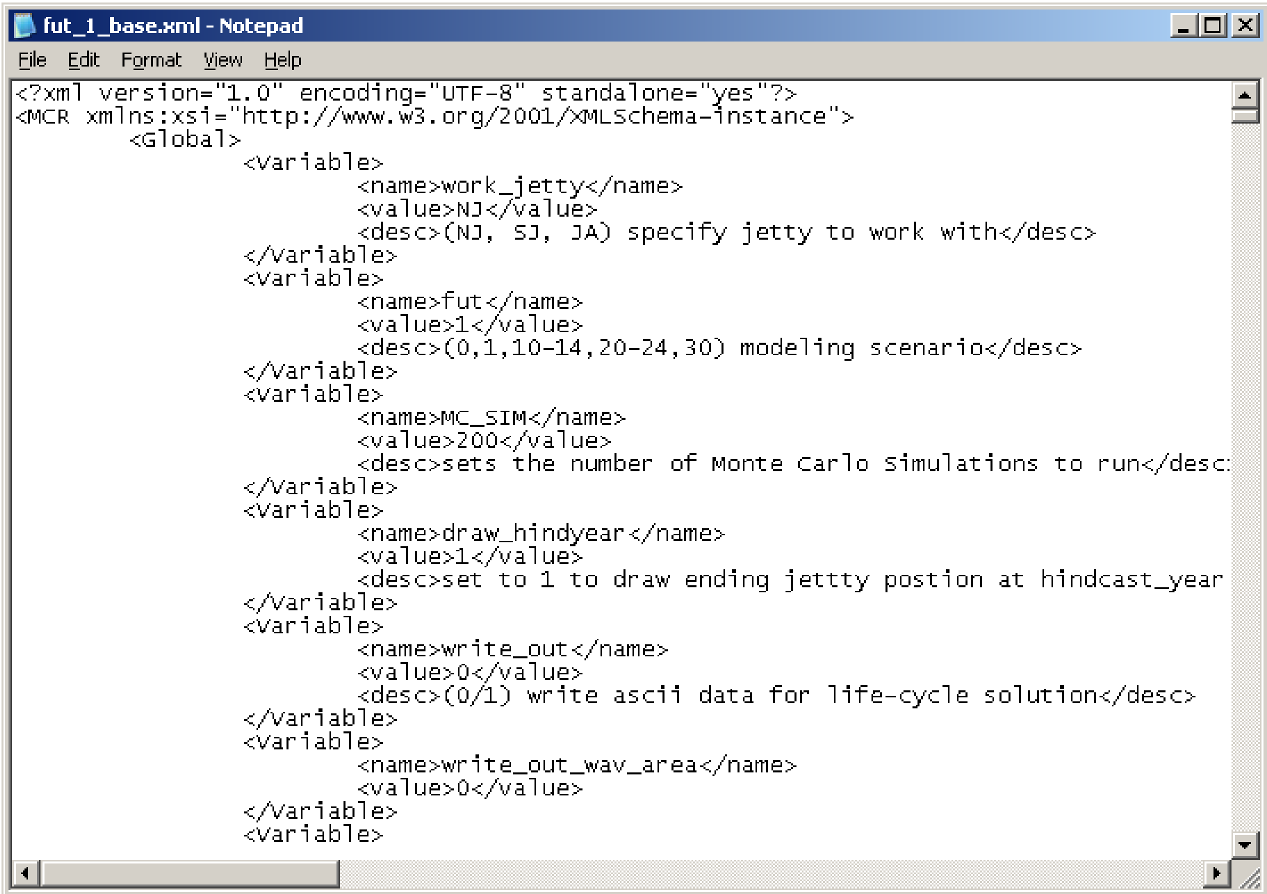
	name	value	desc
2	comp_num	0	index of composite alternative (fut 20 or 30)
3	total_LC	1	flag to calc total LIFE cycle costs for fut > 20 (initial
4	constrain_foot_print	1	(0/1) force upper cross-section to not extend beyc
5	defer_repair_begin	1	initial repair strategy, before rehab (see defer_rep
6	defer_repair_set	1	0 - fix-as-fails, 1 - interim repairs, 2 - aggressive re
7	proj_impl	0	(year from begin_year) rehab implementaiont (0 f
8	root_fill	0	(0/1) filling jetty root lagoon
9	head_cap	0	(0/1) enure that head cap option is enabled for fut
10	spur_place	0	(0/1) 1 - spurs are built, 0 - no spurs
11	spur_mit	0.3	reduction in scour along jetty toe and related adja
12	spur_mit_morph_fore	0.7	reduction in shoaling volume entering MCR chann
13	spur_mit_morph_near	0.9	reduction in shoaling volume entering MCR chann
14	spur_mit_scour	0.3	reduction in scour afftecting jetty toe due to spur
15	rand_shore_edge	1	(0/1) 1 - allow randomness for ending position of s
16	jetty_extension	0	(ft) extension of rehabbed jetty beyond present h
17	hold_head	0	(0/1) parameter set to 1 if jetty head is to be held
18	RSM	0	(0/1) If RSM is fully enacted on north side MCR; th
19	seg_sel	60	produce cross-section plots for given segment

Figure 2: Editing Input Parameters for Selected Alternative in Excel Spreadsheet



name	value	desc
work_jetty	NJ	(NJ, SJ, JA) specify jetty to work with
fut	1	(0,1,10-14,20-24,30) modeling scenario
MC_SIM	200	sets the number of Monte Carlo Simulations to run
draw_hindyear	1	set to 1 to draw ending jettty postion at hindcast_year for hindcast ru
write_out	0	(0/1) write ascii data for life-cycle solution
write_out_wav_area	0	
write_out_all	0	
figure_save	2	0 - no figures, 1 - 1024x800 size, 2 - full screen
add_fig_draw	0	(0/1) draw figures 4-8 and 10
path_input	..\..\preload\input	input folder with preloaded files
path_input_ini	..\input	input folder with initial geomentry and armor from hindcast simulati
path_output	output	output folder
path_output_mc	output_mc	output folder for MC simulations
navd2mllw	0.3	ft, add value to convert from NAVD to MLLW
WATER_GAMMA	64.2	seawater density

Figure 3: Editing Global Input Parameters in Excel Spreadsheet



fut_1_base.xml - Notepad

File Edit Format View Help

```xml
<?xml version="1.0" encoding="UTF-8" standalone="yes"?>
<MCR xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance">
	<Global>
		<Variable>
			<name>work_jetty</name>
			<value>NJ</value>
			<desc>(NJ, SJ, JA) specify jetty to work with</desc>
		</Variable>
		<Variable>
			<name>fut</name>
			<value>1</value>
			<desc>(0,1,10-14,20-24,30) modeling scenario</desc>
		</Variable>
		<Variable>
			<name>MC_SIM</name>
			<value>200</value>
			<desc>sets the number of Monte Carlo Simulations to run</desc
		</Variable>
		<Variable>
			<name>draw_hindyear</name>
			<value>1</value>
			<desc>set to 1 to draw ending jettty postion at hindcast_year
		</Variable>
		<Variable>
			<name>write_out</name>
			<value>0</value>
			<desc>(0/1) write ascii data for life-cycle solution</desc>
		</Variable>
		<Variable>
			<name>write_out_wav_area</name>
			<value>0</value>
		</Variable>
		<Variable>
```

Figure 4: Example of XML Input File Shown in Notepad

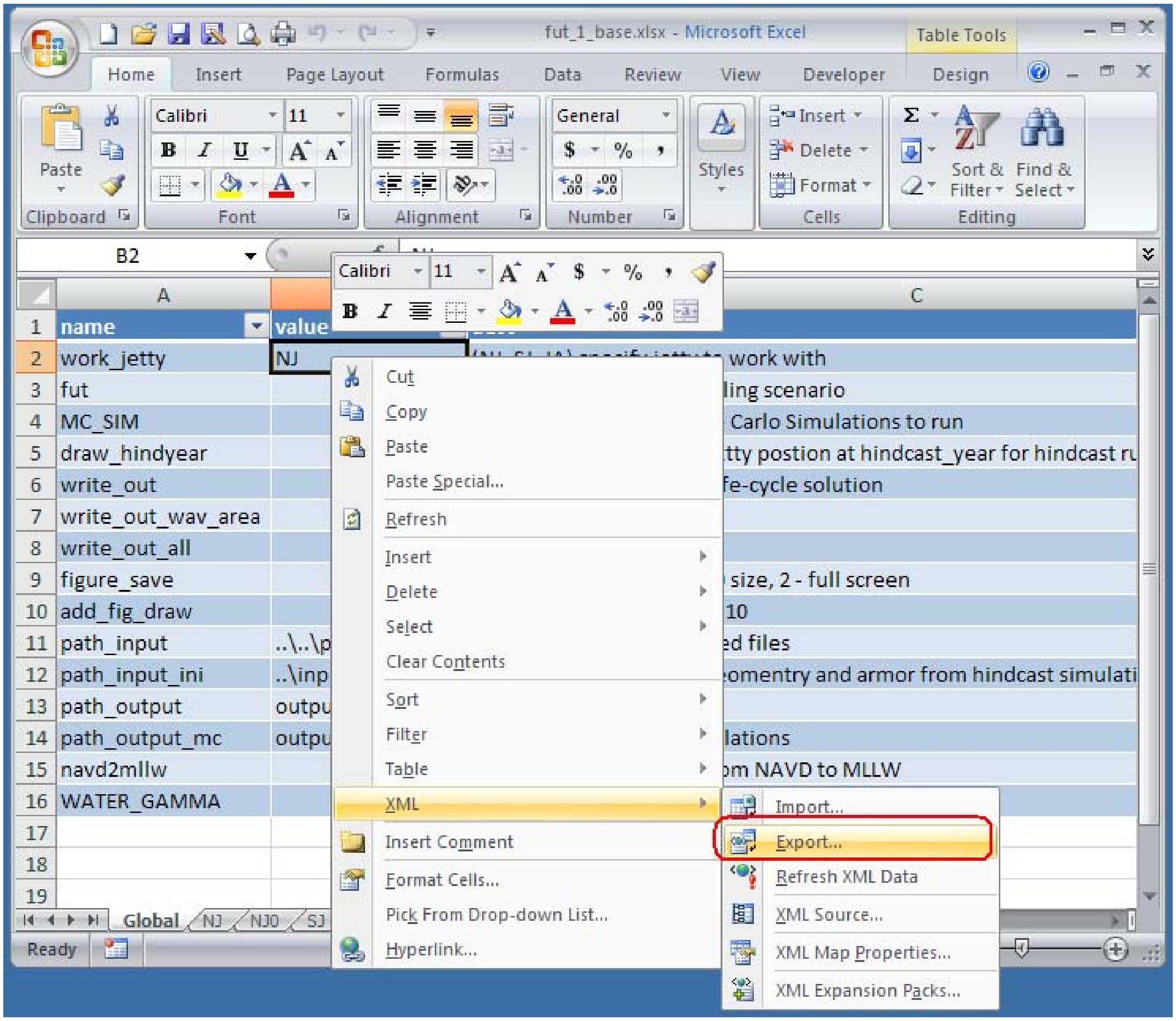


Figure 5: Export Setup into XML Format

3.7. RUNNING THE MODEL

After the input parameters are specified and the main XML file is created, the model can be started to perform calculations. Note that input MAT files should be placed under the folder specified by the "path_input" variable in the XML file. The user is to start MATLAB and navigate to the folder where the XML file is stored; this is the main working folder. All paths specified in "path_NNN" variables are treated as relative to this main folder. The model can be started from the command line in MATLAB by typing "mcr". A dialogue will appear where you can select the XML file.

Table 5 shows the folder structure and list of subroutines within the MCR model.

The model will perform calculations and save outputs into folders specified by variables "path_output" and "path_output_mc". Results of each MC simulation are saved in separate files, which allows for post processing analysis without rerunning the simulations. These results also become an input into the cost analysis calculations.

Table 5: Model Code MATLAB Scripts

Folder			Subroutine	Description
C:\SRBMODEL				Main folder
	mcr			MCR Model Code
			Installation	
			install	Install MCR model
			remove	Remove paths for MCR model
			Main routines	
			mcr	Main jetty structural performance calculation routine
			mcr_add_stats	Calculate additional statistics
			mcr_plot	Plot results from MC output folder for arbitrary cross-section
			Service functions	
			addpathtool	Adds paths to Matlab search path from a text file
		geom		Geometry calculation using M&N algorithm
			findint	Find intersection of two line segments.
			geom_core_area	Calculates core area based on shape of cross-section.
			geom_core_area_diff	Calculate change in core area.
			geom_shp2xy	Convert cross-section shape into node coordinates.
			geom_toe_adj	Calculate new cross-section geometry from toe scour.
			geom_wav_adj	Calculate new cross-section geometry from wave damage.
			geom_wav_area	Calculates wave area based on shape of cross-section.
			geom_xy2shp	Convert cross-section node coordinates into shape definition.
			run_test	Example and test of cross-section degradation calculations.
		subs		
			Main routines	
			damage_calc_ja	Damage calculations for Jetty A.
			damage_calc_nj	Damage calculations for North Jetty.
			damage_calc_sj	Damage calculations for South Jetty.
			damage_hudson	Damage calculations using Hudson formula.
			geometry_calc_ja	Geometry adjustments for Jetty A.
			geometry_calc_nj	Geometry adjustments for North Jetty.
			geometry_calc_sj	Geometry adjustments for South Jetty.
			geometry_calc_new	Geometry adjustments using M&N formulation.
			geometry_calc_orig_ja	Geometry adjustments for Jetty A (original code).
			geometry_calc_orig_nj	Geometry adjustments for North Jetty (original code).
			geometry_calc_orig_sj	Geometry adjustments for South Jetty (original code).
			mcr_global	Setup global parameters.
			mcr_main	Main loop of Monte-Carlo simulations.
			mcr_main_ja	Perform Monte-Carlo simulation for Jetty A.
			mcr_main_nj	Perform Monte-Carlo simulation for North Jetty.
			mcr_main_sj	Perform Monte-Carlo simulation for South Jetty.
			mcr_mc_post	Post Monte-Carlo calculations.
			mcr_prealloc	Preallocate variables.
			mcr_print	Output results to DAT files.
			mcr_repair_ja	Perform repair for Jetty A.
			mcr_repair_nj	Perform repair for North Jetty.
			mcr_repair_sj	Perform repair for South Jetty.
			mcr_setup	Setup parameters from XML file.
			mcr_setup_ja	Setup parameters for Jetty A.
			mcr_setup_nj	Setup parameters for North Jetty.
			mcr_setup_sj	Setup parameters for South Jetty.
			mcr_stats	Calculate statistics after Monte-Carlo simulations.
			mcr_plot_main	Create plots.
			repair_calc_ja	Repair calculations for Jetty A.
			repair_calc_nj	Repair calculations for North Jetty.
			repair_calc_sj	Repair calculations for South Jetty.

Table 5: Model Code MATLAB Scripts (continued)

Folder			Subroutine	Description
			Subroutines	
			JettyA_Wave_Interpolate_new	Calculate damage wave height along Jetty A.
			MCR_Jetty_Reliability_Waves_2	Reliability calculations.
			MCR_Storm_Environment_fx	Calculate storm parameters.
			North_Jetty_Wave_Interpolate_head_new	Calculate damage wave height along North Jetty.
			North_Jetty_Wave_Interpolate_new	Calculate damage wave height North Jetty.
			South_Jetty_Wave_Interpolate_new	Calculate damage wave height along South Jetty.
			mcr_cost_main	Submodule to perform cost calculations (main).
			mcr_cost_part1_ja	Submodule to perform cost calculations for Jetty A (part 1).
			mcr_cost_part1_nj	Submodule to perform cost calculations for North Jetty (part 1).
			mcr_cost_part1_sj	Submodule to perform cost calculations for South Jetty (part 1).
			mcr_cost_part2_ja	Submodule to perform cost calculations for Jetty A (part 2).
			mcr_cost_part2_nj	Submodule to perform cost calculations for North Jetty (part 2).
			mcr_cost_part2_sj	Submodule to perform cost calculations for South Jetty (part 2).
			mcr_cost_part3	Submodule to perform cost calculations (part 3).
			mcr_cost_part_ini_ja	Submodule to perform cost calculations for Jetty A (initialization).
			mcr_cost_part_ini_nj	Submodule to perform cost calculations for North Jetty (initialization).
			mcr_cost_part_ini_sj	Submodule to perform cost calculations for South Jetty (initialization).
			mcr_cost_setup	Submodule to load cost parameters.
			mcr_cost_setup_ja	Submodule to load cost parameters for Jetty A.
			mcr_cost_setup_nj	Submodule to load cost parameters for North Jetty.
			mcr_cost_setup_sj	Submodule to load cost parameters for South Jetty.
			mcr_cost_stat	Submodule to perform cost calculations (statistics).
			mcr_mc_ini_cost_ja	Submodule to setup parameters before Monte-Carlo calculations for Jetty A (cost).
			mcr_mc_ini_cost_nj	Submodule to setup parameters before Monte-Carlo calculations for North Jetty (cost).
			mcr_mc_ini_cost_sj	Submodule to setup parameters before Monte-Carlo calculations for South Jetty (cost).
			mcr_mc_ini_ja	Submodule to setup parameters before Monte-Carlo calculations for Jetty A.
			mcr_mc_ini_nj	Submodule to setup parameters before Monte-Carlo calculations for North Jetty.
			mcr_mc_ini_sj	Submodule to setup parameters before Monte-Carlo calculations for South Jetty.
			mcr_plot_f1_bot1	Submodule for plotting figure 1 (part bot1).
			mcr_plot_f1_bot2	Submodule for plotting figure 1 (part bot2).
			mcr_plot_f1_top1	Submodule for plotting figure 1 (part top1).
			mcr_plot_f1_top2	Submodule for plotting figure 1 (part top2).
			mcr_plot_f1_top3	Submodule for plotting figure 1 (part top3).
			mcr_plot_ini	Submodule for plotting (initialization).
			Service functions	
			interp1ex	Linear interpolation with extrapolation outside interval.
			mcr_xml	Read variables from XML file.
			xml2stru	Convert xml file into a MATLAB structure
	preload			Convert Excel files to MAT files
			runall	Run all preload routines
		input		Location of input MAT files for all simulations
		JA		
			Pre_load_xls_data_JA_new	Preload routine for Jetty A
		NJ		
			Pre_load_xls_data_north_new	Preload routine for North Jetty
		SJ		
			Pre_load_xls_data_south_new.m	Preload routine for South Jetty
		tables		Location of input Excel files
	xmltool			Low level lools to build input XML files

4. DESCRIPTION OF MODEL OUTPUT

Various types of SRB model output can be saved to files, depending upon SRB parameters set within the model. Output produced by the SRB model includes ACSII text-based data files (for life-cycle repair tonnage and incremental dredging volume) expressed in a mean value and standard deviation. Multiple graphical summaries are produced for pertinent model metrics describing the spatial and time-varying conditions of a given jetty. The entire MATLAB simulation environment, containing all variables accessed or created by the SRB model, can be saved as a .mat file. Presently, the MCR SRB model outputs variables and files in MATLAB *.mat format, ASCII text files in *.dat format, and various figures illustrating results of the hindcast and MC forecast simulation.

Model outputs are saved under the folder specified in "path_output" variable. The model outputs plots of specific lifecycle parameters and exported datafiles of all data as computed in the model. There are several model 'switches' that can be set to output additional files and/or figures. Results of each Monte Carlo simulation are saved into a MAT file under path defined in "path_output_mc" variable. Each MAT file has a name equal to sequence number of the MC simulation. These results can be used to perform the cost analysis.

Tables 6 and 7 list the figures and data files which can be exported from the model.

Table 6: List of Exported Simulation Figures

Lifecycle Simulation Figures	
1	**Lifecycle:** Plot of initial & simulated final cross-section(s) for a specific STA.
2	**Lifecycle:** Jetty crest profile evolution (hindcast and forecast modes)
3	**Lifecycle:** Change in cross-sectional area evolution for a specific STA.
4	**Lifecycle:** Simulated cross-section change (UPPER cross-sectional area)
5	**Lifecycle:** Simulated cross-section change (TOTAL cross-sectional area)
6	**Lifecycle:** Jetty reliability over a lifecycle (CHANNEL-side and OCEAN-side)
7	**Lifecycle:** Jetty Structural reliability
8	**Lifecycle:** Variation in Jetty reliability
9	**Lifecycle:** Jetty Functional reliability
12	**Lifecycle:** Jetty repair and breach frequency / 100' segment
13	**Lifecycle:** Jetty cumulative occurrence of repairs and breaches
14	**Lifecycle:** Jetty repairs and breaches / 100' segment
Figures from Monte Carlo Simulations	
15	**Monte Carlo:** Jetty crest profile evolution (hindcast and forecast modes)
16	**Monte Carlo:** Simulated cross-section change (UPPER cross-sectional area)
17	**Monte Carlo:** Simulated cross-section change (TOTAL cross-sectional area)
18	**Monte Carlo:** Variation in Jetty reliability over a lifecycle
21	**Monte Carlo:** Jetty repair and breach frequency / 100' segment
22	**Monte Carlo:** Jetty cumulative occurrence of repairs and breaches
23	**Monte Carlo:** Jetty repairs and breaches / 100' segment

Table 7: List of Output Data Files and/or Formats (if Several Files are Output in this Format)

Possible Data Exports		Format / Filename
1	Threshold values for various repair alternatives	***.MAT**
2	Cross-section geometries from last year of hindcast (for forecast simulations)	**NJ_2006_GEOM.mat** **SJ_2007_GEOM.mat** **JA_2006_GEOM.mat**
3	Jetty armor values (armor stone size and stability coefficients, for forecast simulations)	**NJ_2006_ARMR.mat** **SJ_2007_ARMR.mat** **JA_2006_ARMR.mat**
4	Time-varying Wave areas (upper cross-section)	**WAVE_AREA_NJ.DAT** **WAVE_AREA_SJ.DAT** **WAVE_AREA_JA.DAT**
5	Time-varying wave areas before repairs are made	**WAVE_AREA_REPAIR_NJ.DAT** **WAVE_AREA_REPAIR_SJ.DAT** **WAVE_AREA_REPAIR_JA.DAT**
7	ALL variables for a given hindcast or forecast	***.MAT**

Table 8 lists the figures that are output from the model. In addition to exporting figures, the model will also save and export the data from each of the modeling simulations. Table 9 lists the datafiles that are saved at the end of each model run. Datafiles are in MATLAB .mat and ASCII text file .dat format.

Table 8: Exported Figures of Simulation Results

Figure	Description
1	Jetty lifecycle cross-section and profile evolution plot
2	Jetty lifecycle profile evolution
3	Jetty lifecycle cross-sectional area evolution (1 STA)
4	Simulated lifecycle change in jetty upper cross-section
5	Simulated lifecycle change in total jetty cross-section
9	Variation in jetty lifecycle reliability
15	Lifecycle repair and breach frequency per 100-ft segment
16	Lifecycle cumulative repair and breach occurrences
17	Lifecycle repair and breach occurrences per 100-ft segment
20	MC: Jetty lifecycle crest profile evolution
23	MC: Lifecycle repair and breach frequency per 100-ft segment
24	MC: Lifecycle cumulative repair and breach occurrences
25	MC: lifecycle upper cross-section area evolution
26	MC: lifecycle total cross-section area evolution
27	MC: Variation in jetty lifecycle reliability
29	MC: Lifecycle repair and breach occurrences per 100-ft segment

Table 9: Output Result Data Files

Filename	Data
NJ_SOLUTION_ALL_variables_*.mat	All workspace variables are saved in MATLAB .mat format. The * represents the repair scenario modeled (e.g. "base_condition"
WAVE_AREA_NJ.DAT	Upper Cross-section area remaining
WAVE_AREA_REPAIR_NJ.DAT	Cross-section area existing prior to repairs

The SRB model output parameters which are used as inputs to the separate cost analysis are listed in Table 10. A description of the separate cost analysis can be found in Chapter 2 and Appendix C of the *MCR Jetty System Major Rehabilitation Evaluation Report* (USACE 2012).

Table 10: Output Result Data Files

Filename	Data
Mean Data	
mean_MC_BOM_TONS_JETTY_INCR	Averaged emergency repair tons of the whole jetty each year
mean_MC_EOM_TONS_JETTY_INCR	Averaged expedite repair tons of the whole jetty each year
mean_MC_OM_TONS_JETTY_INCR_B	Averaged base repair tons of the whole jetty each year
mean_MC_OM_TONS_JETTY_INCR_I	Averaged interim repair tons of the whole jetty each year
mean_MC_OM_TONS_JETTY_INCR_S	Averaged scheduled repair tons of the whole jetty each year
mean_MC_REH_TONS_JETTY_INCR_S	Averaged rehab tons of the whole jetty each year
mean_MC_D_VOL_JETTY_INCR	Averaged dredge volume (CY) of the whole jetty each year
Standard Deviation Data	
std_MC_BOM_TONS_JETTY_INCR	Standard deviation emergency repair tons of the whole jetty each year
std_MC_EOM_TONS_JETTY_INCR	Standard deviation expedite repair tons of the whole jetty each year
std_MC_OM_TONS_JETTY_INCR_B	Standard deviation base repair tons of the whole jetty each year
std_MC_OM_TONS_JETTY_INCR_I	Standard deviation interim repair tons of the whole jetty each year
std_MC_OM_TONS_JETTY_INCR_S	Standard deviation scheduled repair tons of the whole jetty each year
std_MC_REH_TONS_JETTY_INCR_S	Standard deviation rehab tons of the whole jetty each year
std_MC_D_VOL_JETTY_INCR	Standard deviation dredge volume (CY) of the whole jetty each year
mean_MC_BOM_TONS_JETTY_INCR	Averaged emergency repair tons of the whole jetty each year
mean_MC_EOM_TONS_JETTY_INCR	Averaged expedite repair tons of the whole jetty each year
mean_MC_OM_TONS_JETTY_INCR_B	Averaged base repair tons of the whole jetty each year

5. DESCRIPTION OF MODEL PROCEDURE FOR A TYPICAL JETTY SEGMENT

Jetty Segments are the basis in the SRB life-cycle model. Environmental loading, structure response, project consequences, and life-cycle cost are all evaluated based on jetty segments. In this section, the model procedure for a typical jetty segment is described, including the jetty segmentation, damaging process, damaging function, repair tonnage and the event tree.

5.1. JETTY SEGMENTATION

Jetty Segmentation

Within the SRB model, a jetty is divided into 100-ft long semi-independent responding segments. Segmentation allows for the jetty to be modeled as a system of interacting components, the response of each being described by a specific performance mode relating to head recession, foundation erosion, slope stability, and wave-induced damage. The SRB model uses these performance modes to simulate jetty response over a specified period of time (a given life-cycle), by evaluating the cumulative structural response of the jetty cross section in 1-year time steps.

Lateral Subdivision of Jetty Cross Sections

For each segment, the initial condition is described by specific cross-section geometry and armor-core stone attributes, which can vary along segments and on each side of the jetty (ocean side vs. channel side). The centerline of the present jetty crest serves as the boundary to split the segment cross section into channel vs. ocean side. Refer to Figure 8 for jetty cross-section element definition. Segment attributes include toe elevation, crest elevation, crest width, jetty side slope, armor stone characteristics (size-tons, stability number, density), and core stone presence. All segment attributes are described in terms of a mean value and standard deviation, to enable segment-based reliability calculations.

Vertical Subdivision of Jetty Cross Sections

Each segment is divided into two vertical areas (upper section and lower section) based on an elevation of -5 ft MLLW. Above this elevation (WAV_EL) wave damage generally controls jetty cross-section evolution; below WAV_EL the cross-section evolution is generally controlled by scour or static slope instability issues. If jetty toe elevation is higher than -7 ft MLLW, then the demarcation between upper and lower sections is set at the jetty toe elevation, plus 2 ft. This allows for the vertical subdivision of a jetty cross section in shallow water regions, where the jetty toe may be higher than -5 ft MLLW. The 2-ft offset is the minimum vertical distance required to represent geometric changes in the lower section of a jetty (within the SRB model), as motivated by slope/foundation adjustment processes associated with jetty toe scour.

5.2. ENVIRONMENTAL FORCES AND DAMAGE PROCESSES

Wave height is the environmental parameter that drives the damages in this model based on the damage function defined for each jetty segment. Damage to structures exposed to waves is determined by water depth and wave height. Waves may be depth limited if the water depth is shallow. If the structure is located in relatively deep water, wave damage is typically limited to the upper part of a structure and there was limited foundation-related degradation to affect the lower part of the structure. However, if a given structure is located in relatively shallow water and wave loading is both severe and depth-limited, then the entire cross-section can be degraded by wave action (from the structure toe to the crest). If the foundation of a structure is subjected to severe toe scour or slope instability, then much of the structure's entire cross-section can be degraded within the expected life-cycle.

As discussed above, each jetty segment section is divided into two areas, upper section and lower section. The upper section is damaged by dynamic effects which are attributable to wave actions (wave breaking and wave overtopping). The lower section is damaged by static effects due to toe scour and side slope failure.

Static stability affects the lower part of the jetty cross section, generally below –5 ft MLLW, on the ocean side and channel side of the jetty (Figure 6). Within this analysis, static stability addresses the susceptibility of the jetty toe to be affected by wave-current scour, and resistance of the jetty slope to fail along a slip-plane. The jetty toe is the interface where the jetty intersects the morphology on which it is founded. Jetty damage motivated by static stability propagates up-slope to affect the upper region of the jetty cross-section, above -5 ft MLLW. Static stability of the lower cross-section region (below -5 ft MLLW) is evaluated stochastically within the SRB model based on jetty slope re-adjustment (creeping failure) in response to toe scour. Static stability performance is indirectly evaluated through the analysis of the upper jetty cross section, which can be affected by both static and dynamic stability performance modes.

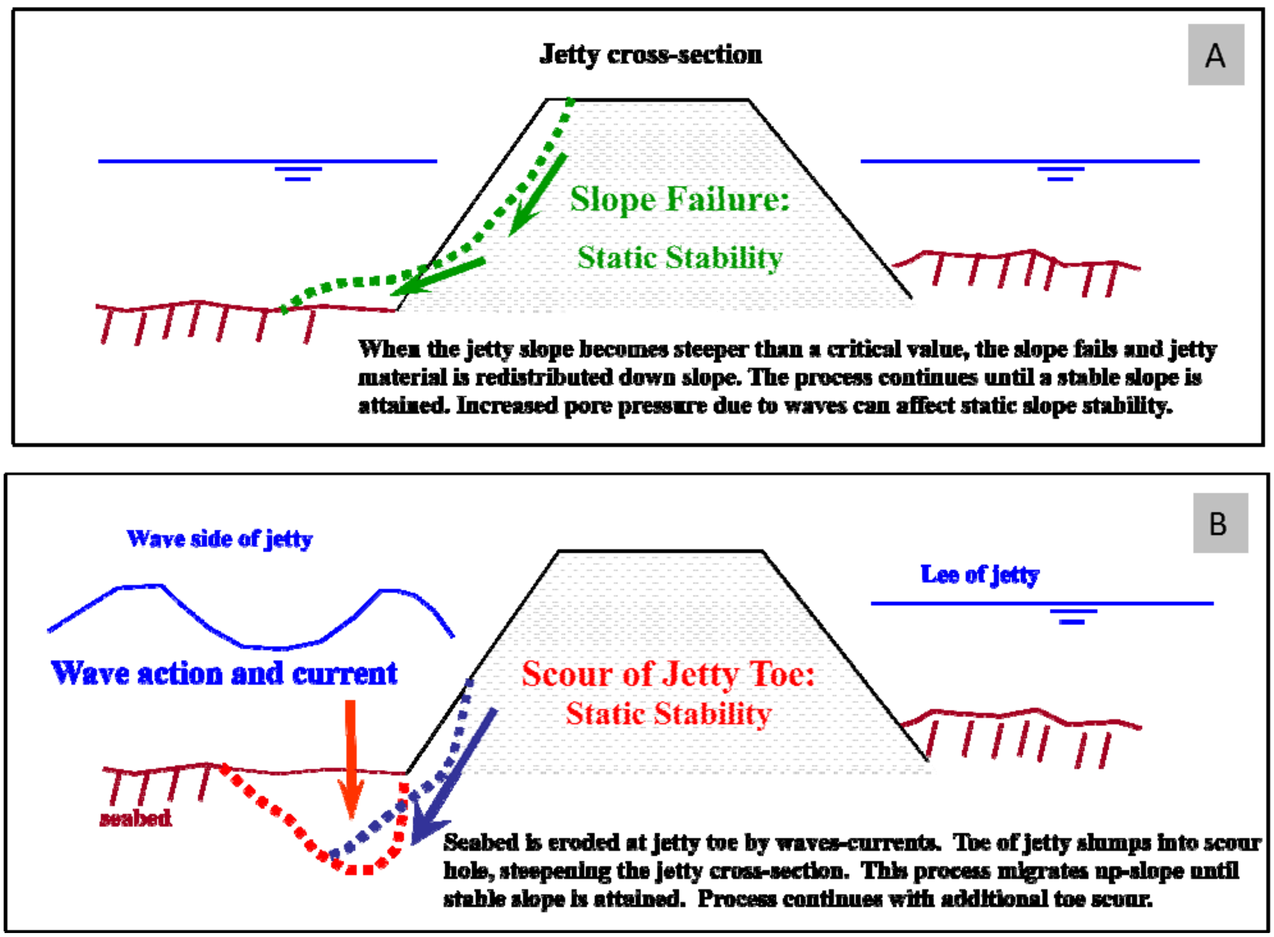


Figure 6: Jetty Performance Modes for Static Stability

Dynamic stability affects the upper part of a jetty cross section as a result of wave action, generally from –5 ft MLLW up to the jetty crest, on the ocean side and channel side of a jetty, as shown in Figure 7. On the side of the jetty directly exposed to wave action, dynamic stability is manifest by the direct impact of waves on the jetty and the potential displacement of individual armor units. On the lee side of the jetty, dynamic stability addresses the effect of waves overtopping the jetty crest and displacing armor or down-slope, off of the jetty cross-section. There are many locations along MCR jetties which experience direct wave attack along both sides of each jetty, in which case each side of the jetty experiences direct wave action and overtopping wave action.

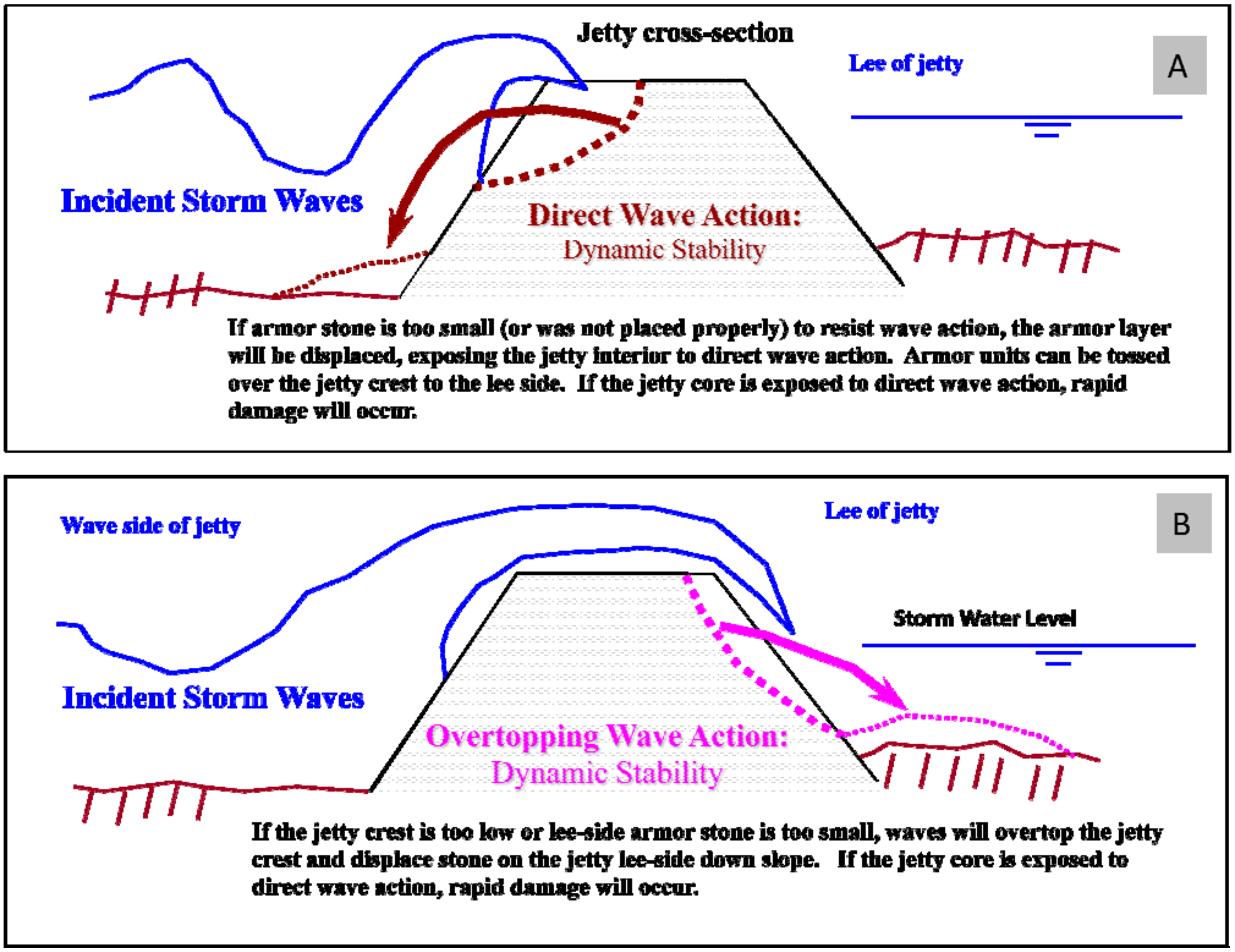


Figure 7: Jetty Performance Modes for Dynamic Stability

All the possible damage modes for a jetty segment are illustrated in Figure 8.

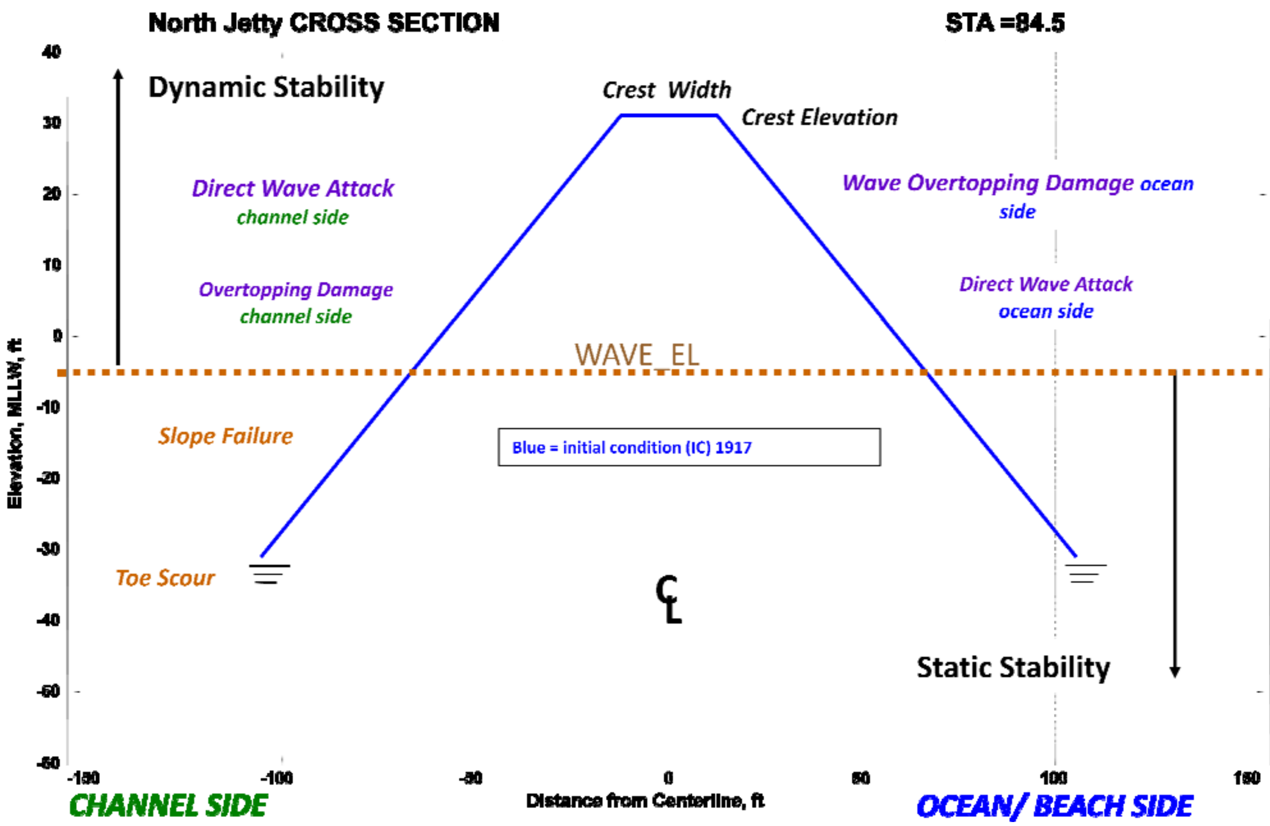


Figure 8: Representation of a Jetty Cross-Section Segment

5.3. DAMAGE QUANTIFICATION/DAMAGE FUNCTION

The structure response or damage due to the environmental force is evaluated in terms of cross-section area change (loss) over time due to jetty degradation. Jetty repairs are activated within the SRB model, after the jetty cross-section is reduced below a specified threshold value. Jetty repairs are calculated in terms of the tonnage of armor stone required to re-establish the jetty cross section to its standard dimensions.

The degree and rate of structure degradation (as affected by wave action) is evaluated using damage functions which are based on incident wave height vs. incremental cross-section damage. The damage functions were developed through detailed physical model studies conducted at ERDC, featuring MCR jetty cross-section attributes [Ward et al., 2007]. Within the SRB model, wave- induced jetty damage is calculated for each storm event realized within each year, using wave-damage functions. Figure 9 through Figure 12 describe wave damage functions developed for specific jetty cross section configurations, for North Jetty. North Jetty damage functions were used to simulate Jetty 'A' cross-section response. The wave height ordinate values expressed in the damage functions are equivalent to the significant wave height averaged during the peak two hours of prototype storm duration.

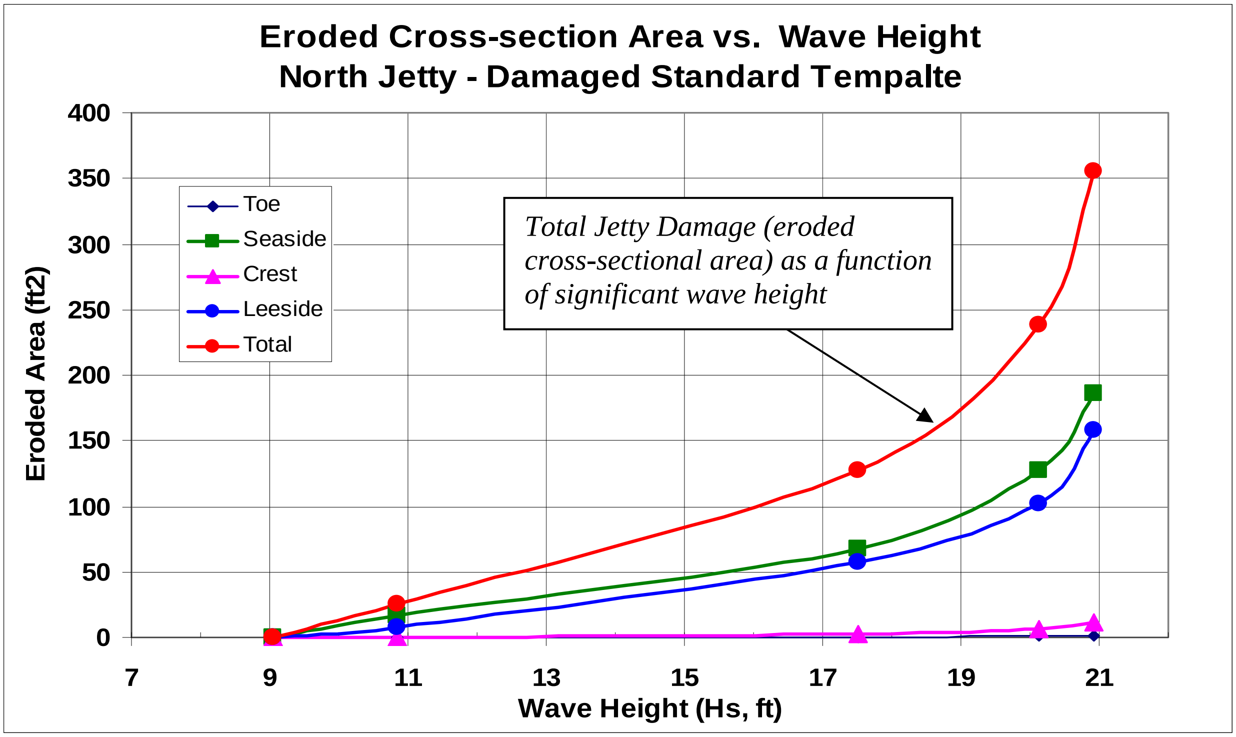


Figure 9: Damage Functions for MCR North Jetty and Jetty 'A' – for Jetty Segments Where a Standard Cross-Section has been used and Becomes Damaged

(Damage functions developed through detailed physical model studies conducted at ERDC [Ward et al., 2007]).

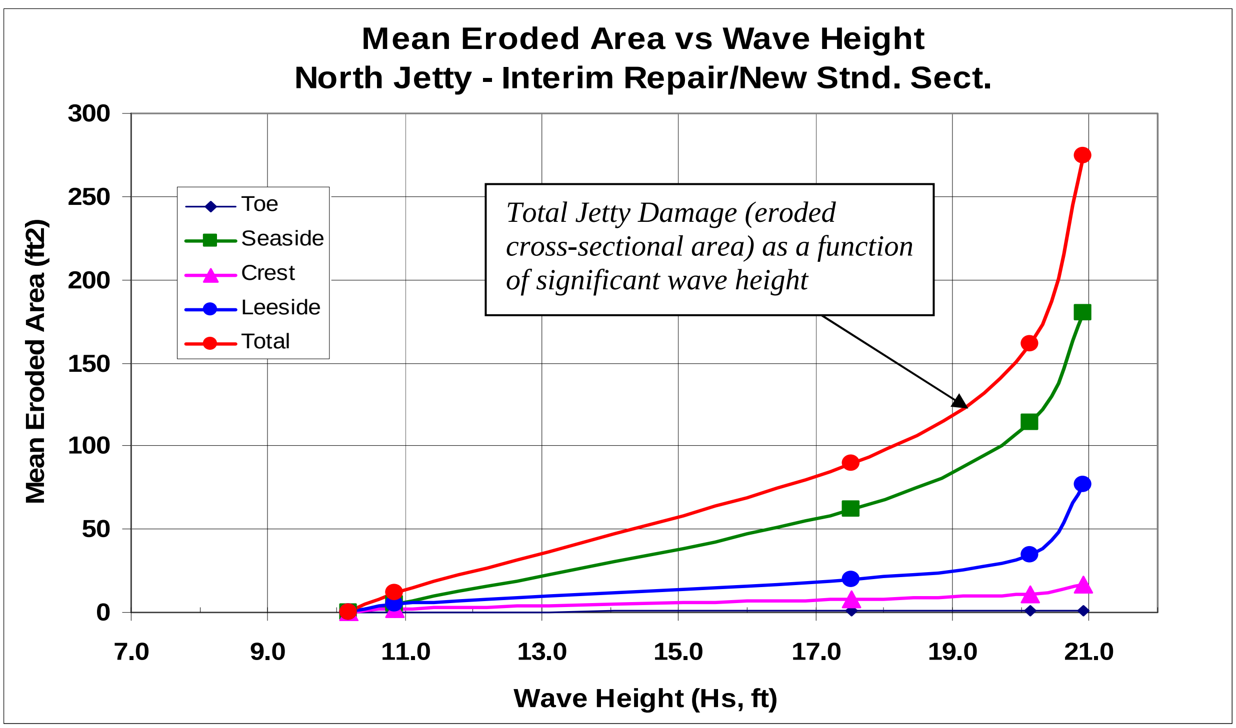


Figure 10: Damage Functions for MCR North Jetty and Jetty 'A' - for Jetty Segments Based on a Standard Template that Has Not Been Damaged

(Damage functions developed through detailed physical model studies conducted at ERDC [Ward et al., 2007]).

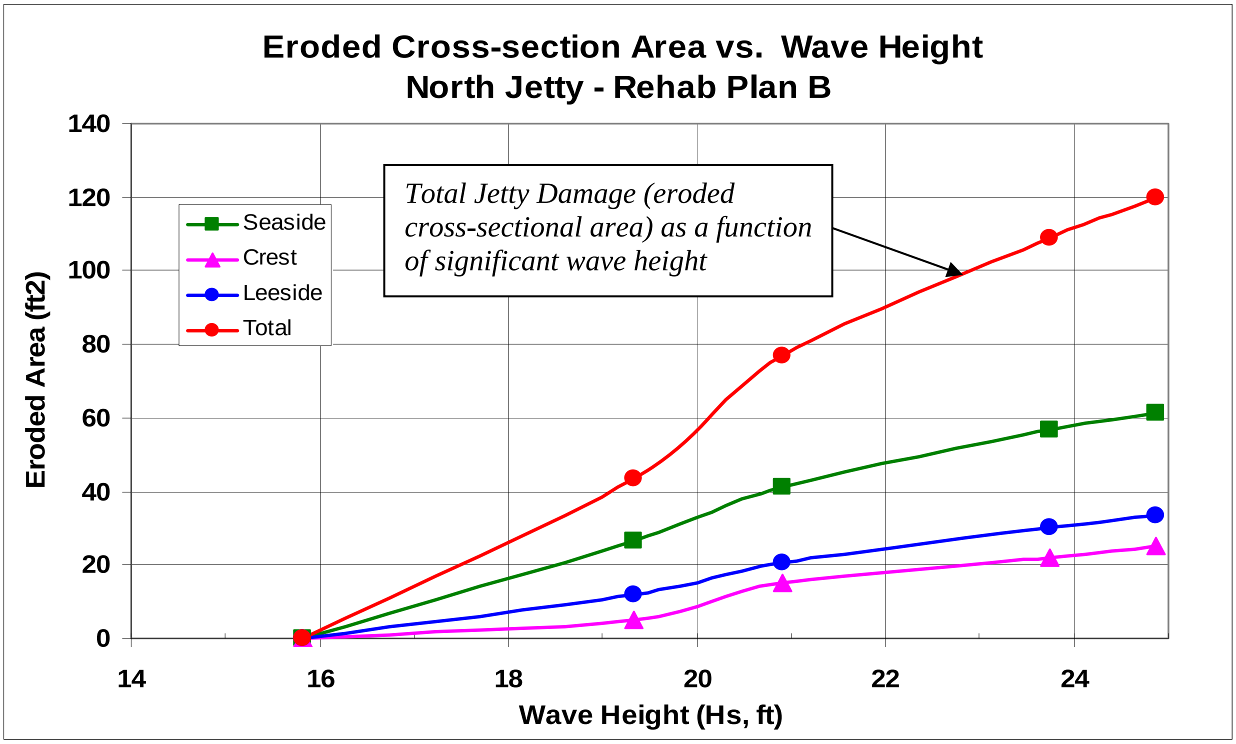


Figure 11: Damage Functions for MCR North Jetty – for North Jetty Rehab Plan B
(Damage functions developed through detailed physical model studies conducted at ERDC [Ward et al., 2007]).

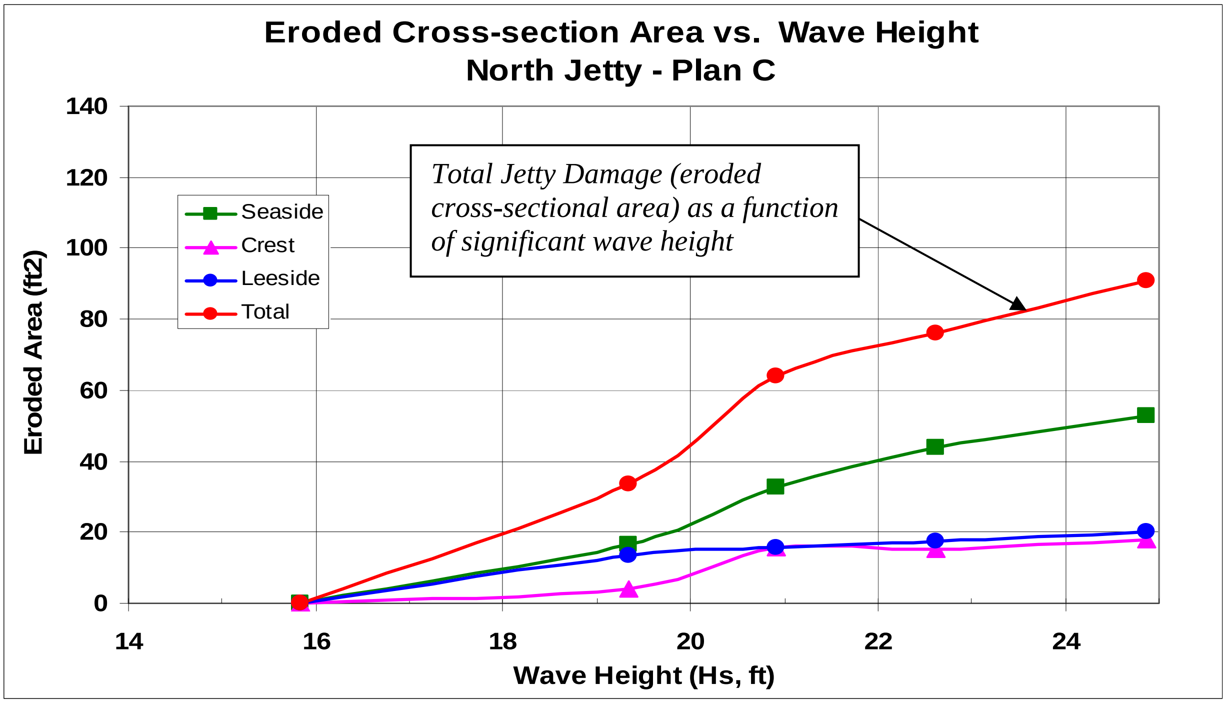


Figure 12: Damage Functions for MCR North Jetty- for North Jetty Rehab Plan C
(Damage functions developed through detailed physical model studies conducted at ERDC [Ward et al., 2007]).

Specific jetty cross-section configurations were used to emulate existing damaged jetty sections, repaired "standard repair template" sections, and rehabilitation alternatives. The threshold value for the onset of wave damage, as described by specific damage function, was adjusted depending upon the level of progressive deterioration for the jetty cross-section of interest. The wave damage threshold was also adjusted to account for the robustness of various jetty maintenance scenarios.

The threshold values for jetty head cross-sections were adjusted to account for increased or decreased resilience for a given jetty head configuration. Figure 13 shows how the maintenance threshold for enacting repairs can vary based on the type of maintenance strategy assigned to a given jetty. The cross-section at this location of the jetty was repaired two times during 1917-2006. The scheduled repair strategy is more proactive than the base condition by allowing jetty repairs to occur earlier in the degradation phase, to reduce the chance of segment failure (before repairs can be initiated). Scheduled repairs also employ a more resilient (better built cross-section) than the base condition, so the degradation rate for scheduled repairs is usually less than for the base condition. Threshold adjustment (for value of wave height initiating jetty damage) was implemented based on stability equations indicating: when a given armor unit size (W_{50}), stability number (Kd or equivalent), and cross-section configuration would be damaged by wave action.

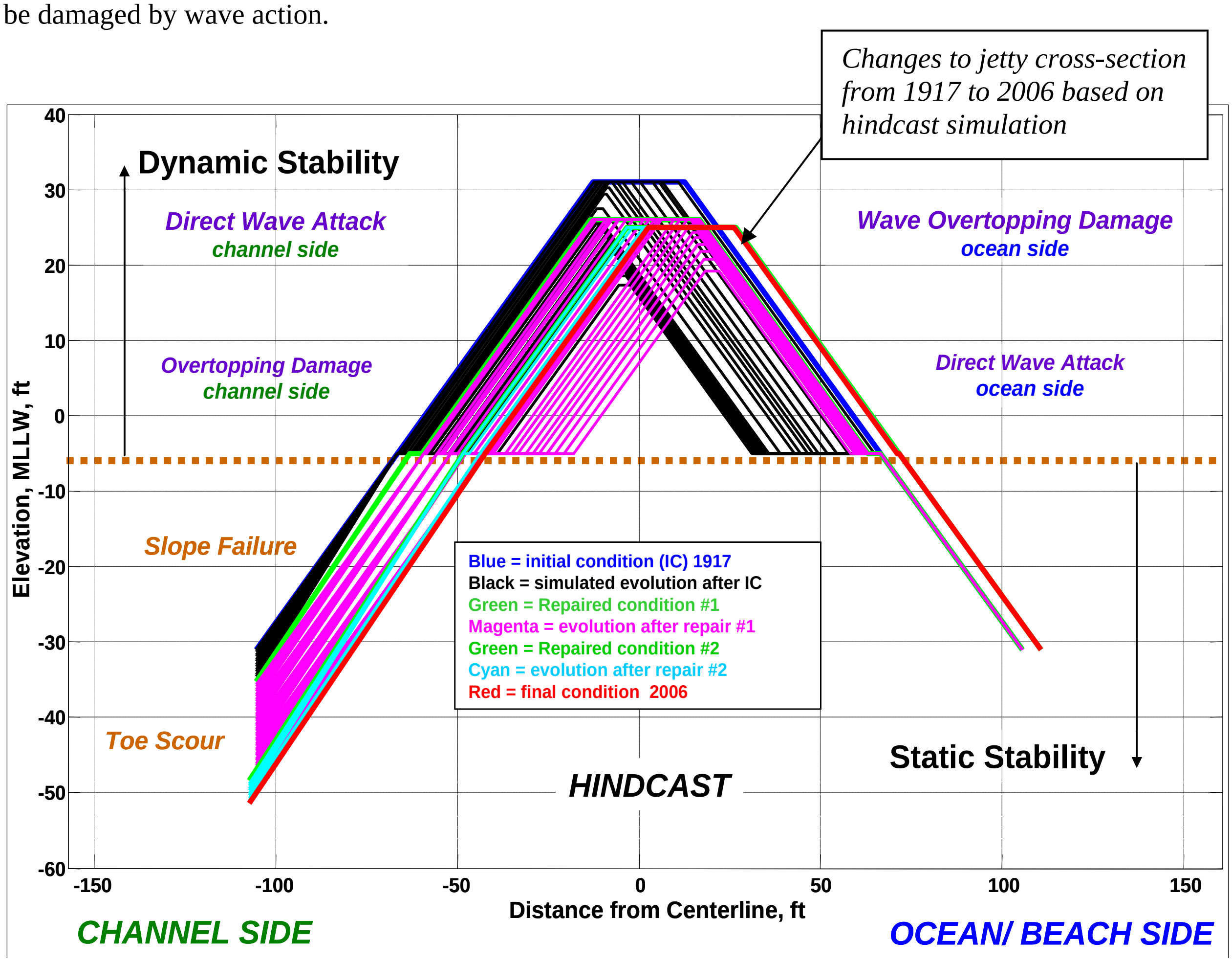


Figure 13: Evolution of Jetty Cross-Section at Station 84+50 Based on One Realization for Hindcast Simulation for the MCR North Jetty

5.4. MAINTENANCE AND REPAIR TONNAGE

Jetty repairs may be enacted at 3 different levels of response, depending on the urgency for repairs. In a normal O&M level, jetty repair areas are identified and executed in a methodical manner (multi-year planning effort). In an expedited level, jetty repairs are fast-tracked and made within 1 year of problem identification. Expedited repairs may be made to prevent the onset of a breach, when the jetty is in an advance state of degradation. Expedited repairs are enacted for the South Jetty and Jetty A, in response to a jetty breach. In an emergency level, jetty repairs are executed within 2-6 months, in response to a serious breach along the North Jetty. Within the SRB model, jetty repairs associated with normal O&M and expedited repair efforts are tracked separately from emergency repairs, which are associated with significant breach events.

The longer a damaged jetty segment goes without repair, the higher the rate of cross-section degradation due to wave action, and the more likely that the jetty segment could breach before repairs are made. In rare instances, a jetty segment may be damaged at such a high rate as to fail (loose function) before timely repair can be implemented. A given jetty segment has the potential to lose function when the upper cross-section area has been reduced to less than 20% of the standard upper cross-section. Within the SRB model, a jetty segment is assumed to fail when the upper cross-section is reduced to less than 15% of the standard upper cross-section. If a jetty segment adjacent to a breached segment has less than 40% of its cross-section remaining, the adjacent segment can be induced to breach. This process is intended to account for the destabilizing effect that a breached jetty has on adjacent areas of the jetty. Within the SRB model, the maximum length for a given breach event-location is 3 segments.

For each year within a life-cycle simulation, there can be 1 to 11 storms that can affect the individual segments along a given MCR jetty. If the incident wave height for a given storm event exceeds a specified damage threshold value, the jetty segment cross-section is damaged according to applicable damage functions. Wave damage is expressed in terms of cross-section loss. Each side of the jetty is evaluated for a given storm, and wave damage is rendered onto each side of a segment's upper cross-section based on whether the waves are incident to or overtopping the jetty. Annual wave damage imparted onto a given jetty segment results in variable cross-section reduction, per year. The cumulative effect of wave damage reduces the upper cross-section of the jetty over time (for each segment). The when the area of the upper cross-section is reduced to a specified maintenance level, the upper cross-section is repaired to restore the cross-section to a specific design template area. The amount of armor stone (repair tonnage) needed to restore the damaged jetty segment is based on the difference between the design template area and the cross-section just prior to repairs. Repair tonnage for a given jetty segment is calculated assuming that the void ratio for placed armor is 0.7:

Repair Tonnage per 100-ft Jetty Segment (for the upper cross-section) = 0.7 x gamma x 100 x (Initial Template Area – Area Immediately Prior to Repair) / 2000

As an example, based on a typical North Jetty segment repair, the repair tonnage would be:

0.7 x 167 lb/ft3 x 100 ft/segment x (2250 ft2/segment – 800 ft2/segment) / 2000 lb/ton = 8,475 tons

The damage trends and repair scenarios emulated in the SRB model are intended to follow closely with prototype conditions. As the upper cross-section becomes significantly damaged (>1/2 of the crest width is missing on a given side of the jetty), the wave height threshold for initiating damage is reduced and rate of damage sustained by the "damaged" section increases. At this point, the armor layer has been highly disturbed (Kd has decreased) with much of the armor layer being displaced off of the upper cross-section. If sufficient armor stone has been displaced off the jetty cross-section such that core stone is subjected to direct wave action, then the effective size of the "armor" stone is decreased in proportion to the relative amount of true armor stone remaining on the jetty slope.

5.5. EVENT TREE

Jetty segments are the basis in the SRB life-cycle model. The SRB life-cycle model has a yearly base in time and a 100-ft segment base in space. Each segment is modeled following the event tree diagram shown in Figure 14. An annual cycle of a jetty is repeated for every year in term of structural performance modes (static and dynamic), sustained damages, consequences, and life-cycle costs.

The event tree starts with the initial condition at year "i". The jetty segment initial condition is derived based on the accumulated previous years damage and repair. The segment attributes include toe elevation, crest elevation, crest width, jetty side slope, armor stone size, armor stability number, stone density, and core stone presence. The shoreline position is adjusted based on present jetty head location. Each parameter is represented by a mean value and standard deviation. Forcing environment (Wave heights and water level) of the year is applied on the initial segment condition. The forcing environment for year "i" is realized through stochastic simulation. Jetty performance modes are assessed for each jetty segment "j" based on the realized forcing environment, and jetty damage for year "i" is stochastically evaluated.

Each year, random k (1 to 11) storms are modeled. The following two evaluations are applied in each storm for each segment. The dynamic stability of the segment is first evaluated. The evaluation is applied on both ocean and channel side including based on selected appropriate wave damage functions and threshold values. The damages (cross-section area loss) are quantified by incident wave damage, overtopping damage, and jetty crest damage. The following step is the segment static stability evaluation, including the scour at the toe and slope failure along both channel side and ocean side of the channel. Cross-section degradation is evaluated.

The total damage in the "i" year to the segment is determined by the combination of the dynamic effects and static effects during the k storms in the year. The cumulative cross section damages are tabulated and the cross-section geometry is adjusted accordingly. Then the cross-section damages resulting from the static slope adjustment due to toe scour are accessed and the cross-section geometry is adjusted if jetty slope exceeds critical value.

Finally, the consequences and the corresponding jetty life-cycle performance metrics are calculated. Consequences for year "i" can include repair activities for jetty segments, functional loss of a jetty segment, and incremental channel dredging due to segment function loss. Implementation of jetty repairs as year "i" is based on a threshold evaluation. Jetty repairs are enacted if the jetty cross-section at a given segment falls below a specified maintenance threshold, which is a random variable. If a jetty segment sustains a loss of function within a given year "i" (jetty head recession or a jetty breach), then additional adverse consequences may be realized in terms of added channel dredging costs; which is also a random variable. The event tree diagram is repeated for n-years for all jetty segments, until the entire life-cycle period is realized.

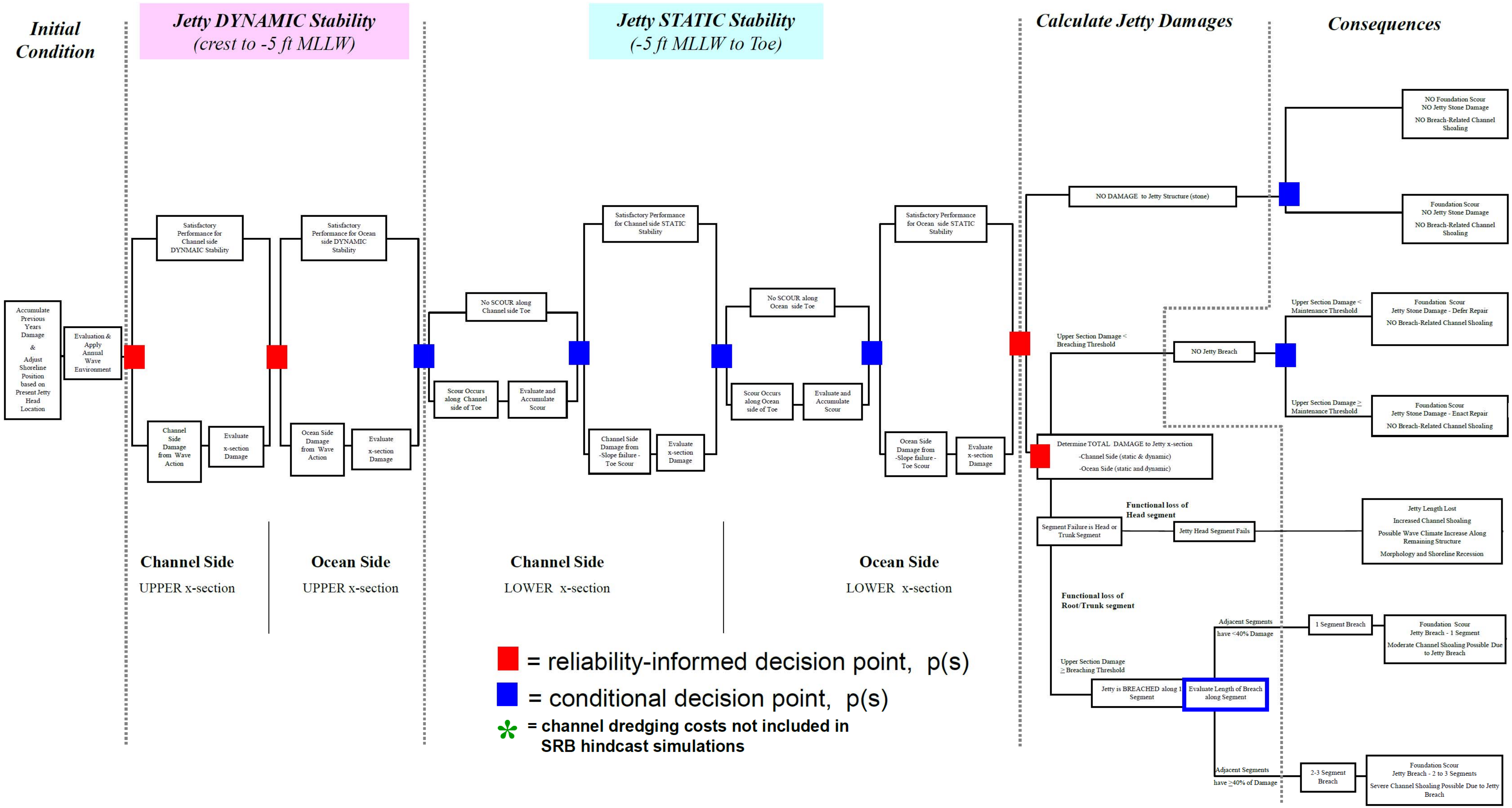


Figure 14: MCR Jetties Project Event Tree Schematic Diagram

6. MODEL CALIBRATION

To validate forecasted lifecycle simulations (future conditions) of jetty damage and alternative repair scenarios, the model is first applied in hindcast mode for each jetty; the results of which are compared to historical records of jetty maintenance to provide calibration of relevant parameters. Previous historical stone volumes used and jetty repair locations have been well-documented and the maintenance histories of each were used to calibrate specific variables. The hindcasts extend back to the approximate date of initial construction of each jetty and are simulated to the present day.

Before performing hindcast simulations for a given structure, it is essential that a structure's as-built condition be established to match the actual post-construction condition of the prototype as the initial condition of the MCR SRB model. The historical record for the MCR jetties is good and data are available to define the initial conditions for jetty toe elevation, jetty cross-section geometry, armor/core stone attributes, and historical scour rates for MCR jetties. (Refer to Appendix A1 of the *MCR Major Jetty System Major Rehabilitation Evaluation Report* for historical jetty repair details. Repair history for each jetty is summarized in terms of the location and type of jetty stone placed, construction methods, and unit repair cost). The SRB model hindcast jetty maintenance strategy was set at "interim repair" as discussed in the input procedures section of this User's Manual to emulate the maintenance conditions actually undertaken during the historical life-cycle of each jetty.

When executing a hindcast SRB simulation, the initial condition geometry, jetty armor/core stone attributes, and jetty foundation scour rates (based on historical data) are defined for the entire jetty, on a segment by segment basis. Table 11 summarizes the observed scour rates along the MCR North Jetty, as employed in the SRB model.

Table 11: North Jetty Morphological Factors for Future Base Case Scour Depth at Jetty Toe

Jetty Station	**Side of Jetty**	**PAST Life-Cycle 1917 - 2006**		**Present Seabed Elevation**	**FUTURE Life-Cycle 2006-2070**	
		Estimated	**Observed**		**Estimated**	**Estimated**
		Morphological Factor 1917 : 2006	Total Scour @ jetty (ft)	200 ft offset from toe (ft, NGVD)	Morphological Factor 2006 : 2070	Total Scour @ jetty (ft)
20+00	Ocean	0.70 : 1	deposition	*18*	-	0
50+00	Ocean	0.75 : 1	deposition	*12*	-	0
65+00	Ocean	0.77 : 1	deposition	*2*	1 : 1.1	-5
75+00	Ocean	0.79 : 1	deposition	*-5*	1 : 1.2	-10
85+00	Ocean	0.80 : 1	deposition	-16	1 : 1.3	-10
100+00	Ocean	0.75 : 1	0	-27	1 : 1.2	-15
124+00	Ocean	0.65 : 1	-15	*-31*	1 : 1.1	-10
20+00	Channel	0.6 : 1	0	-27	1 : 1.3	0
40+00	Channel	0.7 : 1	-5	-36	1 : 1.3	0
60+00	Channel	0.8 : 1	-10	-41	1 : 1.3	-10
80+00	Channel	0.8 : 1	-10	-50	1 : 1.3	-15
100+00	Channel	0.7 : 1	-30	-68	1 : 1.3	-10
124+00	Channel	0.65 : 1	-40	*-64*	1 : 1.2	0

The calibration parameters of wave-induced damage thresholds and stone "re-use" parameters are defined and input to the model. The storm wave and water level climate is generated for a given lifecycle iteration (89 years for North Jetty, 97 years for South Jetty, and 67 years for Jetty 'A'), and then jetty lifecycle calculations are performed sequentially for each year, for all jetty segments.

MC simulations are performed by running multiple lifecycle iterations and generating statistical estimates of the life-cycle ensemble. The model skill of the hindcast was assessed by comparing the simulated hindcast result to actual metrics based on sequence of repairs, number of repairs made per jetty segment, and crest elevation of the jetty at the end of the historical performance period. Other available informative metrics include time varying reliability, cross-section area, and cost expended per segment.

Calibration parameters that affect jetty degradation in the model include "wave-damage thresholds" for:

A) initial state jetty cross-section,

B) damaged initial state cross-section,

C) repair cross-section, and

D) damaged repair cross-section.

An additional calibration parameter that affects unit repair costs is the "armor stone re-use factor", which defines how much of the damaged-displaced armor stone is re-used in the subsequent repair; this can be different for each observed repair event. Within the framework of hindcast simulations, the calibration parameters are held constant as user input values. For future lifecycle simulations, the calibrated parameters are allowed to randomly vary about the mean value (the value achieved through calibration).

The model calibration variables are:

- ***dam_var***: the jetty wave damage threshold variation parameter
- ***re_use_stone_factor_repair***: the jetty stone repair factor variation

Calibration of jetty damage thresholds is achieved when simulations from the SRB model converge with the observed lifecycle history in terms of the occurrence and frequency of when the jetty was actually repaired through its historical lifecycle. The model is considered to be calibrated when the simulated jetty profile for the end-state condition is equivalent to the observed end-state condition. The observed end-state condition for each jetty was defined by detailed topographic/bathymetric surveys conducted during 2006-2007.

Upon completion of the North Jetty in 1917, the entire ocean side of the jetty was exposed to wave action due to the inlet's morphological condition. Soon after completion of the North Jetty, the presence of the jetty radically reformed Peacock Spit producing subareal deposition along the north side of the North Jetty. The SRB model simulated the time-varying condition of Peacock Spit, as its rapid accretion first acted to protect the ocean side of the North Jetty from wave and currents, and then re-exposed the jetty to the elements during gradual recession of the spit.

The intensity of wave action along exposed areas of the North Jetty in 1917 was estimated to be less than the present condition due to the orientation and geometry of the underwater shoals. Because of this, the initial condition wave environment along the ocean side of the North Jetty was reduced from present average conditions using a morphological factor varying from 0.7 near the landward end of the jetty, to 0.75 at 4/5 of total jetty length, to 0.65 at the jetty head. For similar reasons, the initial condition wave environment along the channel side of the North Jetty was reduced (from present day value) using a morphological factor ranging from 0.6 at the landward end, to 0.8 at 3/5 of total jetty length, to 0.65 at the jetty head. Morphological factors for the North Jetty are shown previously in Table Table 11: North

Jetty Morphological Factors for Future Base Case Scour Depth at Jetty Toe. These morphological adjustments to the wave environment were estimated based on empirical evidence and professional judgment. The morphology factors changed through time, from the initial condition values, to 1.0 for the present condition. Wave events realized within the SRB model are modified "at the jetty" using the time varying morphology factors (Table Table 11: North Jetty Morphological Factors for Future Base Case Scour Depth at Jetty Toe). A key assumption in the SRB model is that the average long-term *offshore* wave (deepwater) climate, at the time of jetty construction, was similar to present.

The previous Figure 13 presents a somewhat typical cross-section evolution for one realization of the historical 89-year lifecycle at Station 84 for the last iteration of the MC sequence. During this particular lifecycle iteration, Station 84 was simulated to have been repaired two times (1939 and 1997) after initial construction in 1917. The actual timing of repairs for Station 84 occurred in 1939 and 2005. The results for this particular station show that the initial damage to Station 84 occurred along the ocean side due to wave action (upper section damage) before Peacock Spit accretion. During later stages in the lifecycle, the damage affecting Station 84 was motivated by channel-side toe scour and channel-side wave action. Note that by this time the ocean side of the jetty was protected by Peacock Spit accretion; the subareal spit reached maximum accretion in 1930 and began receding in 1935.

A calibration of the new SRB model was performed by converging simulations from the model with the observed life-cycle history, in terms of the occurrence and frequency of when the jetty was actually repaired, the repair year and the amount of repair tonnage through its historical life-cycle, as well as the end-state condition. The observed end-state condition for each jetty was defined by detailed topographic/bathymetric surveys conducted during 2006-2007. The comparison of calibration results (hindcast model as compared to historical observation) are shown in Figures 15 to 20 for North Jetty, Figures 21 and 22 for South Jetty, and Figures 23 and 24 for Jetty A.

The jetty cross-section damage/degradation was modeled based on the two-dimensional physical model study results by ERDC. Damage functions (cross section area damage vs. wave height) were applied for the different jetty cross-sections, including: a) initial state jetty cross-section, b) damaged initial state cross-section, d) repair cross-section, and d) damaged repair cross-section. The "wave-damage thresholds" parameters were used to adjust the wave heights in the damage functions for different type of cross-sections for the purposes of calibration. The "wave-damage thresholds" parameters are expected to be variable along the jetty segments and for different repair/rehab scenarios. These adjustment parameters were determined through the model calibration (hindcast). They are allowed to randomly vary within a range about the mean value (obtained through calibration) in each of the future life-cycle Monte Carlo simulations.

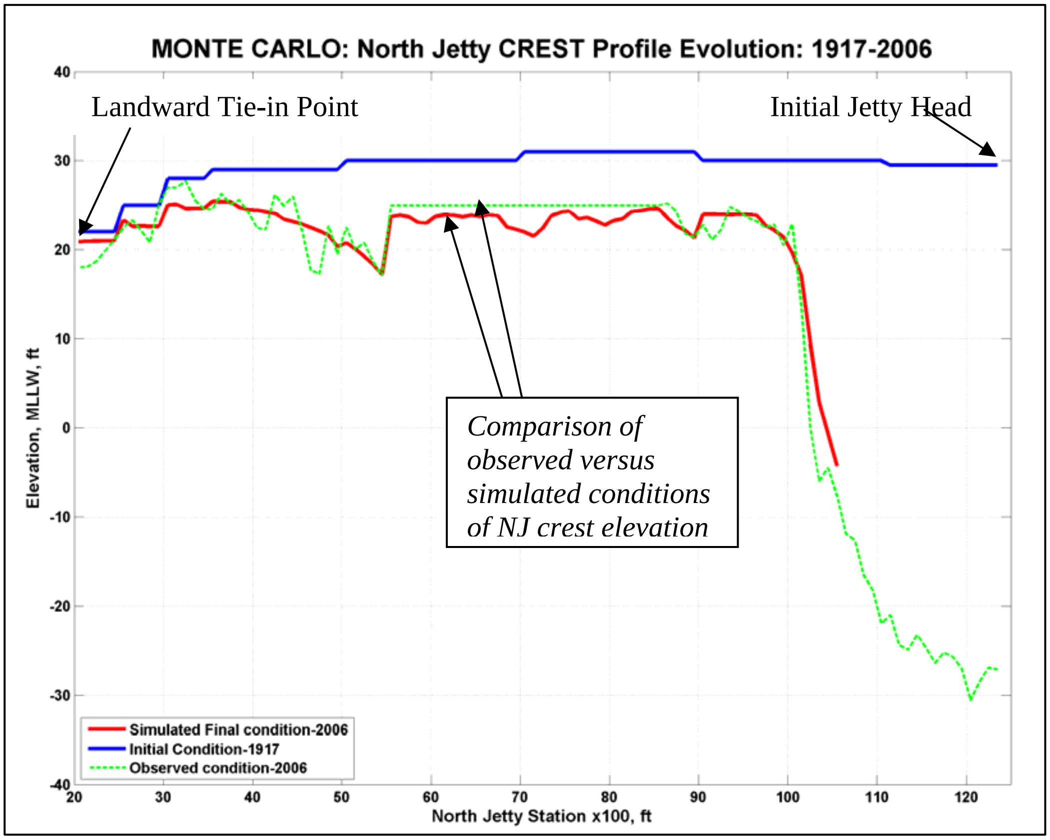


Figure 15: Centerline Profile for the "As-Built" Initial Condition for the North Jetty

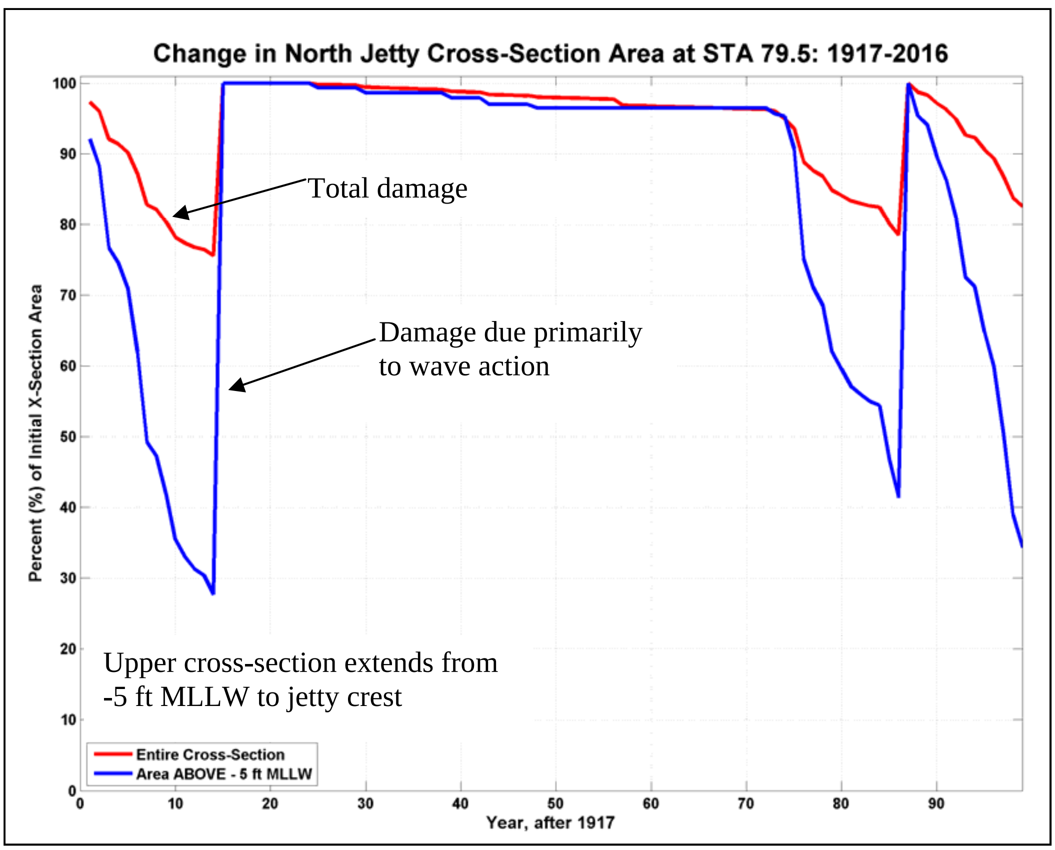


Figure 16: Variation of North Jetty Cross-Section Area at Sta 79.5

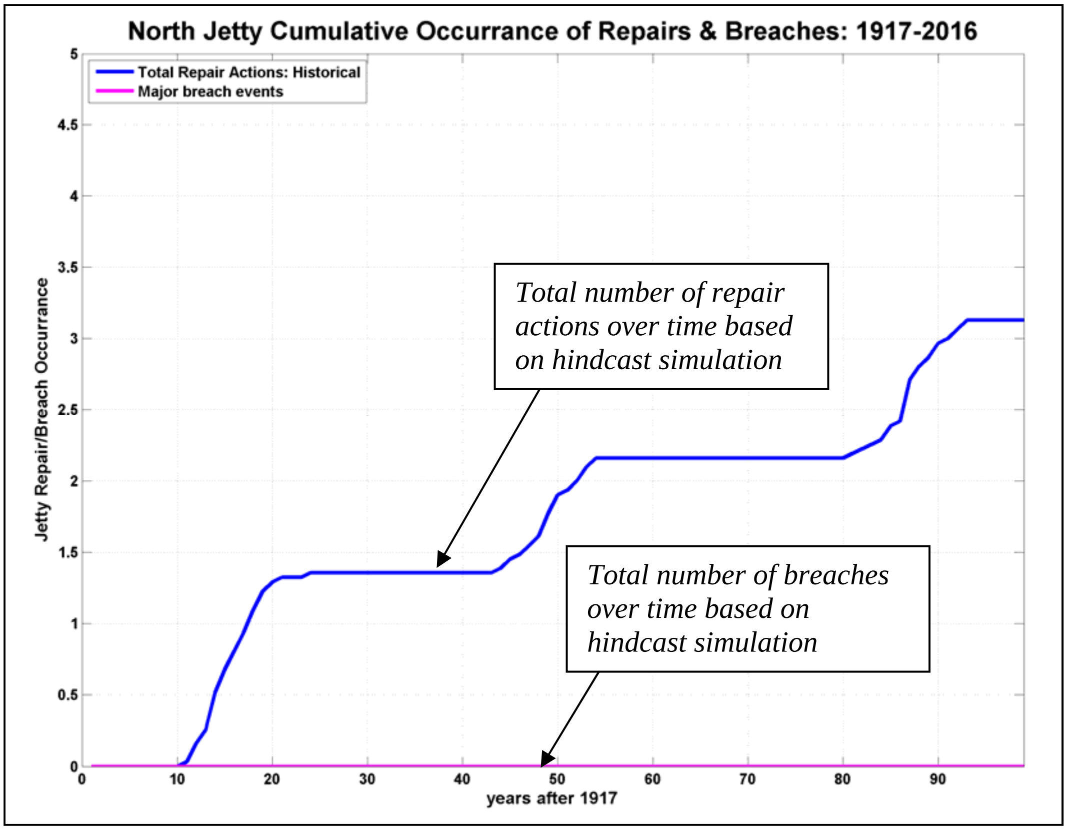


Figure 17: MCR North Jetty Cumulative Jetty Repairs for Hindcast Simulation

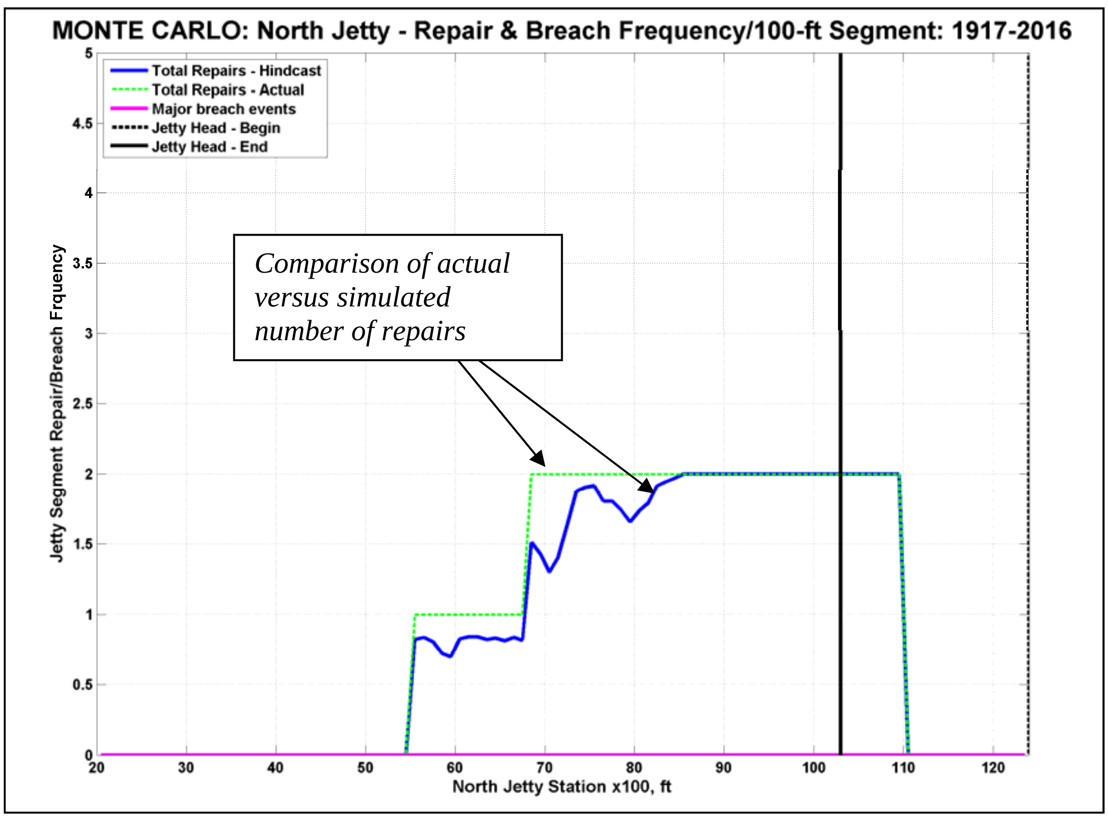


Figure 18: MCR North Jetty Comparison of Actual Jetty Repair History to Hindcast Condition, Based on Frequency and Location of Repairs

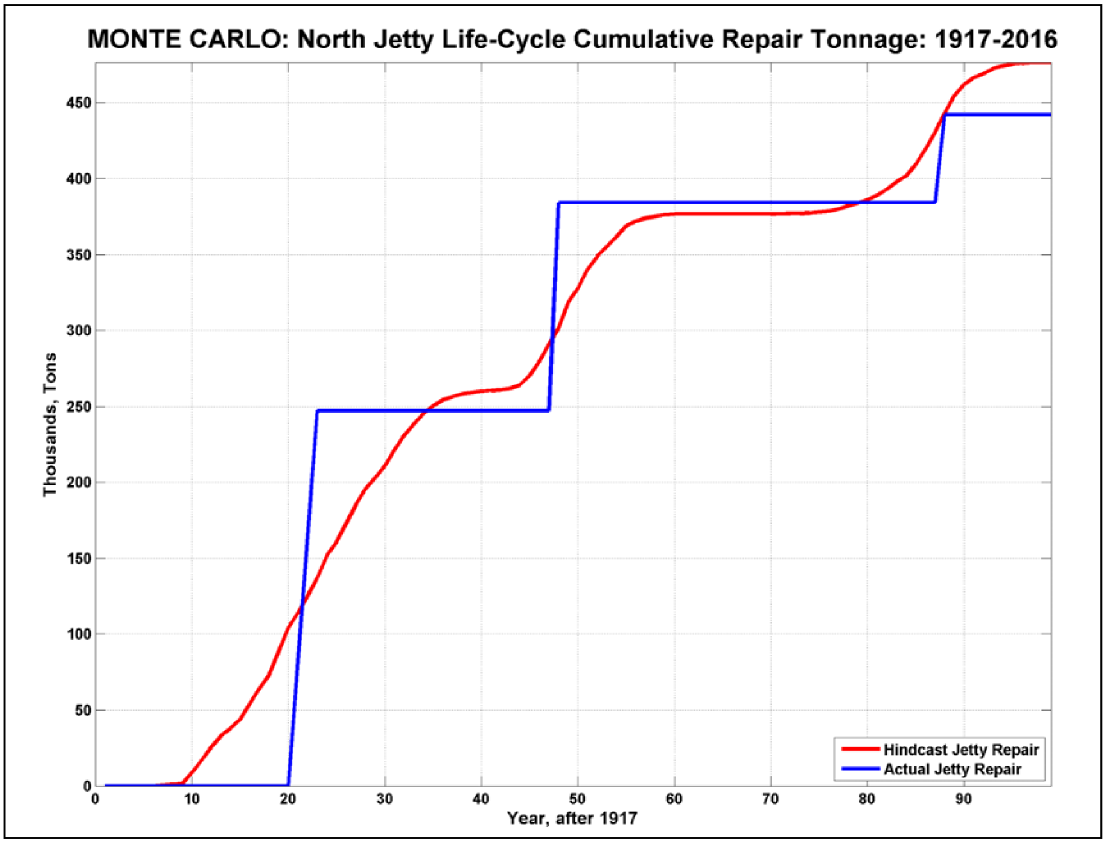


Figure 19: MCR North Jetty Cumulative Jetty Repair Tonnage for Hindcast Simulation

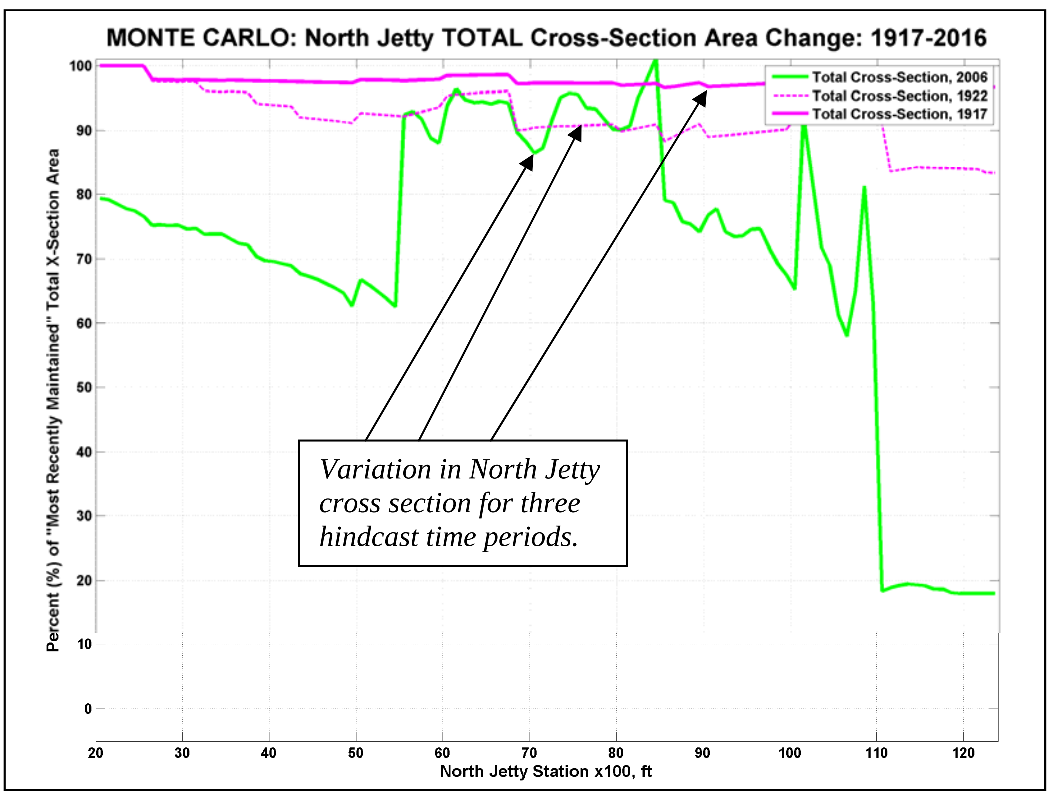


Figure 20: Variation in Total Cross Section Area along Jetty for Three Different Times during the North Jetty Hindcast Period

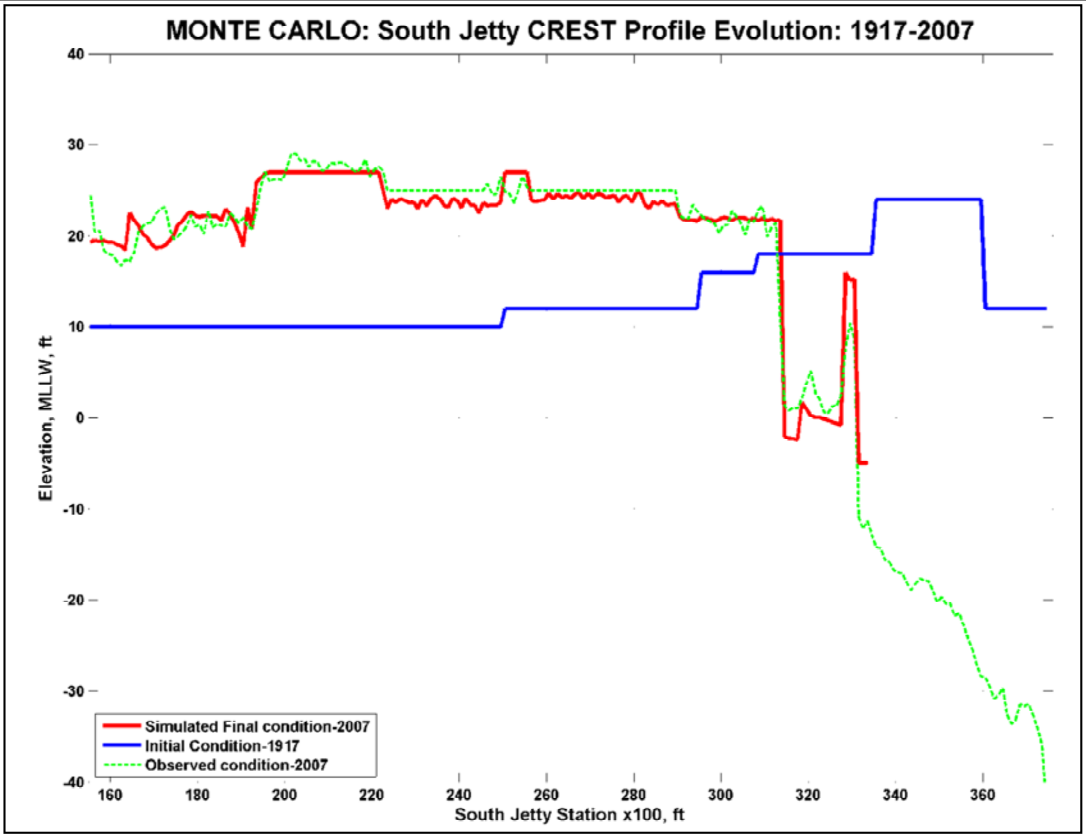


Figure 21: Centerline Profile for the "As-Built" Initial Condition for the South Jetty

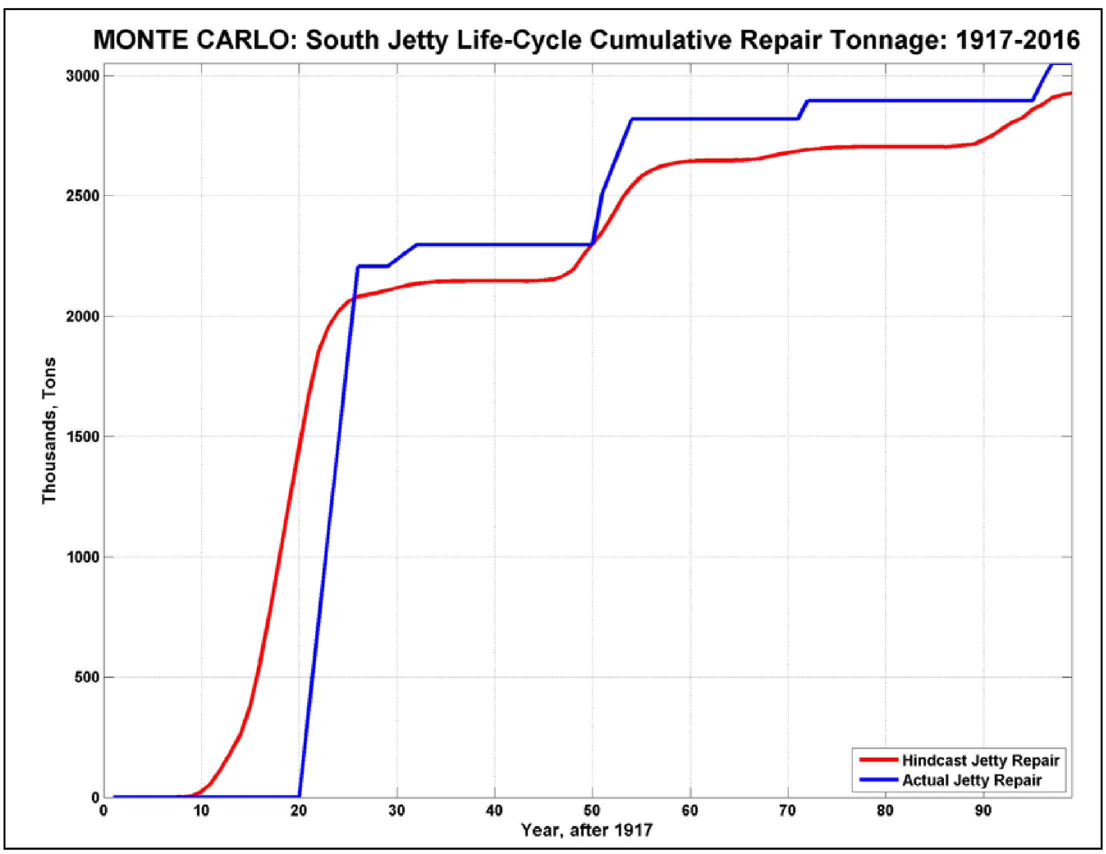


Figure 22: MCR South Jetty Cumulative Jetty Repair Tonnage for Hindcast Simulation

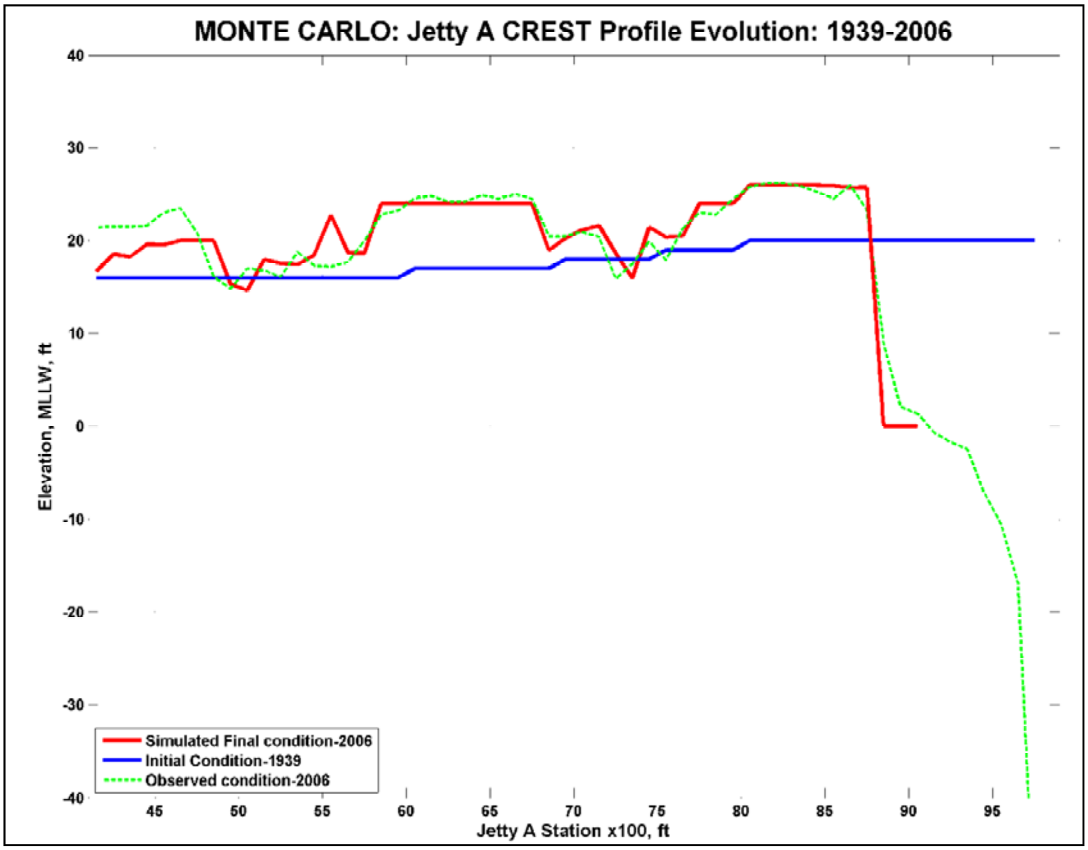


Figure 23: Centerline Profile for the "As-Built" Initial Condition for the Jetty A

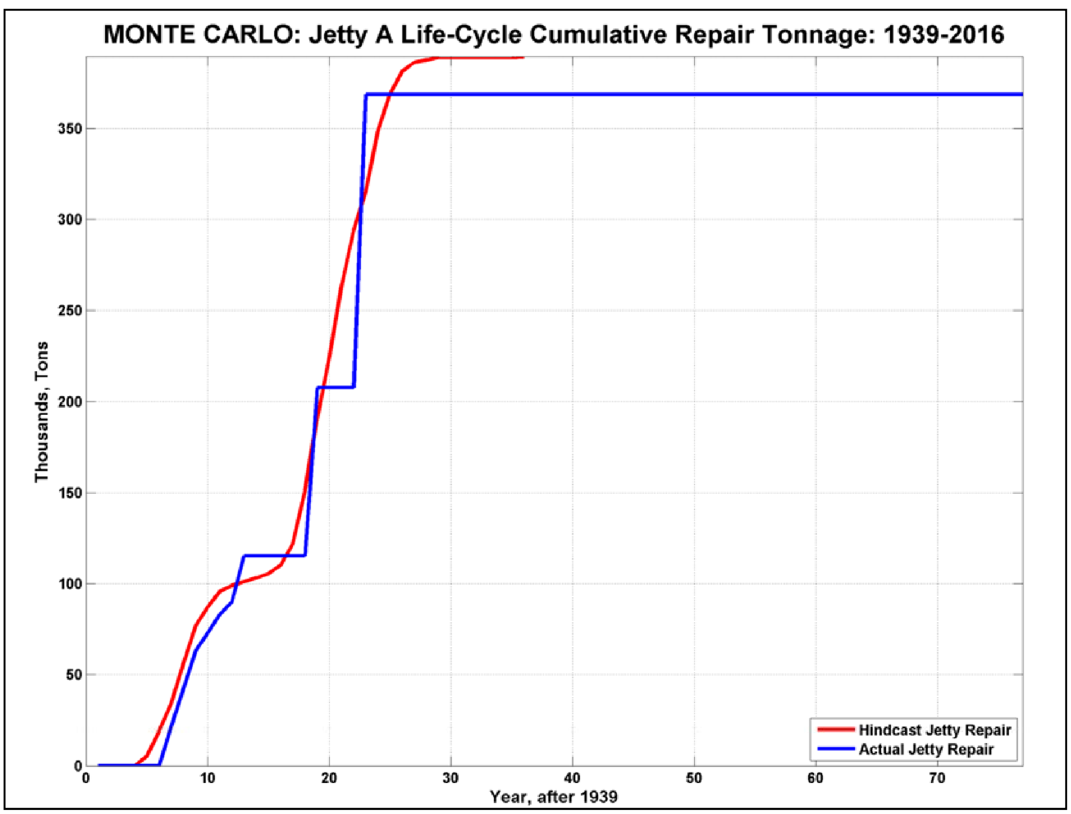


Figure 24: MCR Jetty A Cumulative Jetty Repair Tonnage for Hindcast Simulation

Figure 15 shows the center line profile for the "as-built" initial condition for the North Jetty, observed condition in 2006, and simulated condition in 2006. There is good agreement between the observed and simulated end-state. Note the extent of jetty head recession, which is being aggravated by severe toe scour. As Peacock Spit continues to recede landward in the future, the toe scour effect will translate landward.

Figure 16 shows the progression of damage to the cross section at Station 79.5 and subsequent repairs for the last MC iteration, and complements the information shown in Figure 13. Figures 17, 18 and 19 show the timing, number, location, and tonnage of repairs historically made to the North Jetty. Areas further seaward from Station 70 require greater repair efforts due to the increased exposure to wave action and toe scour. There is good agreement between actual repairs made and the simulated repair requirements. Note that the jetty head has receded landward, despite repairs.

The number of repairs that can be made within the SRB hindcast is controlled by an input parameter. The model can initiate repairs up to the prescribed number, but it is not required to initiate any repairs unless sustained damage exceeds an imposed threshold. No repairs were made to areas inshore of Station 54, which explains why the jetty profile in 2006 was in poor condition. Figure 20 shows the spatial variation of total cross-section area along the jetty for three periods of time (1917, 1922, and 2006), complementing the results shown in Figure 15.

Figures 21 and 22 show some of the calibration results for the South Jetty and Figures 23 and 24 show results for Jetty A, based on hindcast simulations. A complete set of calibration results and discussion for all three jetties can be found in Appendix A2 of the *MCR Major Jetty System Major Rehabilitation Evaluation Report*.

Note: the reader is also referred to the previous user's guide, *Model Documentation Report* (USACE, 2010), for a sensitivity analysis discussion. This model sensitivity analysis was conducted to ascertain the effect that random variation of specific model parameters had on the overall predicted lifecycle cost ranges. The sensitivity analysis was run for each of the three MCR jetties for the BASE-condition (no action alternative). One at a time, model parameters were varied randomly while holding all other parameters at a constant value (mean value). Twenty-five (25) MC simulations were run for each varied parameter to ultimately obtain a representative range of lifecycle costs. This discussion is not repeated in this user's manual as the new model contains the same formulation for all sensitivity parameters and so no significant differences would be expected between the original model and the new model.

APPENDIX A

SRB Model Input Steps

The inputs to the SRB model are completed via a straightforward user interface. The four steps involved are shown below.

Step 1 – Input variables ("values") into Excel file worksheets – shown below.

"Global" worksheet:

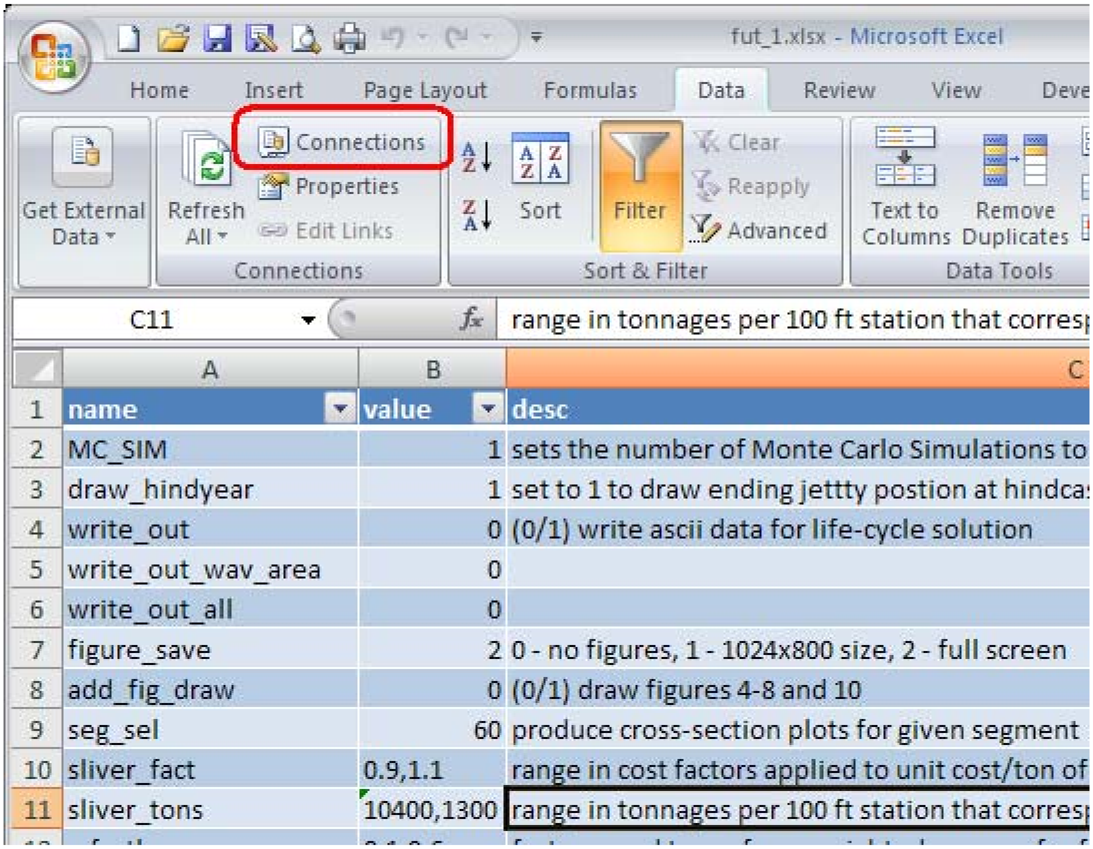
name	value	desc
work_jetty	NJ	(NJ, SJ, JA) specify jetty to work with
fut	1	(0,1,10-14,20-24,30) modeling scenario
MC_SIM	200	sets the number of Monte Carlo Simulations to run
draw_hindyear	1	set to 1 to draw ending jettty postion at hindcast_year for hindcast runs, set ~= 1 to draw at n
write_out	0	(0/1) write ascii data for life-cycle solution
write_out_wav_area	0	
write_out_all	0	
figure_save	2	0 - no figures, 1 - 1024x800 size, 2 - full screen
add_fig_draw	0	(0/1) draw figures 4-8 and 10
path_input	..\..\preload\input	input folder with preloaded files
path_input_ini	..\input	input folder with initial geomentry and armor from hindcast simulation
path_output	output	output folder
path_output_mc	output_mc	output folder for MC simulations
navd2mllw	0.3	ft, add value to convert from NAVD to MLLW
WATER_GAMMA	64.2	seawater density

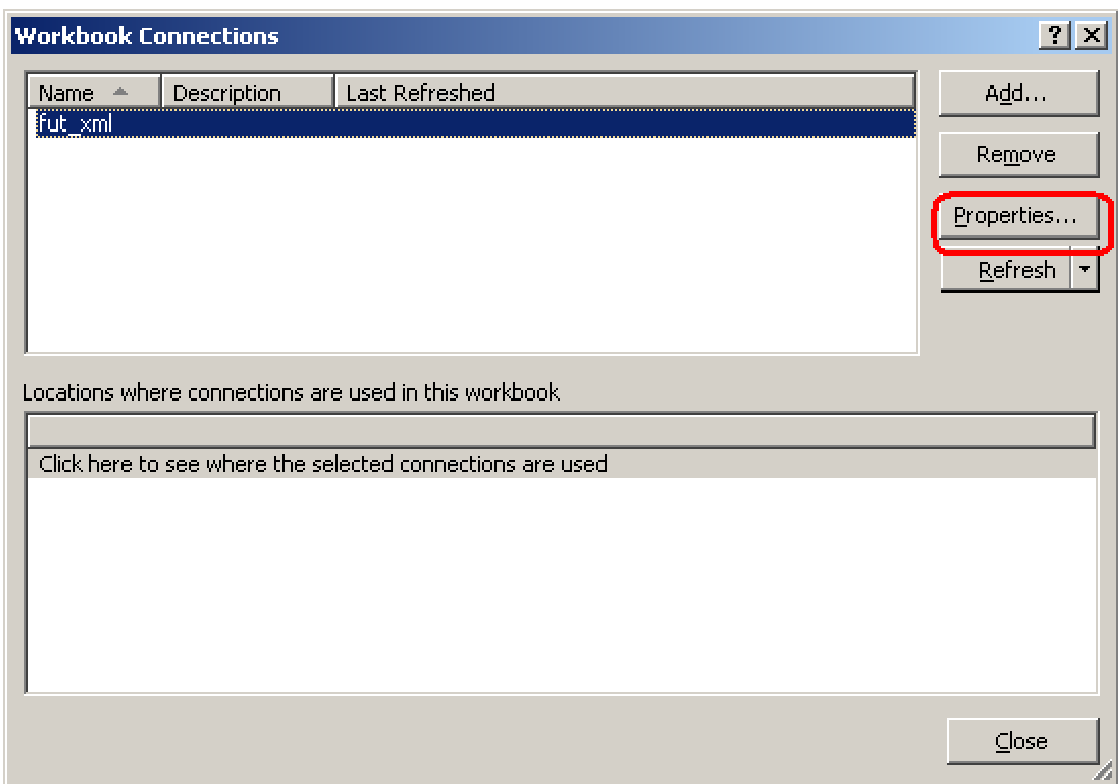
Jetty setup worksheet (NJ, SJ, JA or NJ0, SJ0, JA0 for hindcast) :

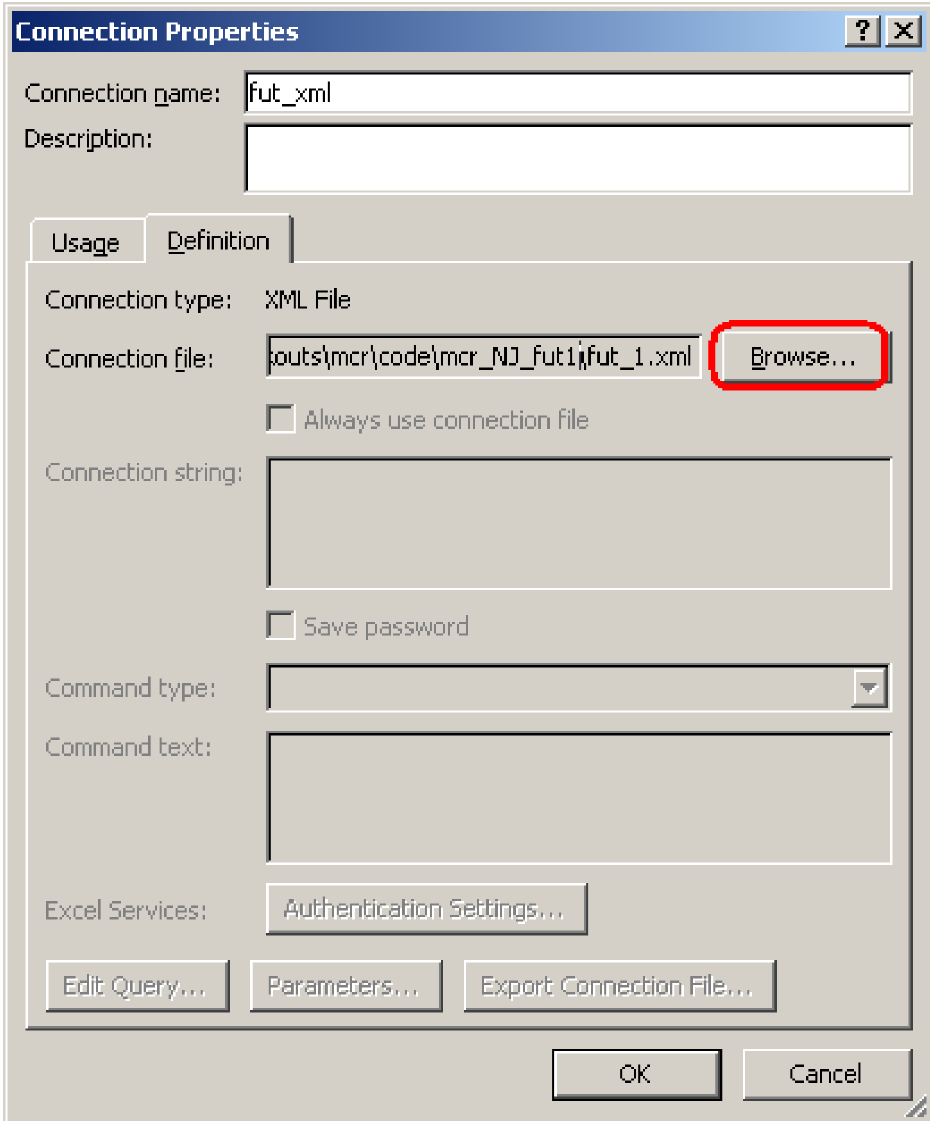
name	value	desc
comp_num	0	index of composite alternative (fut 20 or 30)
total_LC	1	flag to calc total LIFE cycle costs for fut > 20 (initial cost + maintenance); set to 1 to do so; to t
constrain_foot_print	1	(0/1) force upper cross-section to not extend beyond jetty foot-print
defer_repair_begin	1	initial repair strategy, before rehab (see defer_repair_set)
defer_repair_set	1	0 - fix-as-fails, 1 - interim repairs, 2 - aggressive repairs, 3 - scheduled repairs
proj_impl	0	(year from begin_year) rehab implementaiont (0 for fut=0)
root_fill	0	(0/1) filling jetty root lagoon
head_cap	0	(0/1) enure that head cap option is enabled for fut>10
spur_place	0	(0/1) 1 - spurs are built, 0 - no spurs
spur_mit	0.3	reduction in scour along jetty toe and related adjacent shore recession, mitigated due to spu
spur_mit_morph_fore	0.7	reduction in shoaling volume entering MCR channel associted loss of Peacock Spit (nearshor
spur_mit_morph_near	0.9	reduction in shoaling volume entering MCR channel associted loss of Benson Beach (foresho
spur_mit_scour	0.3	reduction in scour afftecting jetty toe due to spur implementation
rand_shore_edge	1	(0/1) 1 - allow randomness for ending position of shore edge
jetty_extension	0	(ft) extension of rehabbed jetty beyond present head position
hold_head	0	(0/1) parameter set to 1 if jetty head is to be held in place (wrt present location, @ time = 0)
RSM	0	(0/1) If RSM is fully enacted on north side MCR; the erosion of Peacock Spit is significantly re
seg_sel	60	produce cross-section plots for given segment
sliver_fact	0.9,1.1	range in cost factors applied to unit cost/ton of jetty stone based on sliver work effort, used
sliver_tons	10400,1300	range in tonnages per 100 ft station that correspond to above sliver work factors; 80% to 10%
wfactless	0.1,0.6	factors used to perform weighted average for functional reliability index
wfact	2.0,1.0	
wfactmore	1.0,0.55	
model_slope	1.5	
model_wav_el	-5	physical model pararemeters for initial existing condition and interim repair template; OK fc
head_recede_yr	100	max annual rate of head recession per year; modelling of head recession tends to be step fx
proj_impl_phase_1_year	2015	
proj_impl_phase_2_year	2016	
proj_impl_phase_3_year	2017	
proj_impl_phase_4_year	2018	
proj_impl_phase_5_year	2019	
proj_impl_phase_6_year	2020	

Specific jetty worksheet (complete sheet not shown for brevity):

Step 2 – Link Excel file to XML file






Connection Properties
Connection name:
fut_xml
Description:
Usage
Definition
Connection type:
XML File
Connection file:
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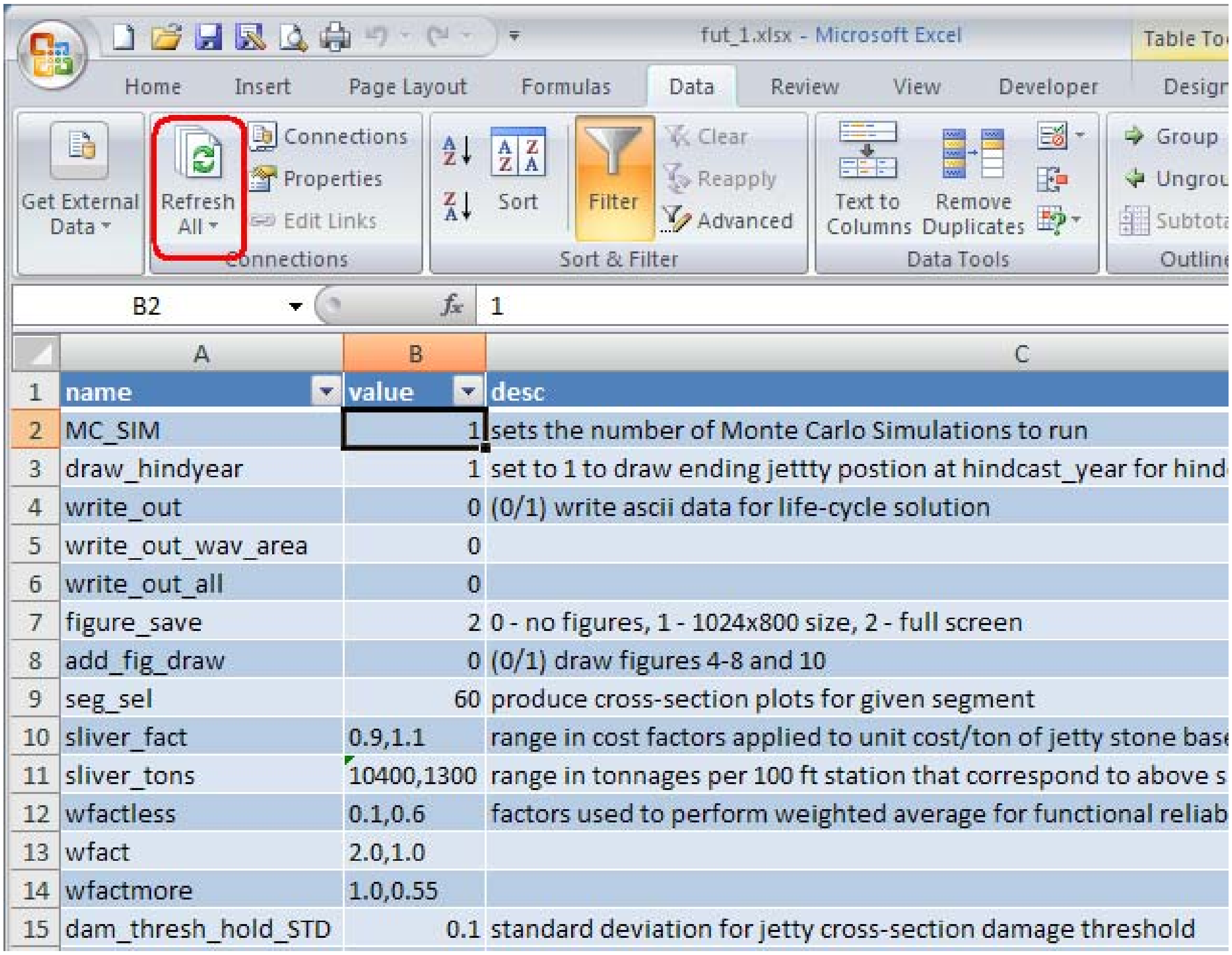
Browse...
Always use connection file
Connection string:
Save password
Command type:
Command text:
Excel Services:
Authentication Settings...
Edit Query...
Parameters...
Export Connection File...
OK
Cancel

Step 3 – Load XML file into Excel



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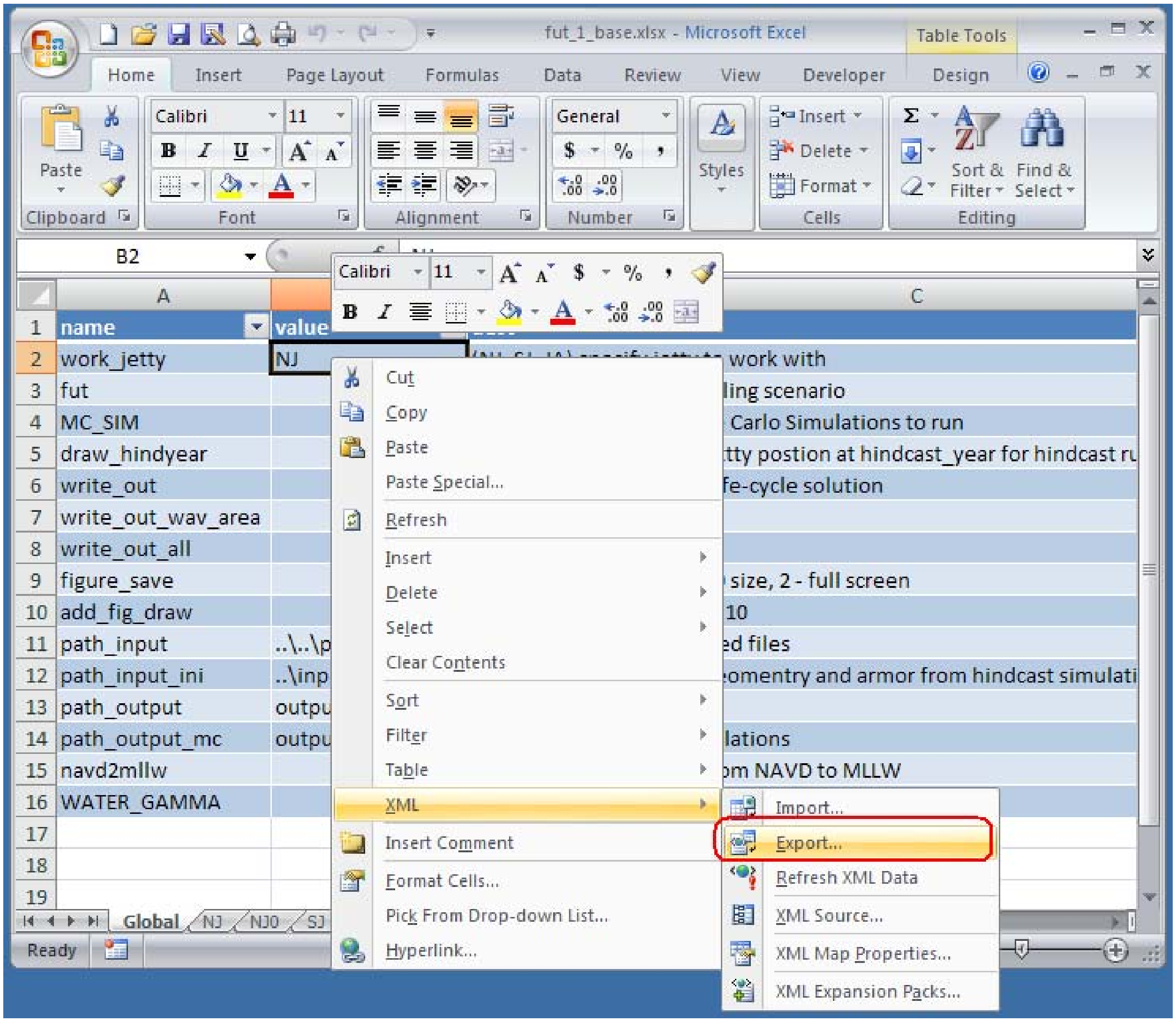
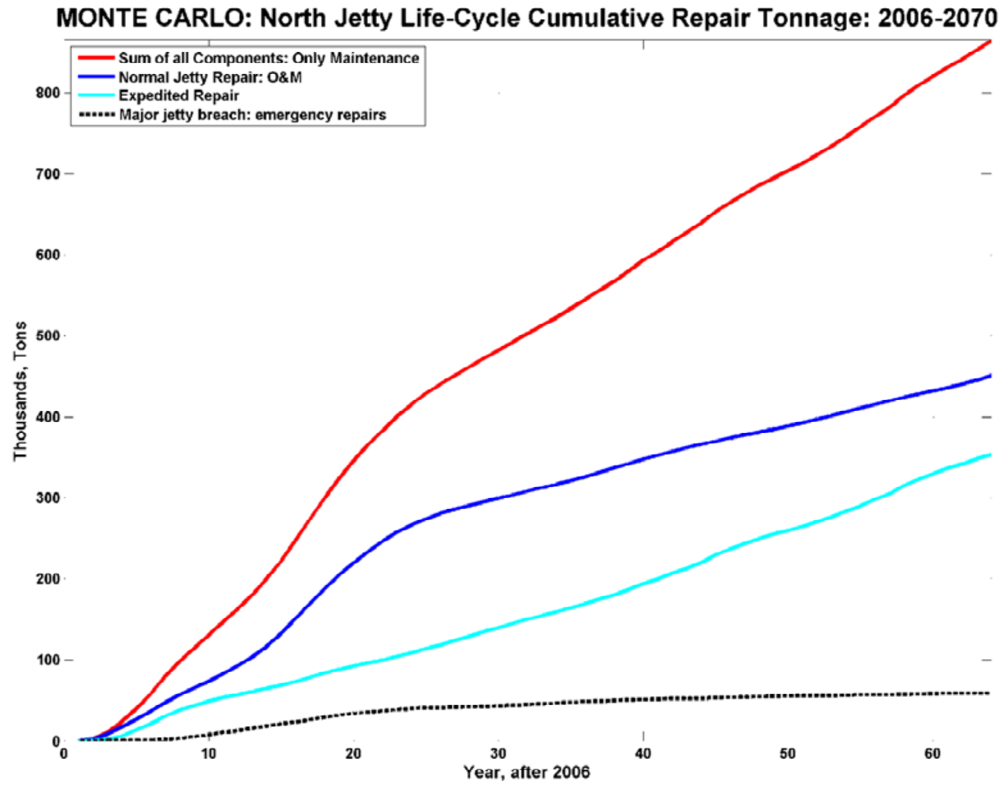


APPENDIX B

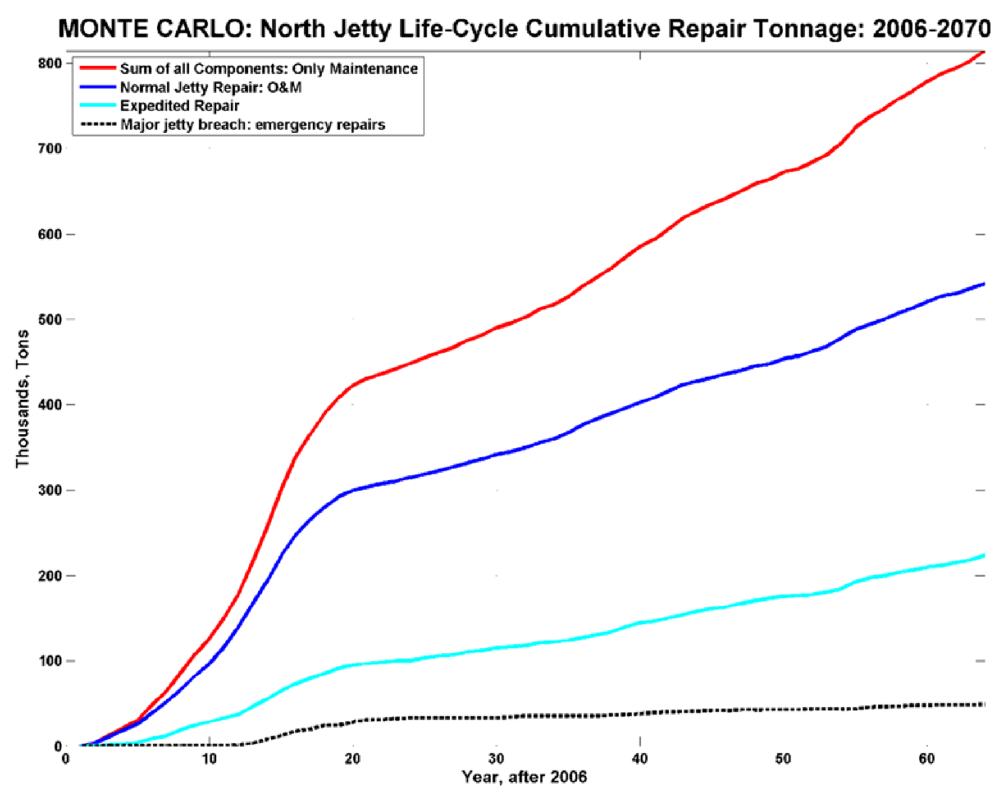
Comparison of SRB Model Results: Original Model versus New Model

Note: the Base Condition for the original model was the Fix-as-Fails case, but for purposes of an "apples-to-apples" comparison in this appendix, the Base Condition for both the original and current models is the Interim Repair case.

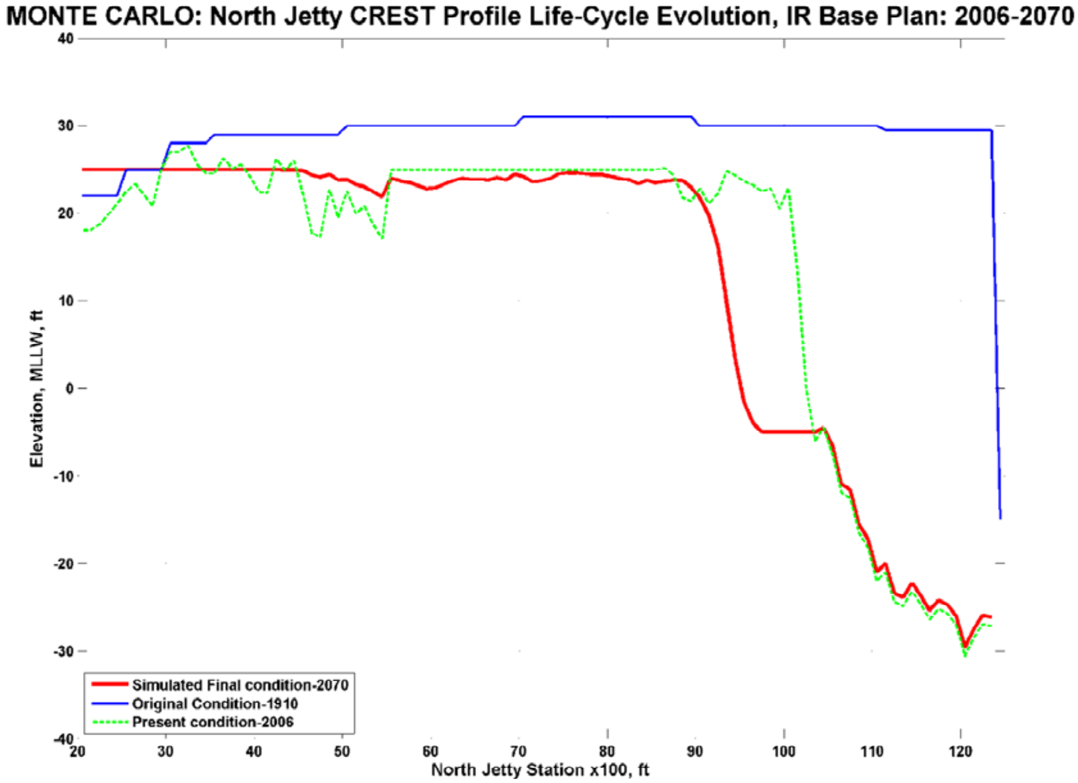
North Jetty, Base Condition,
Cumulated Repair Tonnage, <u>Original</u> Model



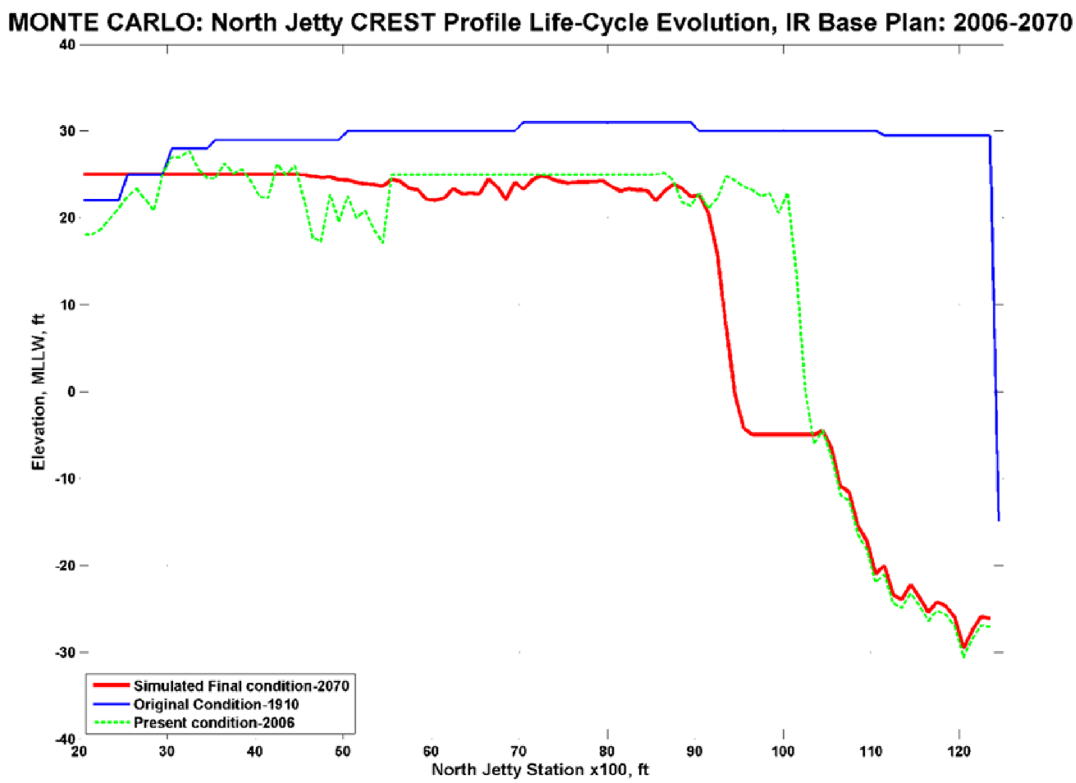
North Jetty, Base Condition,
Cumulated Repair Tonnage, <u>New</u> Model



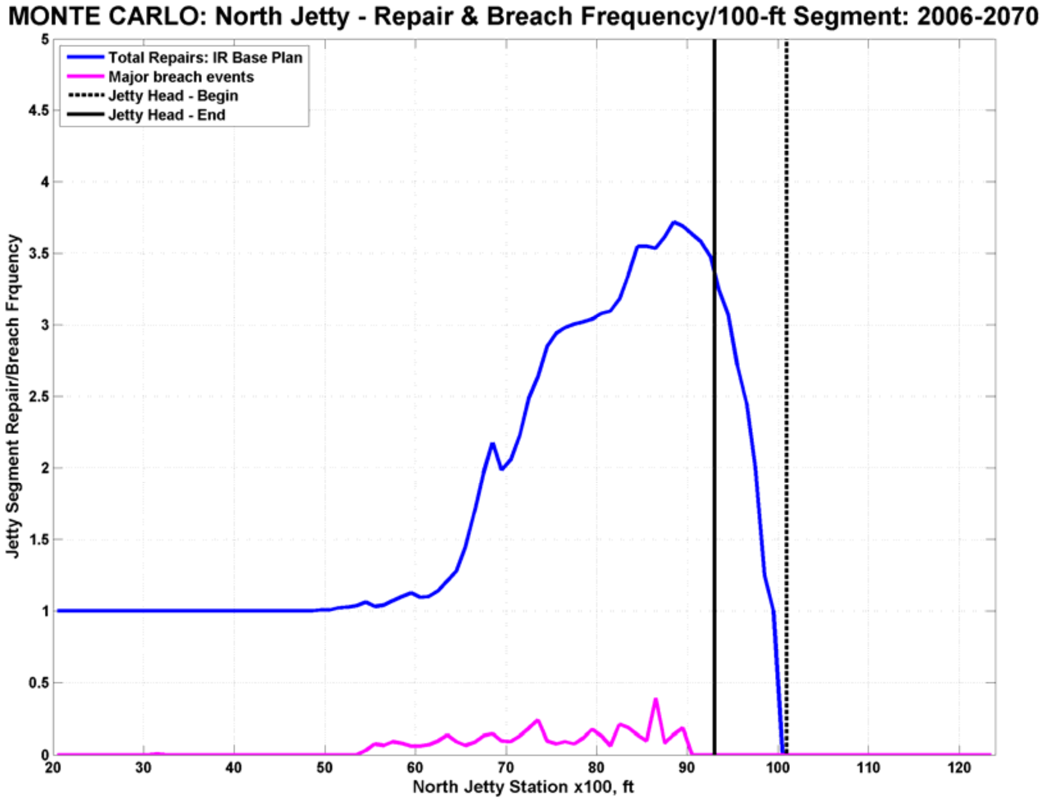
North Jetty, Base Condition,
Crest Elevation, <u>Original</u> Model



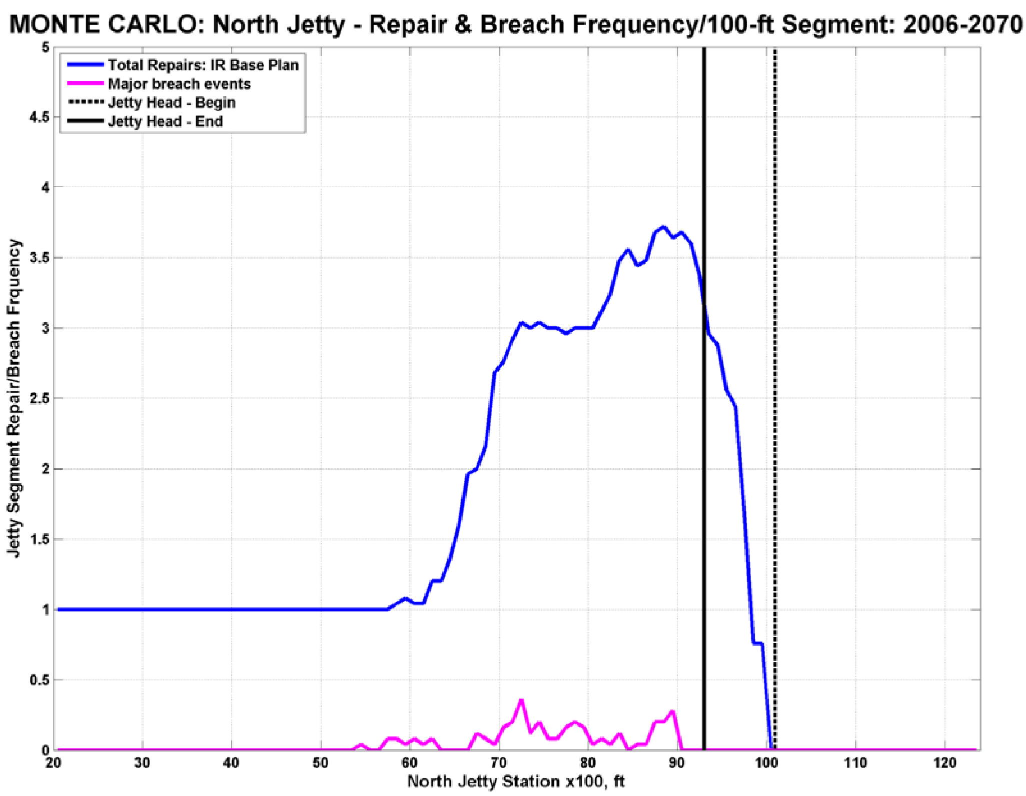
North Jetty, Base Condition,
Crest Elevation, <u>New</u> Model



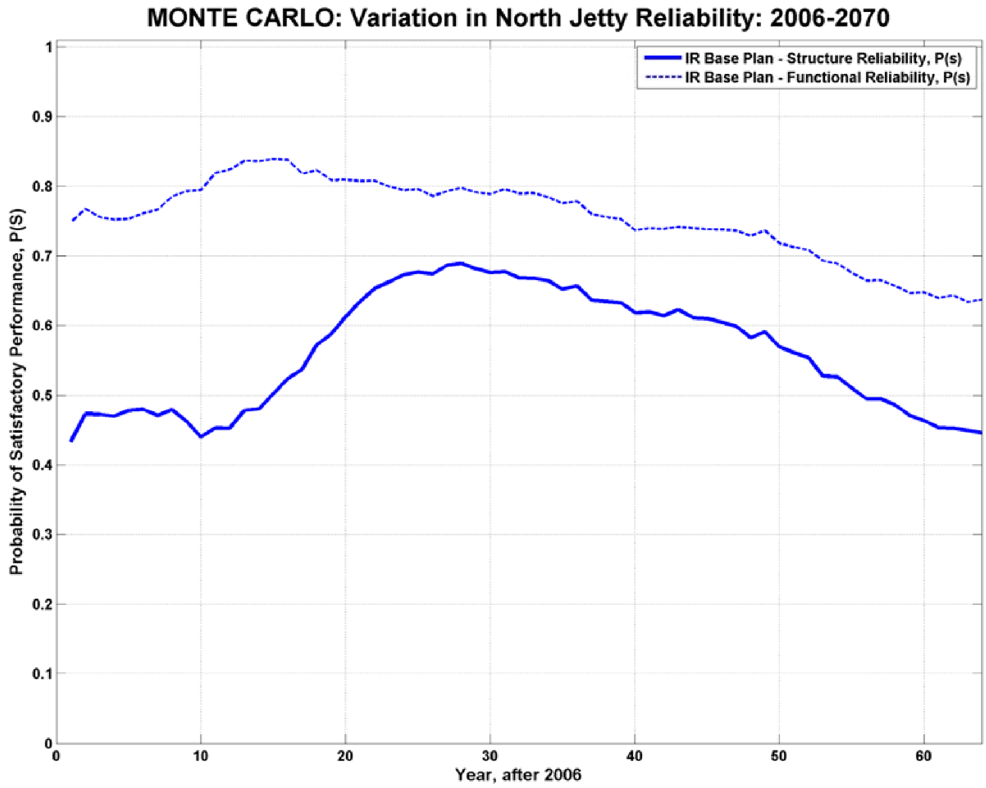
North Jetty, Base Condition,
Repair/Breach Frequency, Original Model



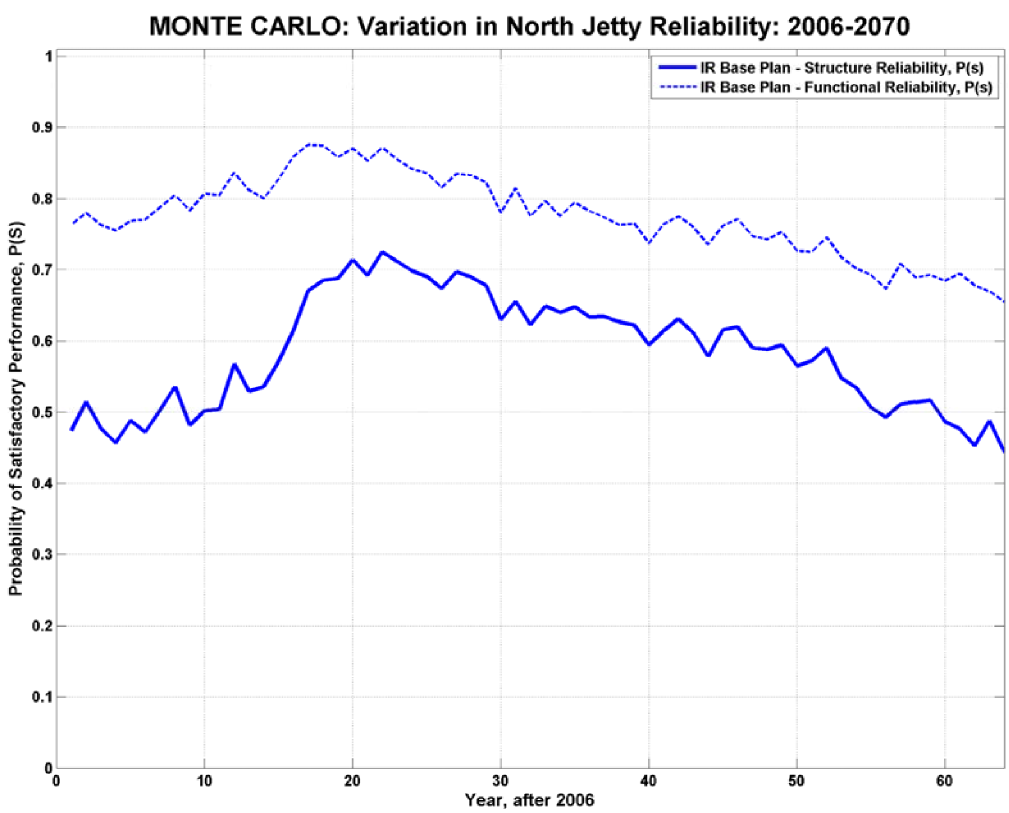
North Jetty, Base Condition,
Repair/Breach Frequency, New Model



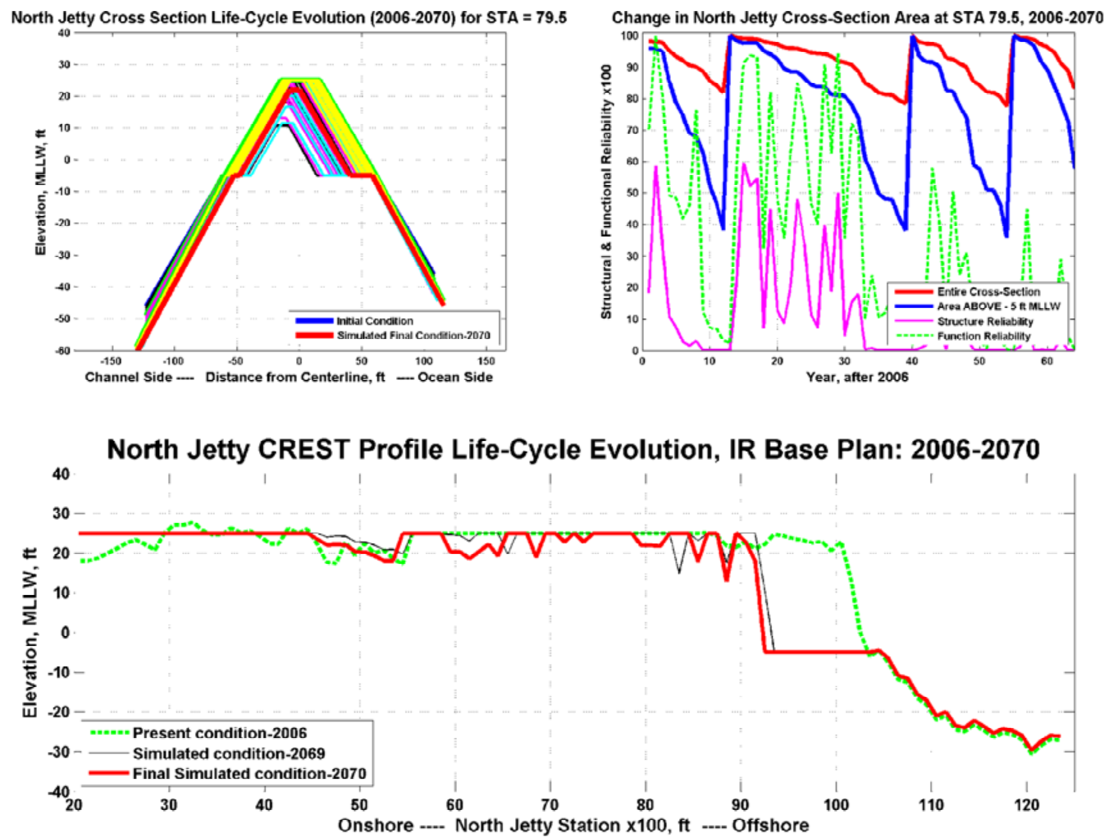
North Jetty, Base Condition,
Reliability, Original Model



North Jetty, Base Condition,
Reliability, New Model



North Jetty, Base Condition, 1 MC Run, <u>Original</u> Model



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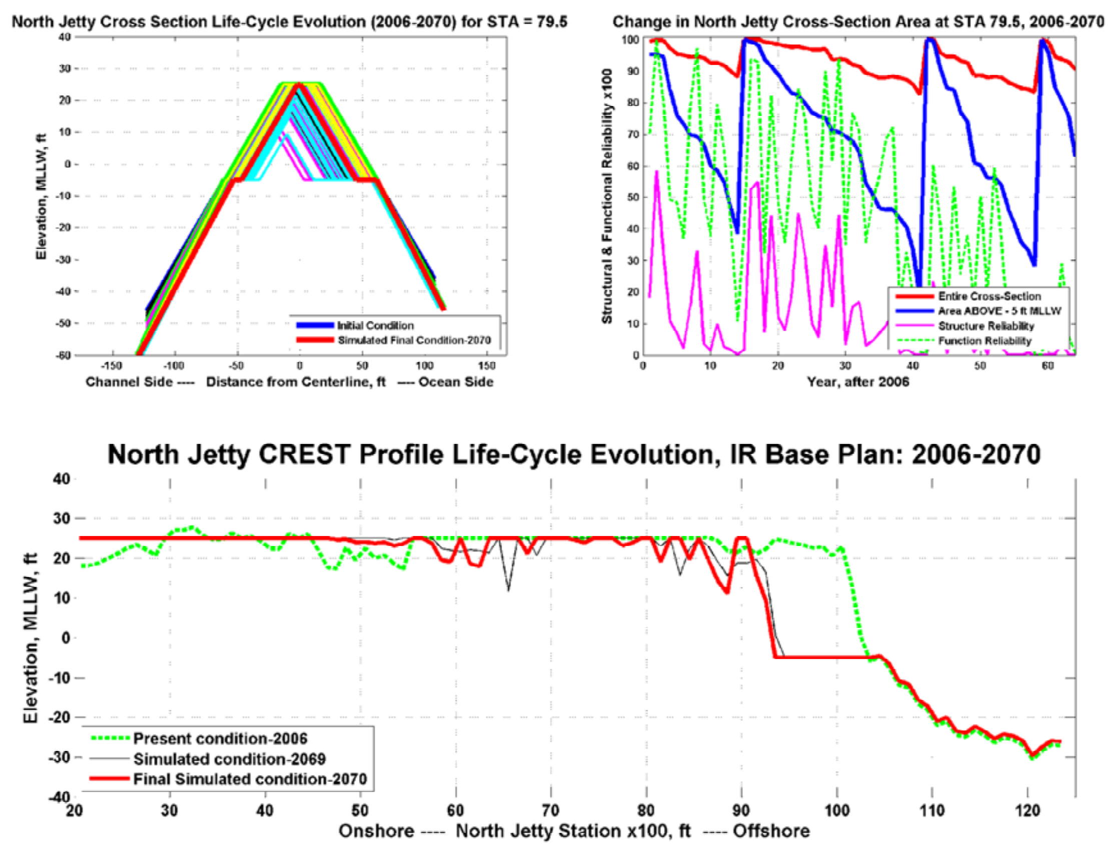
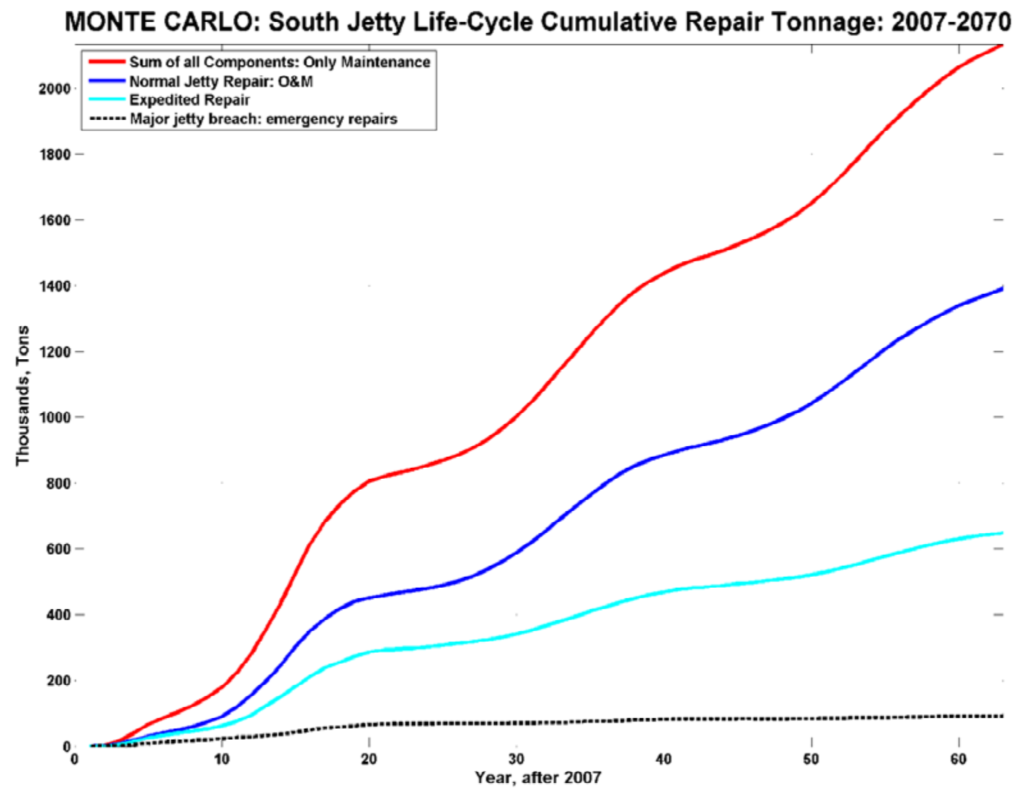
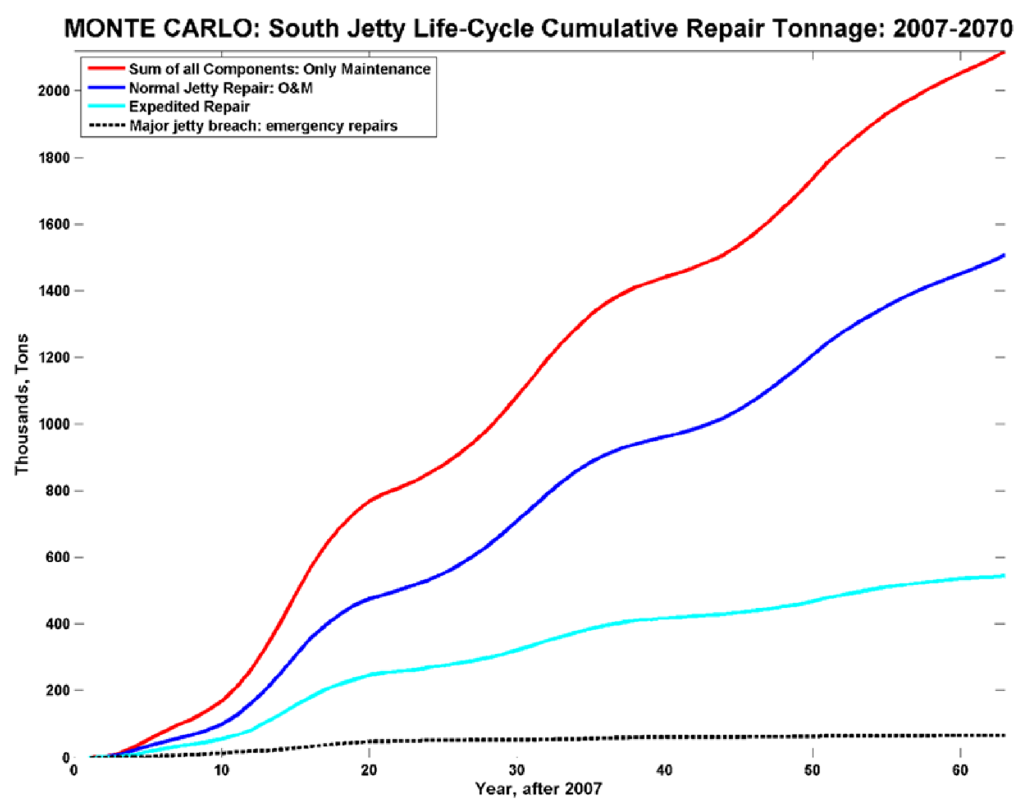


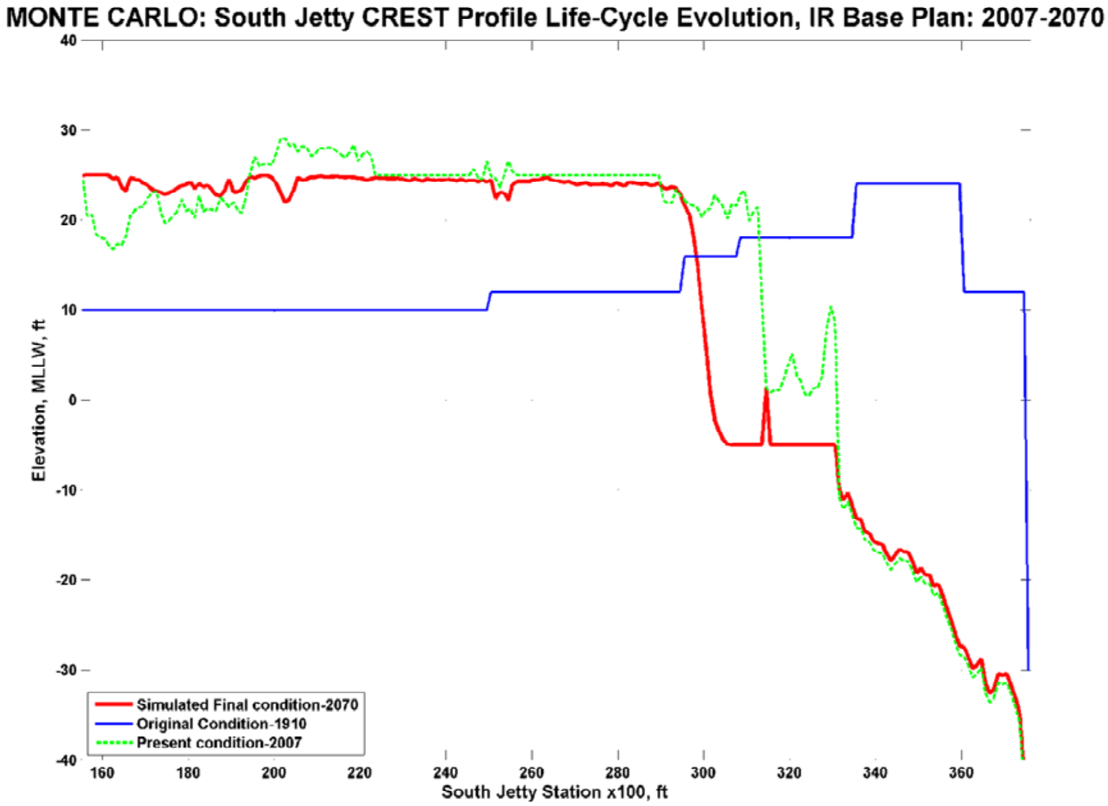
South Jetty, Base Condition,
Cumulated Repair Tonnage, <u>Original</u> Model



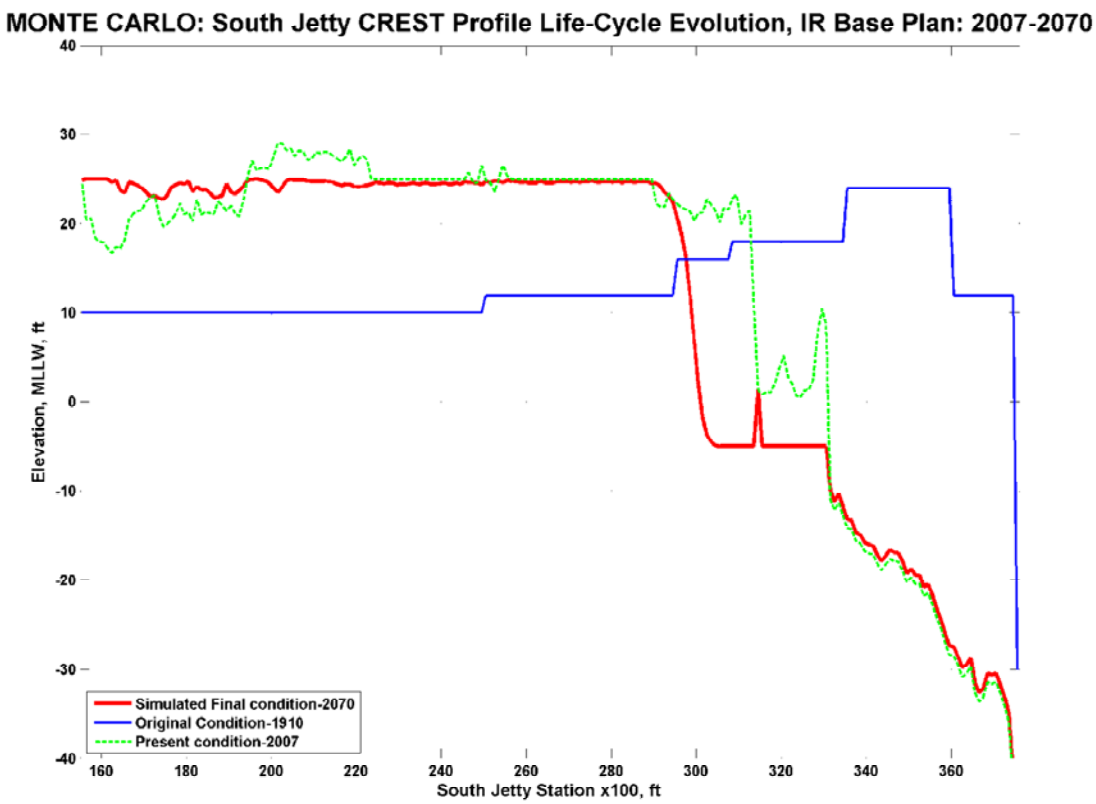
South Jetty, Base Condition,
Cumulated Repair Tonnage, <u>New</u> Model



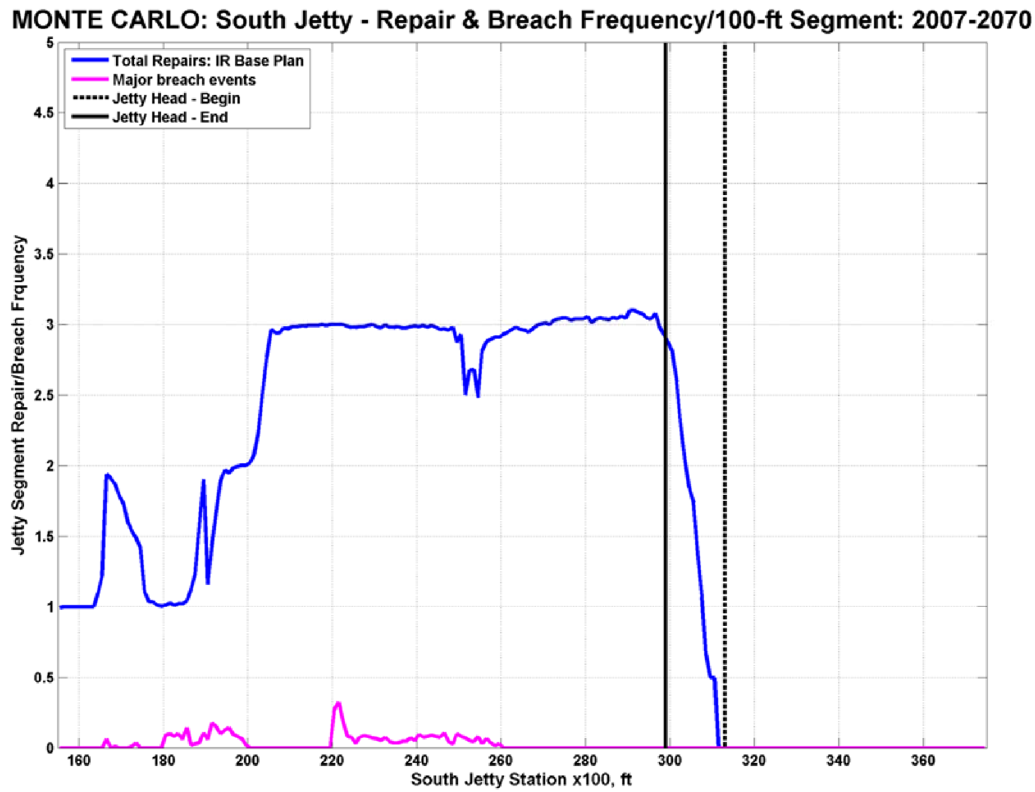
South Jetty, Base Condition,
Crest Elevation, Original Model



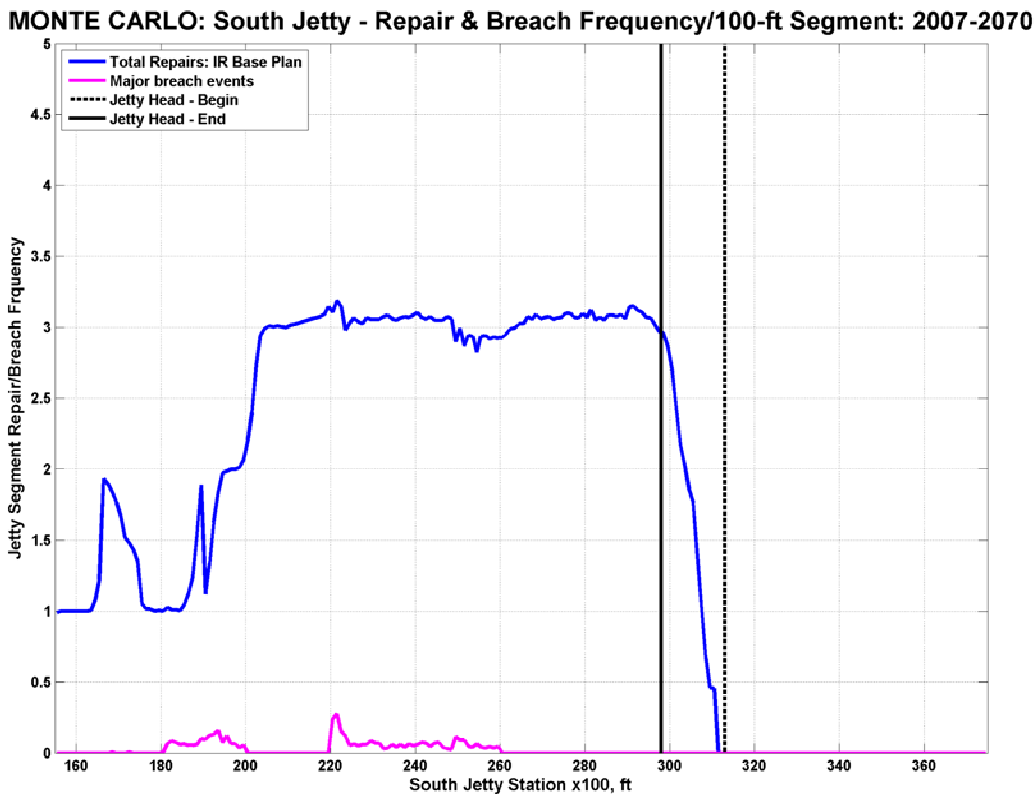
South Jetty, Base Condition,
Crest Elevation, New Model



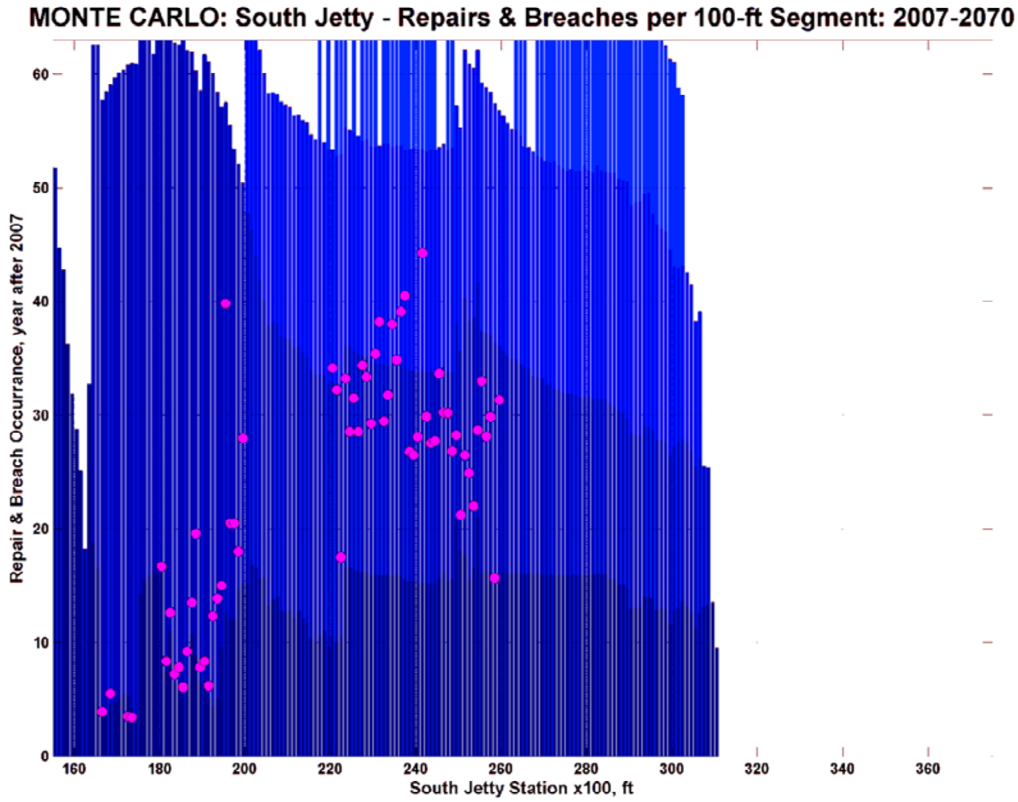
South Jetty, Base Condition,
Repair/Breach Frequency, Original Model



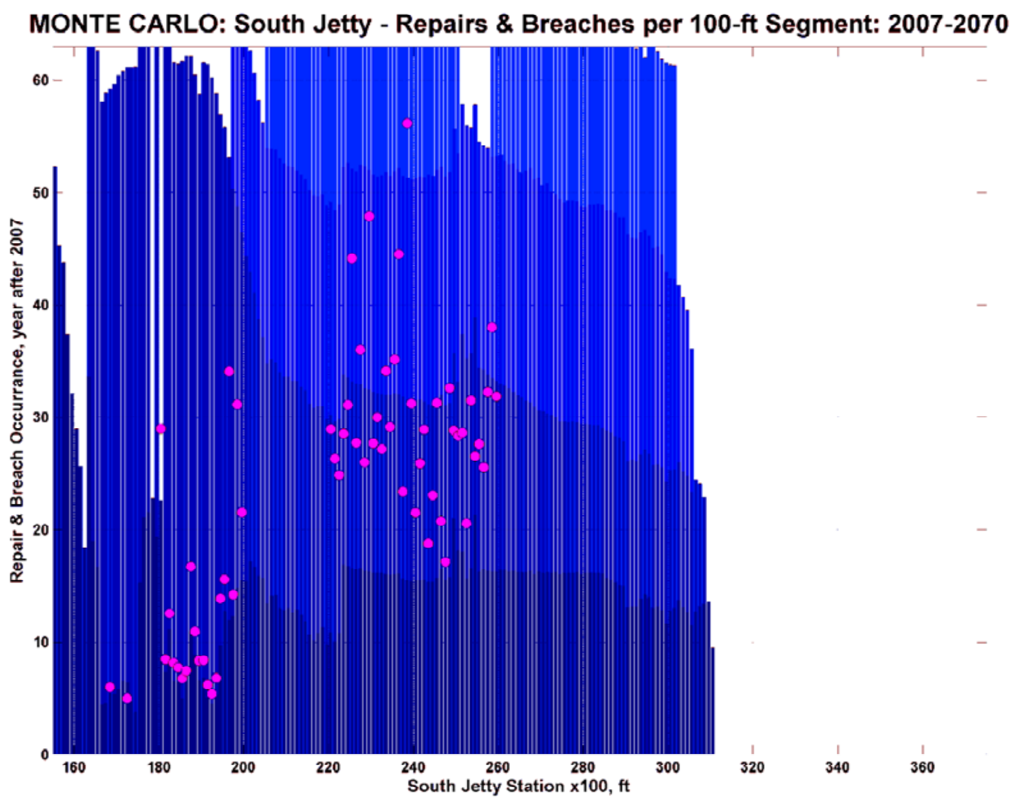
South Jetty, Base Condition,
Repair/Breach Frequency, New Model

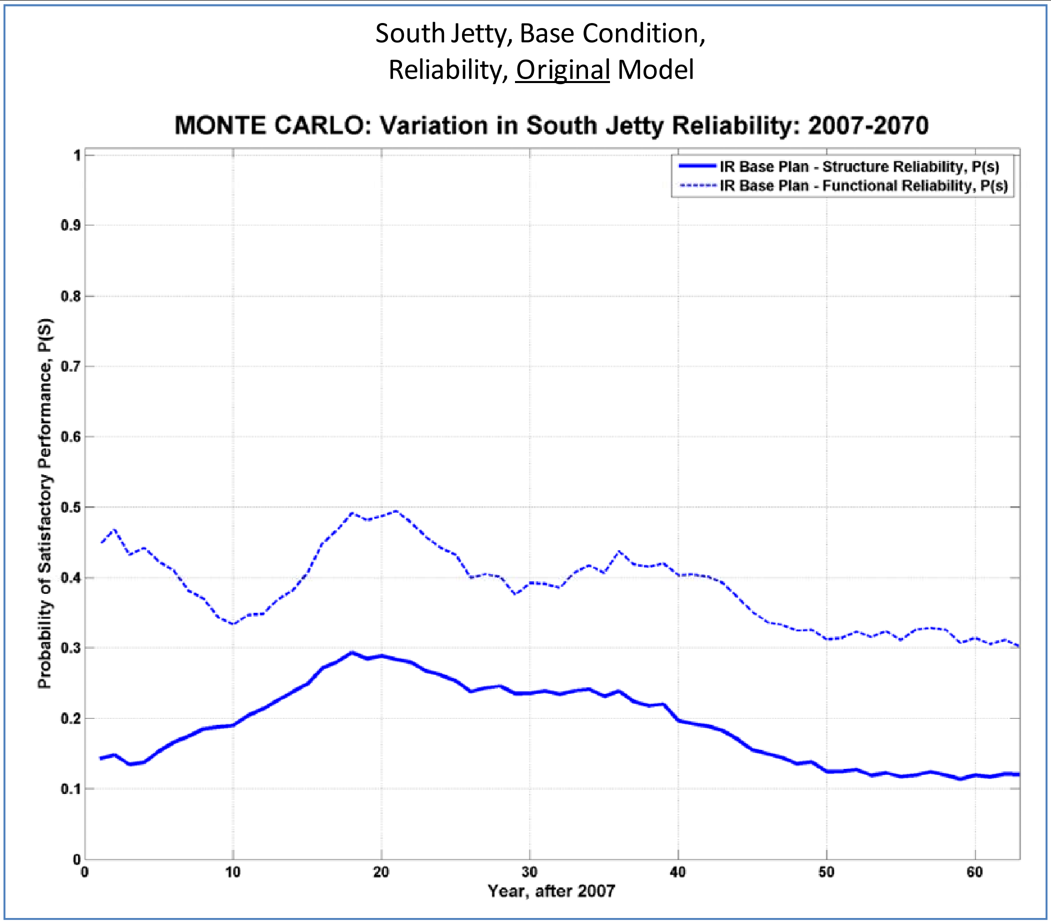


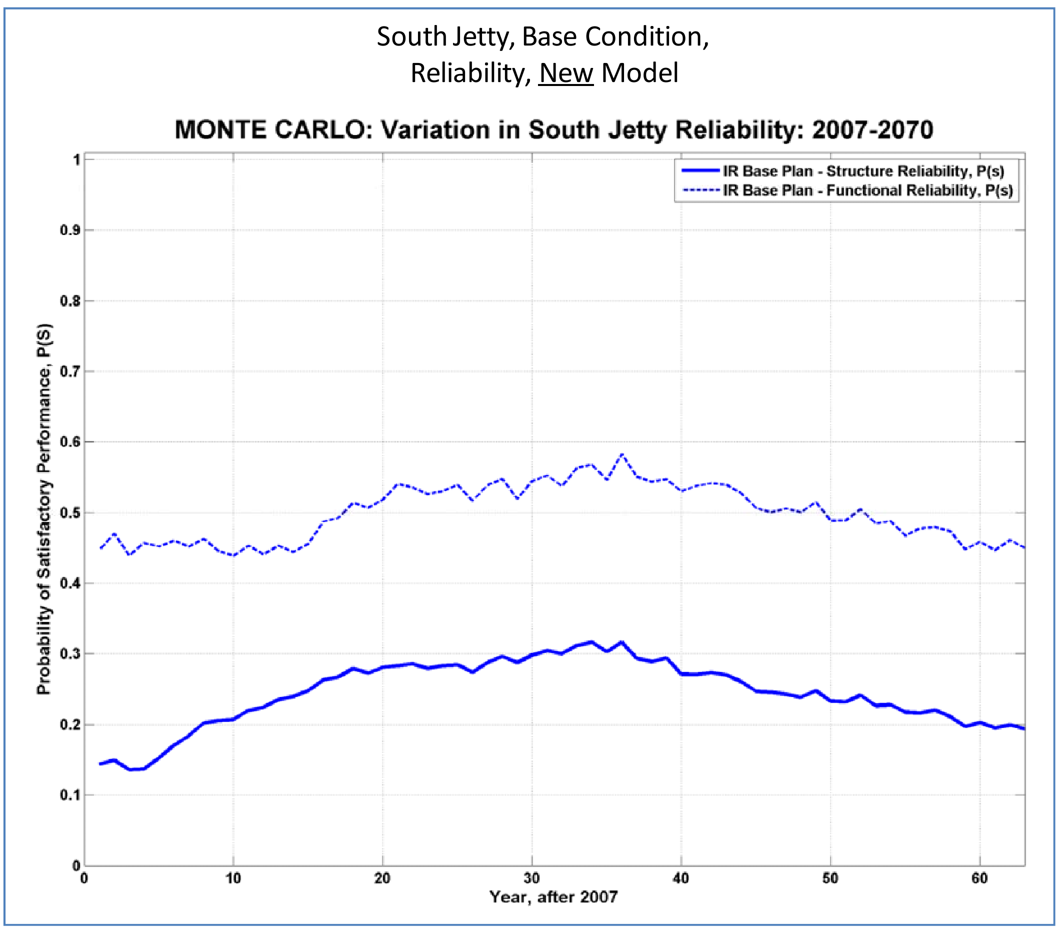
South Jetty, Base Condition,
Repair/Breach, <u>Original</u> Model



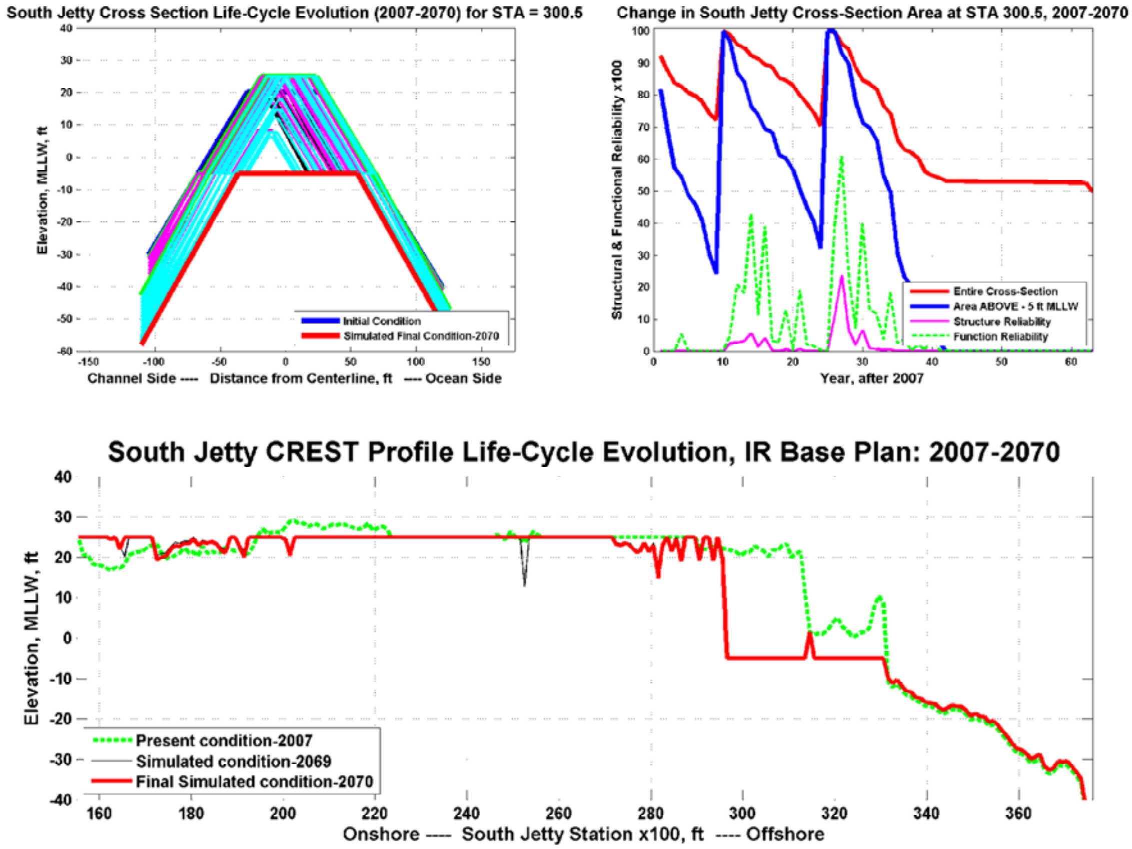
South Jetty, Base Condition,
Repair/Breach, <u>New</u> Model



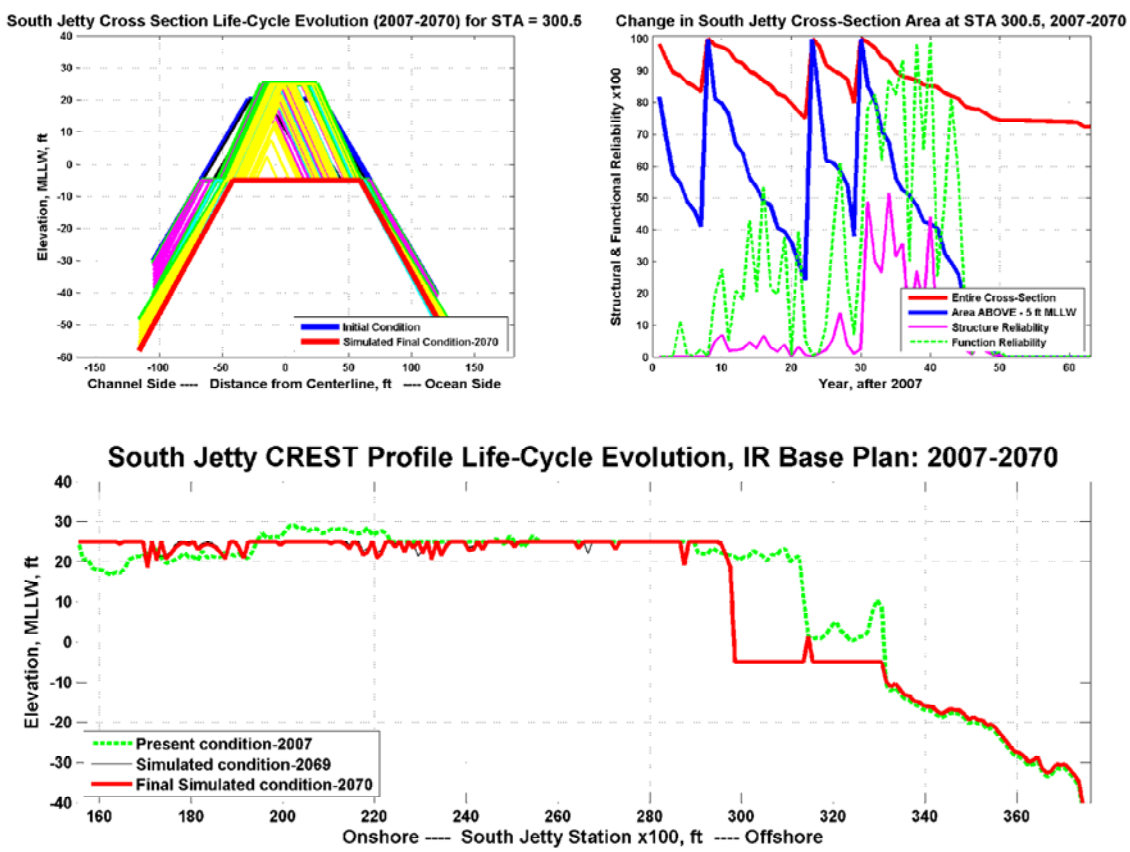

South Jetty, Base Condition,
Reliability, Original Model
MONTE CARLO: Variation in South Jetty Reliability: 2007-2070
IR Base Plan - Structure Reliability, P(s)
IR Base Plan - Functional Reliability, P(s)
Probability of Satisfactory Performance, P(S)
Year, after 2007


South Jetty, Base Condition,
Reliability, New Model
MONTE CARLO: Variation in South Jetty Reliability: 2007-2070
IR Base Plan - Structure Reliability, P(s)
IR Base Plan - Functional Reliability, P(s)
Probability of Satisfactory Performance, P(S)
Year, after 2007

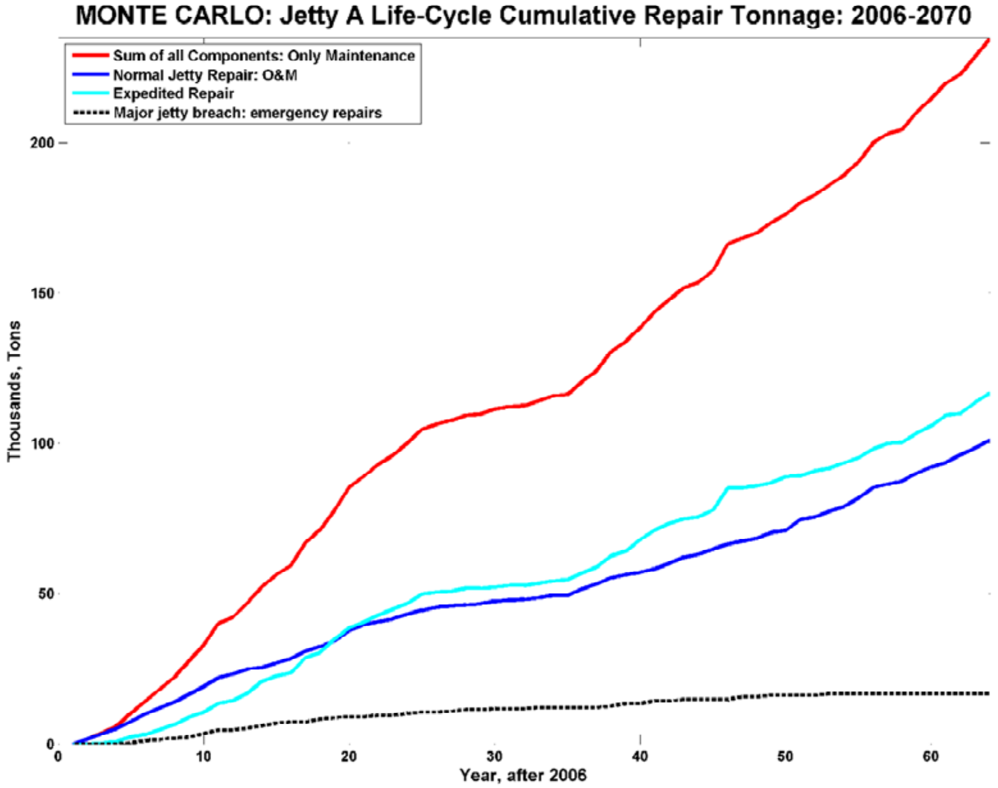
South Jetty, Base Condition, 1 MC Run, Original Model



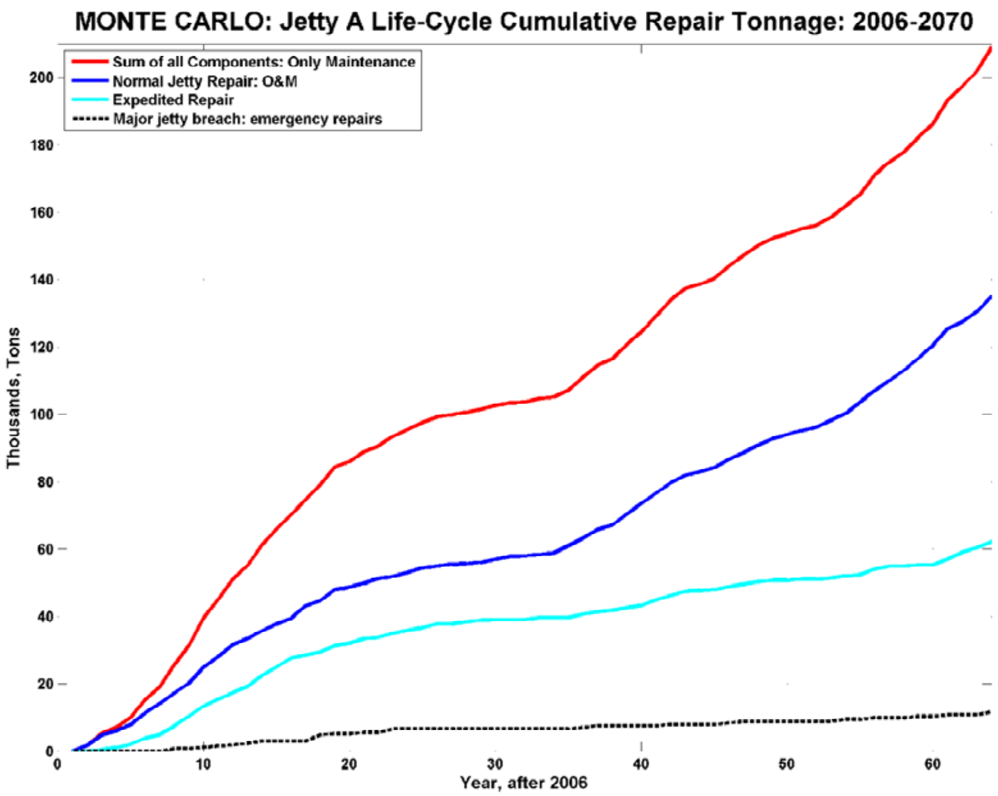
South Jetty, Base Condition, 1 MC Run, New Model



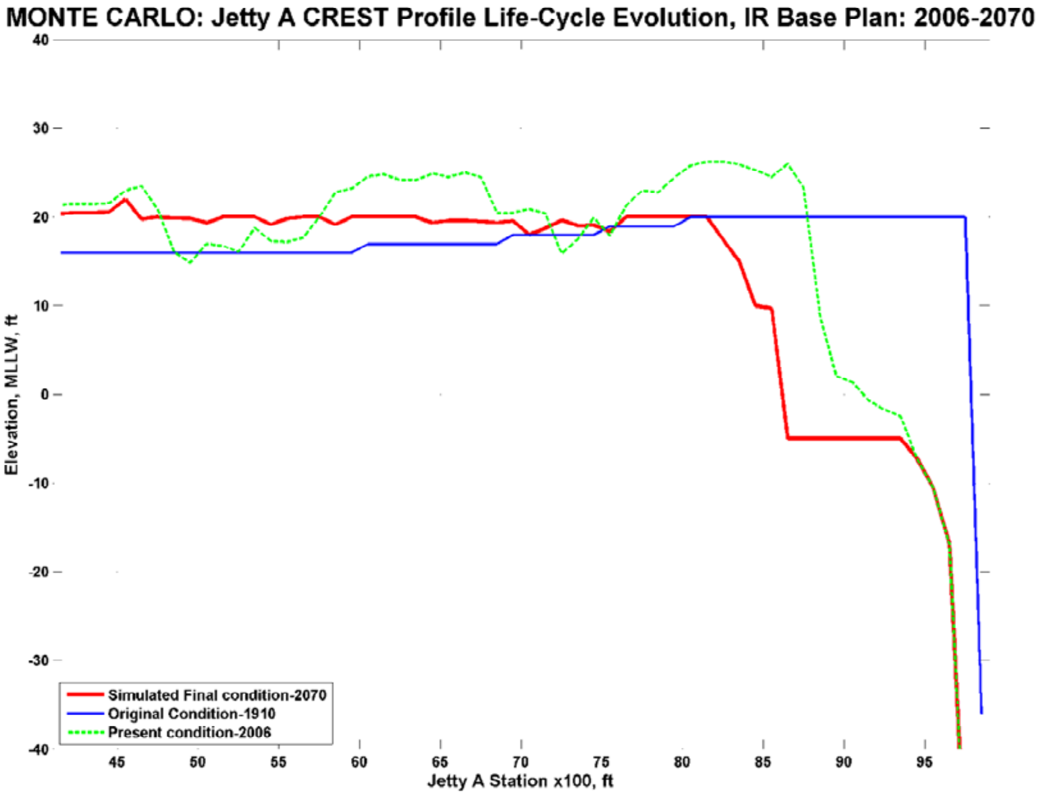
Jetty A, Base Condition,
Cumulated Repair Tonnage, <u>Original</u> Model



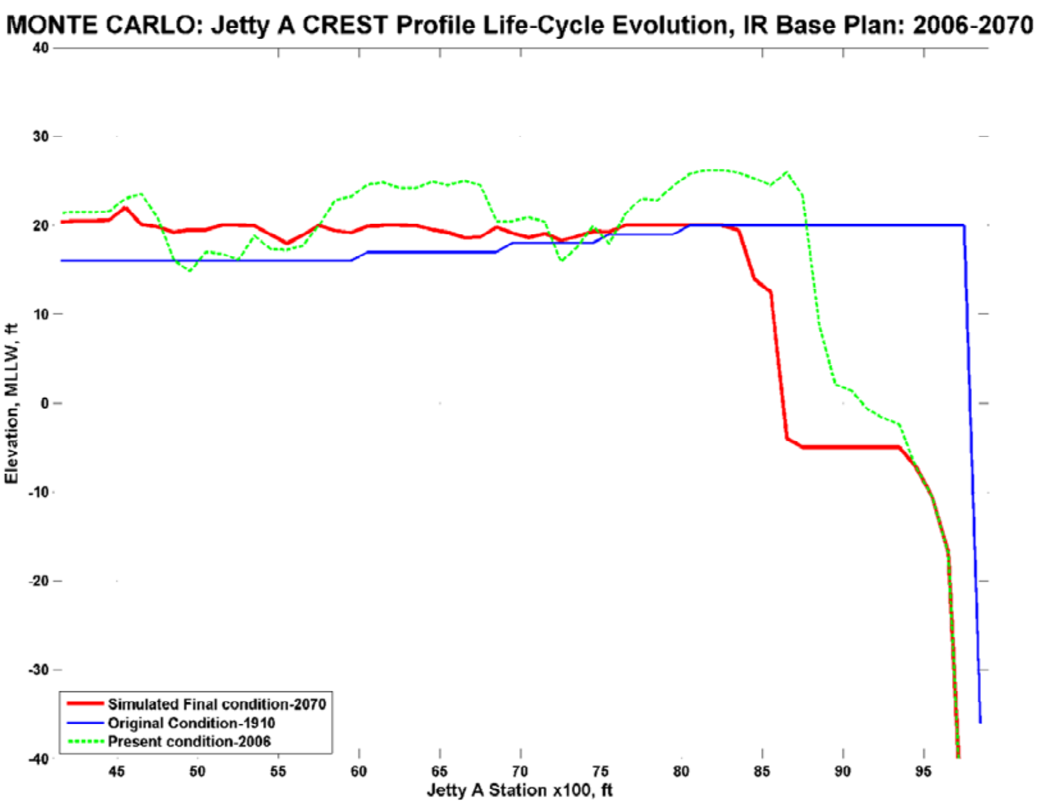
Jetty A, Base Condition,
Cumulated Repair Tonnage, <u>New</u> Model



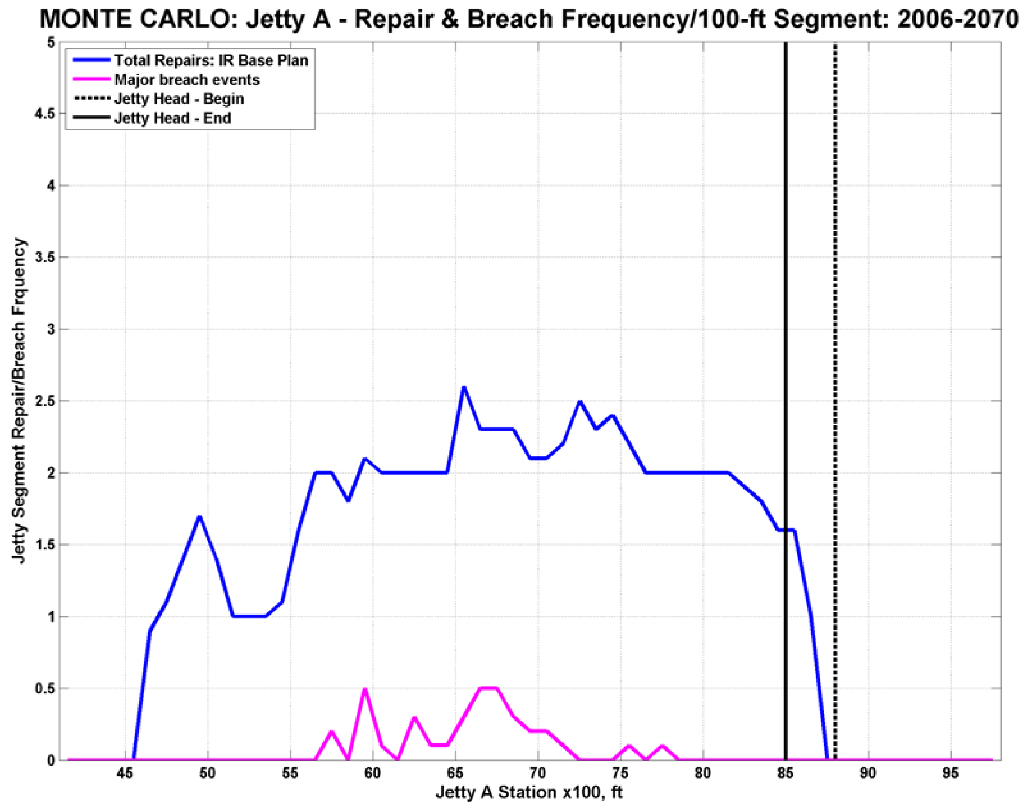
Jetty A, Base Condition,
Crest Elevation, <u>Original</u> Model



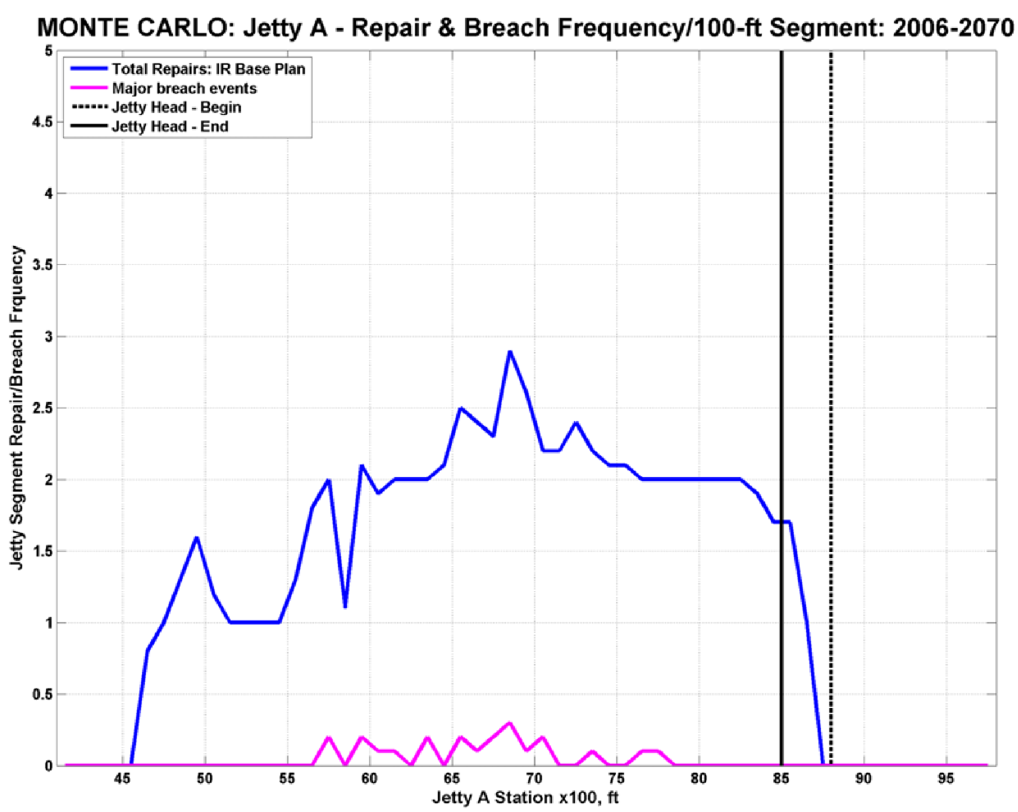
Jetty A, Base Condition,
Crest Elevation, <u>New</u> Model



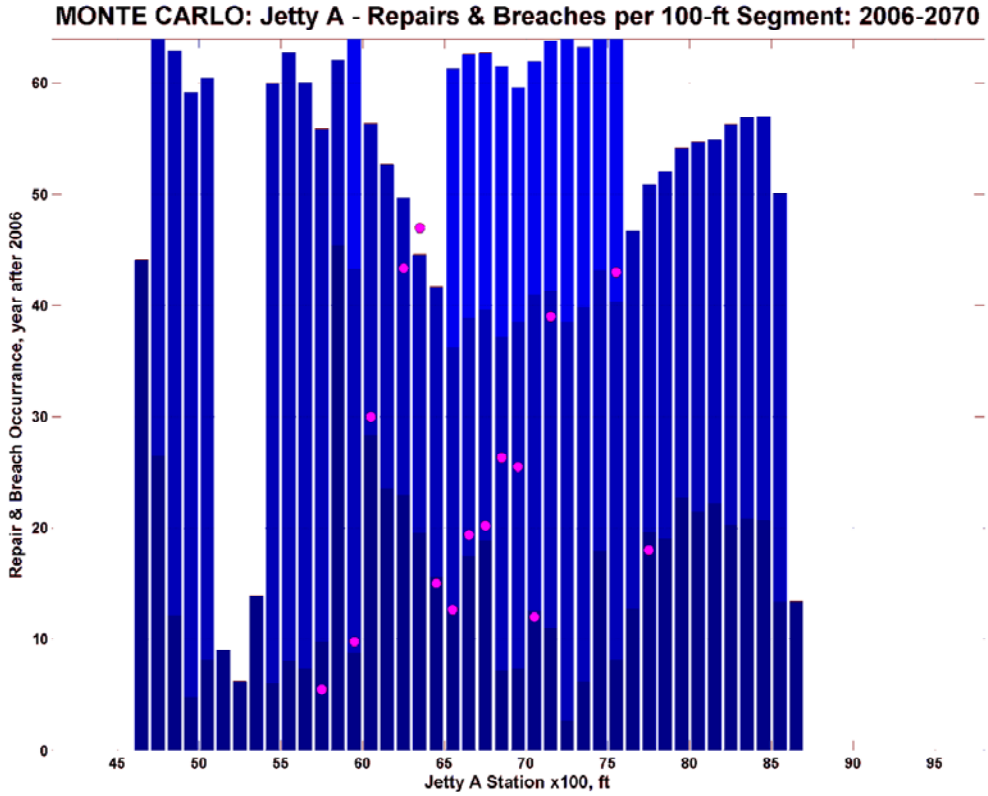
Jetty A, Base Condition,
Repair/Breach Frequency, <u>Original</u> Model



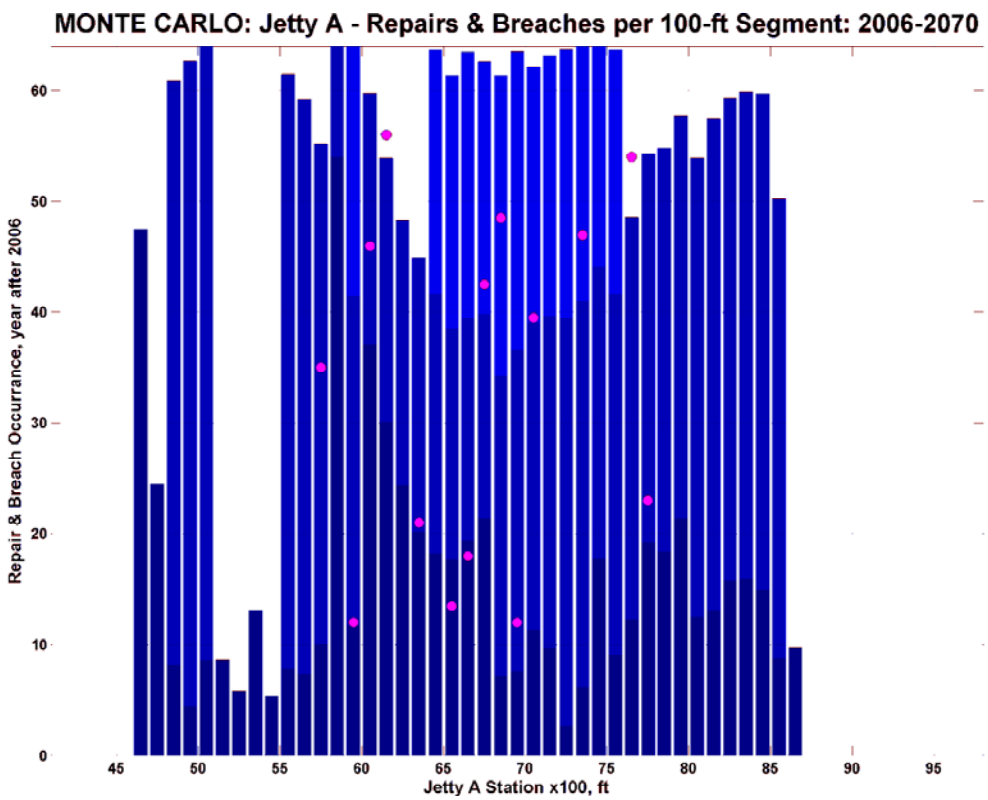
Jetty A, Base Condition,
Repair/Breach Frequency, <u>New</u> Model



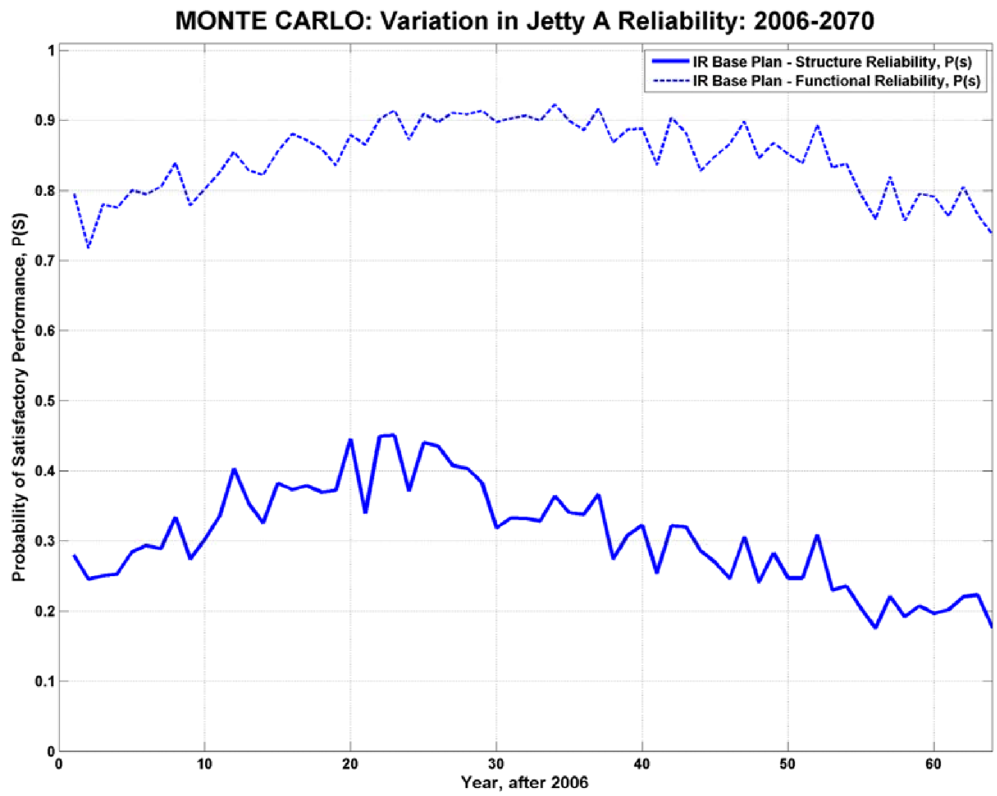
Jetty A, Base Condition,
Repair/Breach, Original Model



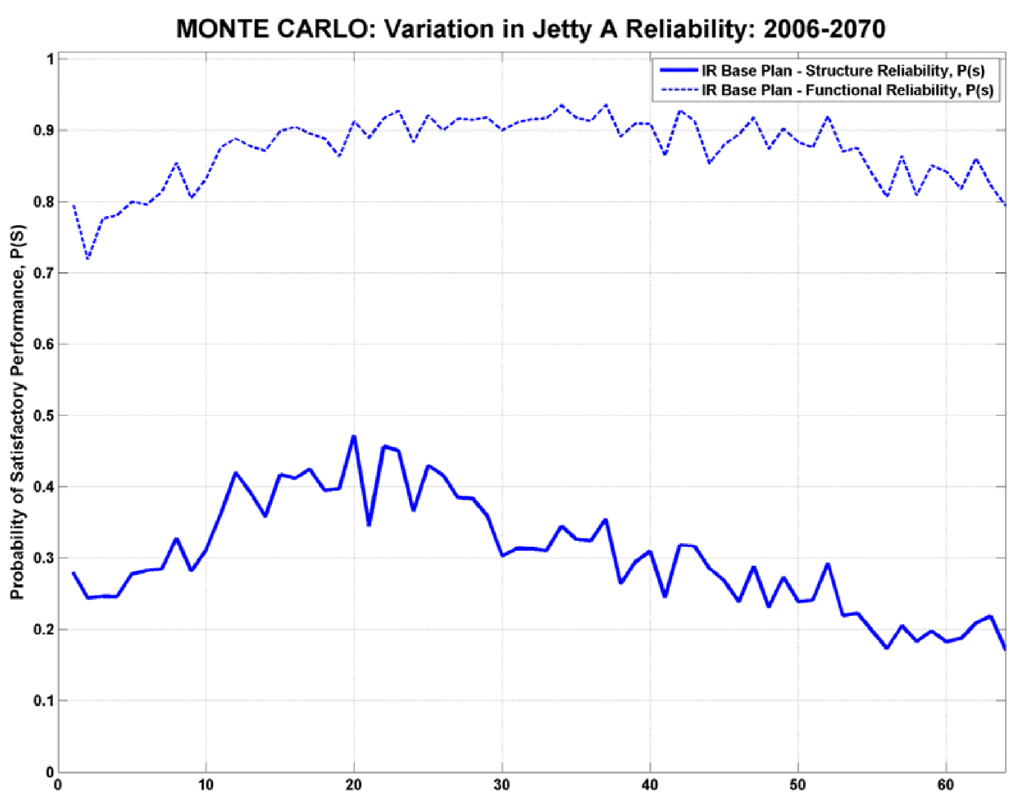
Jetty A, Base Condition,
Repair/Breach, New Model



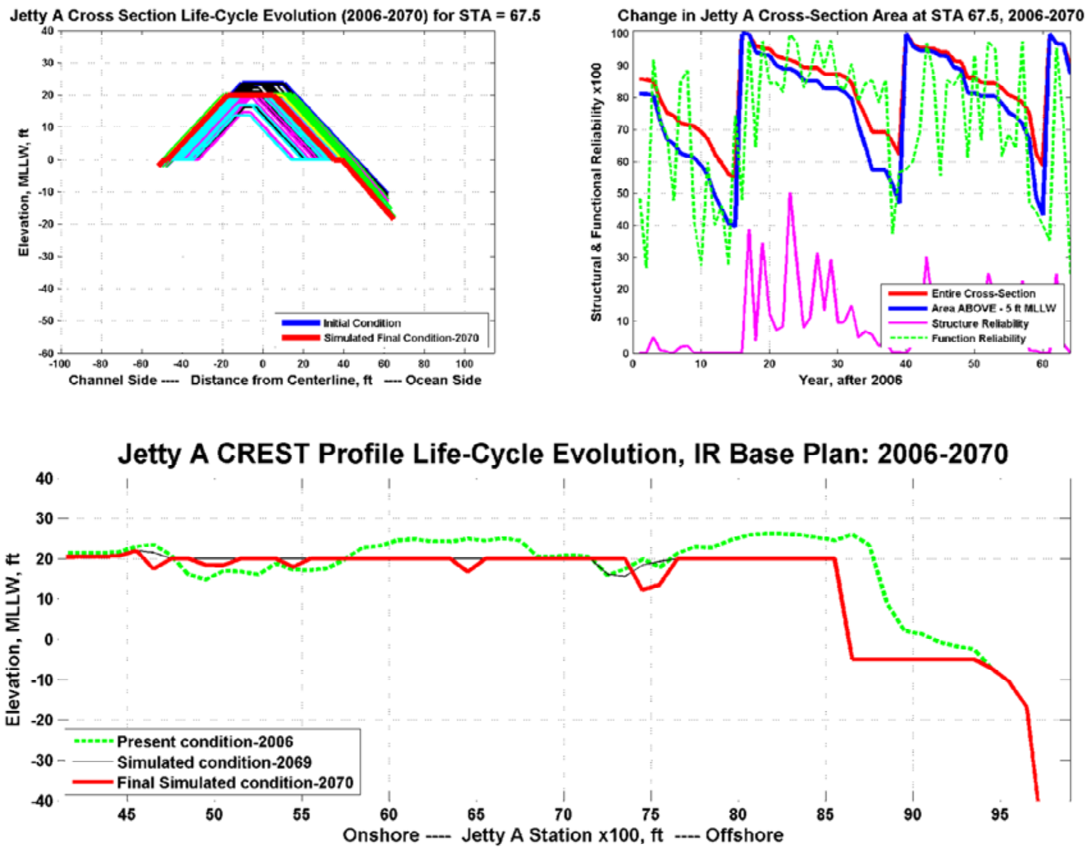
Jetty A, Base Condition,
Reliability, <u>Original</u> Model



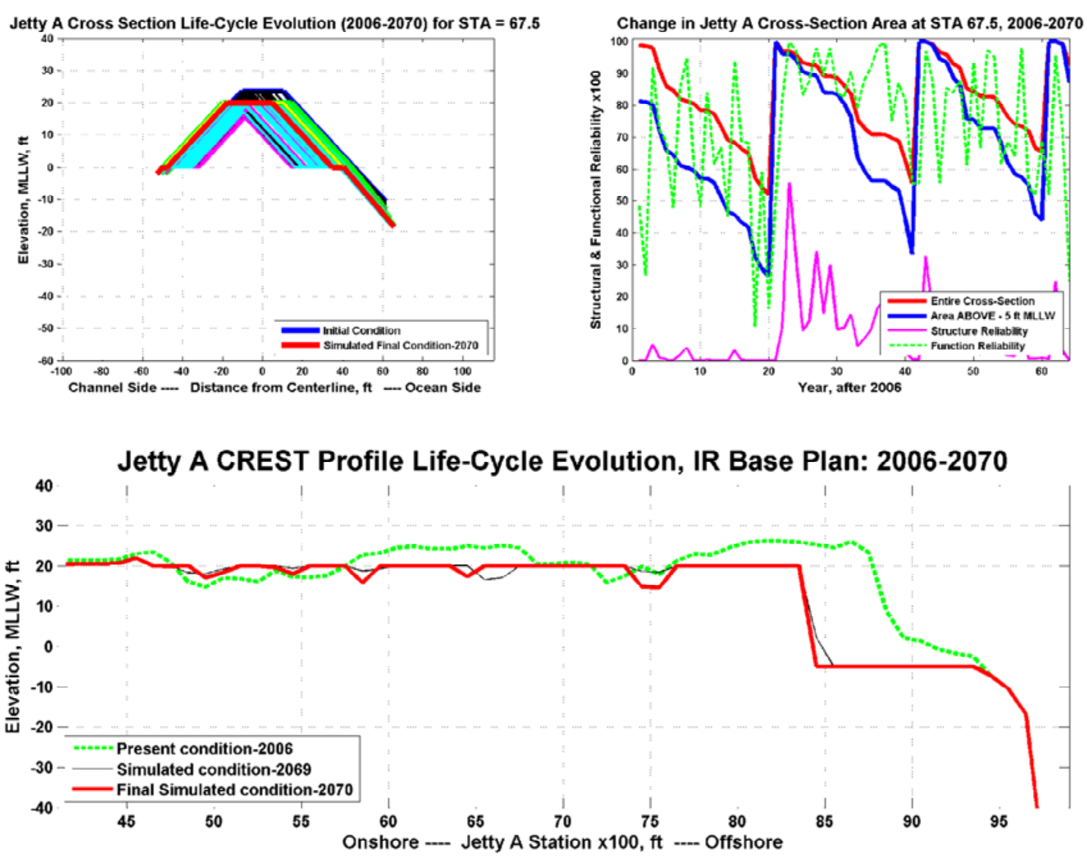
Jetty A, Base Condition,
Reliability, <u>New</u> Model



Jetty A, Base Condition, 1 MC Run, Original Model



Jetty A, Base Condition, 1 MC Run, New Model



MCR Jetty System Major Rehabilitation Evaluation Report

Appendix A4

2010 Mouth of the Columbia River Jetties Annual Inspection Report

US Army Corps
of Engineers
Portland District

JETTY MONITORING PROGRAM

2010 INSPECTION REPORT
MCR Jetties

CENWP-EC-HY
March 2011

CENWP-EC-HY FY10

MEMORANDUM FOR RECORD

SUBJECT: The Mouth of the Columbia River (MCR) jetties: North, South and Jetty 'A' Site Inspection, 13-15 September 2010. Figures *MCR-2010JettyInspection_NJ_1.pdf, MCR-2010JettyInspection_NJ_2.pdf, MCR-2010JettyInspection_SJ_1.pdf, MCR-2010JettyInspection_SJ_22.pdf, MCR-2010JettyInspection_SJ_3.pdf*, and *MCR-2010JettyInspection_JA.pdf* show damage areas noted on aerial photographs, for each jetty, respectively.

1. Introduction. Inspections of all three MCR jetties were made by Richard Gunsolus and Michelle Rhodes, EC-DC, Rod Moritz, and Lynda Charles, EC-HY, from 13 to 15 September 2010. A handheld Garmin 60C GPS was used to record the spatial coordinates of the starting, ending and/or center points of damage areas. Additionally, hip chain measurements were taken to maintain consistency with historic methods.

Jetty 'A' was inspected on 13 September 2010 between 13:00 and 17:30 PDT. The tide was flooding during the inspection, increasing from 4.2' to 7.5' MLLW. The south jetty was inspected on 14 September 2010 between 10:30 and 17:30 PDT. The tide was approaching the bottom of ebb at the 10:30 am (2.7 ft MLLW) and turning to flood tide at 12:30 pm (reaching 7.1 ft MLLW at 17:30). The north jetty was inspected on 15 September 2010 between 10:30 am and 14:00. The tide was ebbing during 10:30 to 13:00 (decreasing from 3.7' to 3.1' MLLW) and flooding for the later part of the north jetty inspection (increasing from 3.1' to 3.7 ft MLLW).

Weather Description during inspection. *On 13 September (Jetty 'A') the weather was clear and sunny; with a light breeze estimated at 5to 10 mph. Wave conditions were flat with little to no wave action. On 14 September (South Jetty) the weather was light fog and high overcast with a mild temperature. The wind speed was low and west waves wave were 1 to 3 ft. On 15 September (North Jetty) the weather was partly cloudy-threatening rain at inspection start and onset of heavy rain at inspection completion. Wind speeds were low and west waves were 2-4 ft, and increasing.*

2. Background

Jetty 'A'

Jetty 'A's primary purpose is to divert (or train) river and tidal currents away from the north jetty. The jetty also serves as a breakwater, stabilizing the West channel and providing shelter from waves for vessels in route to the Ilwaco, WA, boat basin. Original construction of Jetty A was in 1939 from Sta. 40+93.89 to 96+83 using two trestles. The crest width of the jetty varied from 10 ft at the shoreline to 90 ft in the midsection to 30 ft in the offshore reach beyond the dog leg. The first repair was from Sta. 78+00 to Sta. 96+00 in 1945-47; the crest width between these stations was increased to 40 ft during this repair. Five subsequent repairs to the outer section of jetty were performed between the years of 1948-62. The midsection of the jetty which has not been repaired since original construction has received the most damage over the years and has been deteriorating progressively. The entire MCR jetty system is currently being intensely studied under a Major Rehabilitation Study by the Portland District's Engineering and Construction Branch. The study objective is to develop a long term plan for repairing and maintaining the jetties at the MCR.

South Jetty
Original construction of the South Jetty began in 1886 and was completed in 1896. Construction began at Ft. Stevens (Sta. 25+80) and continued west across Trestle Bay and Clatsop Spit to Sta. 250+20. Between 1903-1913, the jetty crest was raised to the high water level between Sta. 210+35 and 250+20. In addition, the jetty was extended from Sta. 250+20 to Sta. 375+52. Repairs have been made to several sections of the jetty since, and are listed below with the dates in parentheses:

- Sta. 175+00 to 257+68.7 (1931-32);
- Sta. 257+68.7 to 305+05 (1933-34);
- Sta. 305+05 to 353+05 (1935-36), including a stone/asphalt terminal from Sta. 340+30 to 344+30;
- Sta. 318+00 to 330+30 (1940-42), including a concrete terminal and stone foundation;
- Sta. 194+00 to 249+00 (1961);
- Sta. 249+00 to 314+05 (1962-65);
- Sta. 194+00 to 249+00 (1982);
- Sta. 223+00 to 245+00 (2006);
- Sta. 258+00 to 285+00 (2007);

North Jetty
Original construction of the North jetty began in 1917 and extended offshore to Sta. 122+00. A seaward dogleg was constructed toward the north, beginning at Sta. 111+80. In 1965, 2,020 feet (Sta. 89+47 to 109+67) of the north jetty was repaired. At this time a 220-foot long resilient jetty head was established. The North Jetty has been inspected every year since 2002. The north jetty underwent an interim repair during the summer/fall of 2005 to repair critical jetty sections between Sta. 55+00 and Sta. 86+00. The reach between Sta. 55+00 to 75+00 received a continuous span of repairs, whereas the reach between 75+00 and 86+00 was repaired in discrete areas only.

The evolution of the North Jetty and surrounding areas has been studied recently as a part of the Regional Sediment Management (RSM) program. One objective of the RSM program is to investigate the effectiveness of dredge disposal at the Shallow Water Site (SWS), located immediately west of the North Jetty head, as well as alternative disposal areas (e.g. near-shore placement on Benson Beach, or south of the south jetty) for supplying sand to the sediment-starved Benson Beach and Clatsop Spits. Additionally, the North Jetty Site (NJS), located channel-side of, and adjacent to, the North Jetty, has been utilized as a disposal site since 1999 to retard the channel-side scour along the North Jetty, in an attempt to prevent further damage to the jetty. The MCR Major

Rehabilitation Study will attempt to utilize all known facts of the region to develop a long term outlook for maintenance and repair of the MCR jetty system.

3. Damage Assessment. Damaged areas are ranked from **minor** (low concern) to **moderate** (needs watching) to **major** concern (imminent failure). Minor areas noted consist of sections that exhibit some minor stone movement or loss, but which does not affect the overall stability of the slope and body of the jetty. Areas noted as moderate damage affect larger regions of stone and have the potential to develop into more imminent areas of concern. Moderately damaged areas typically involve sloughing of slope stone with encroachment on, but no intrusion into, the jetty crest stone. Major damage areas indicate that failure has already occurred and functional impacts are imminent. Major damage areas include those in which the jetty crest stone has been affected (for example, jetty breach or jetty crest stone movement and sloughing as a result of lower slope stone movement that can destabilize rapidly).

4. Historical Observations

Jetty 'A'

As mentioned above, the mid-section of the jetty, which has not been repaired since construction, has received the most damage over the years and is progressively deteriorating. In addition, the jetty head has lost a significant amount of length since original construction.

In 2009, the jetty head was reported to have lost 969 ft since original construction in 1939. Damage to the trunk and root has previously been split into three separate reaches (outer section, midsection, and landward section). The outer section (Sta. 82+00 to the jetty head) was considered to be in moderately good condition in 2004 without any significant damages. The midsection (Sta. 67+00 to 82+00) has been damaged the most heavily. The landward section (Sta.41+00 to 67+00), was noted as having several minor Oceanside scallops in addition to an area of reduced crest elevation in 2004. Beginning in 1995, the shoreline adjacent to the jetty A root has been monitored for continued erosion to the foredune (i.e. scarp).

In 2006, the offshore extent of the jetty head was measured via GPS as Sta. 87+97, or a total loss of 886 ft (within hip-chain accuracy). At the time, the head of Jetty 'A' had not receded since 2004, but the area was still classified as major damage. The importance of the length of Jetty A has to do with the structure's effectiveness for diverting currents away from the north jetty and maintaining the present alignment of the navigation channel.

The midsection of the jetty has experienced the worst damage, as noted in 2006. Specifically, in the reach between Sta. 70+60 to 76+52, armor stone has been displaced resulting in crest elevations 5-10 ft below the design crest elevation. At some of the lowered crest locations, there is visual evidence of tidal flows through the jetty resulting in pools of water forming along the eastern (bayside) side-slope. Although this may be considered an effective breach condition on many jetties, currently the damage does not pose an imminent functional threat because due to the widened footprint in this reach of jetty. The section would require extensively more damage to become hydraulically connected through the jetty. This area should be monitored frequently because the damage has the potential to progress over time and further destabilize the jetty and surrounding areas.

The landward reach of jetty was noted in 2006 as remaining in good condition with only minor scalloped damage areas. The major, moderate and minor damage areas noted in 2006 are listed below:

- *Jetty A head position:* Sta. 87+97 (Major)
- *Midsection (jetty trunk)*: Sta. 74+14 to 76+39, worst area (Sta. 74+80 to 75+40) / Sta. 72+00 to 76+39 / Sta. 70+70 to 71+18 (Major)
- *Midsection (jetty trunk)*: Sta. 78+37 to 78+92 / Sta. 77+68 to 78+05 / Sta. 71+33 to 71+68 / Sta. 68+10 to 69+52 Sta. 55+72 to 56+44 / Sta. 54+67 to 55+30 / Sta. 49+64 to 50+12 (Moderate)
- *Midsection (jetty trunk)*: Sta. 84+94 to 85+56 / Sta. 83+29 to 84+00 / Sta. 79+11 to 79+39 / Sta. 76+67 to 76+95 (Minor)
- *Landward Section*: Sta. 67+20 to 67+40 / Sta. 62+20 to 62+38 / Sta. 56+67 to 57+56 / Sta. 54+00 to 54+20 (Minor)

In 1995, a baseline was established in effort to measure the progression of erosion occurring at the shoreline between jetty A and Cape Disappointment. As of this year many of these baseline points have been destroyed making the year to year comparison of the monitoring difficult. In effort to re-establish a measurement of the erosion, GPS points were recorded in 2005 and 2006 at 30 ft intervals along the top of the scarp edge. In this manner, large changes in horizontal positioning of the shoreline can be easily and quickly compared.

South Jetty

The most recent South Jetty repairs (in 2006 and 2007) focused on repairing the most critically damaged sections of the jetty. At the time, there were other sections that had sustained extensive damage, but were not considered critical (on the verge of breaching). These sustained damages, and others that have formed since, will be addressed in the Major Rehabilitation Study. The South Jetty was last inspected in 2008 in which the following major and moderate damage areas were noted:

- *South jetty head:* Sta. 312+65 (major)
- *South jetty trunk:* Sta. 287+87 to 289+00 / 258+00 to 290+00 (Interim Repairs 07) (major)
- *South jetty root:* Sta. 161+67 to 161+96 / Sta. 163+20 to 163+40 (major)
- *South jetty trunk:* Sta. 303+56 to 304+54 (Moderate)

North Jetty

Jetty sections shoreward of the 2005 interim repair (inshore of Sta 55+00) have not been repaired since original construction. In this region, the jetty side slopes have been damaged and become steepened/unstable. The jetty crest width is very narrow and consists of jumbled stone. It has been referred to as 'knife-like' in reference to the peaked-ness shape of the jetty crest and slope. Inshore of Sta. 55+00, the channel side of the jetty has been damaged by wave action and foundation scour; such that one-quarter to one-half of the jetty cross-section is missing. The beach side of the jetty inshore of Sta. 55 has reduced stability due to poor stone-stone contact and steepened side slope. Reaches of the north jetty offshore of the 2005 repairs (Sta 86+00) have exhibited signs of extensive damage. In 2009, minor, moderate and major damage areas were noted as follows:

- *North jetty head:* Current Sta. 100+40 (Major)
- *North jetty trunk:* Sta. 91+30 to 92+24 / Sta. 87+40 to 88+91 (Major)
- *North jetty root:* In general, areas inshore of Sta. 55+00 are moderately damaged. Specific areas of major damage include (byt a are not limited to) Sta. 53+05 to 55+00 / Sta. 52+23 to 52+55 / Sta. 50+60 to 51+14.
- *North jetty trunk:* Sta. 89+03 to 90+32 / Sta. 89+27 to 89+76 (Moderate)
- *North jetty channel-side trunk:* Sta. 98+74 to 99+28 / Sta. 94+57 to 95+09 / Sta. 92+54 to 93+29 (Minor)
- N*orth jetty ocean-side trunk:* Sta. 97+67 to 97+90 (Minor)

Overall, the channel-side section of the North Jetty has suffered damage resulting from scour at the toe. Continued loss to the north jetty head and the corresponding relation to the shoreline recession north of the jetty (Benson Beach) are of concern and are being monitored within the RSM program.

5. <u>2010 Observations</u>

a. Jetty 'A' Inspection

In 2010 Jetty 'A' remained in various degrees of degradation along the entire length of the jetty. Damaged areas spanned the range from minor to major, with the worst damage being noted at the head and mid-section. The offshore extent of the jetty head was not orthogonal to the jetty axis, but, rather, at an angle. The southeast edge of the jetty head extended further offshore than the southwest edge. The armor stone on all sides of the jetty head are exhibiting signs of damage in the form of sloughing or cascading stone, leaving the much smaller diameter sub-material stones exposed to waves and currents. In-house stationing reconfiguration took place this year which changed the previous readings slightly, including an adjustment to the head reading. No additional head loss was noted from the 2009 inspection with the head reading standing at Sta. 87+17 which is 966' loss from the original construction length.

The mid-section of the jetty trunk has multiple locations of lower crest elevations. Some of these locations are most likely under water at the highest tides and storm surges. The width of the jetty footprint is wide through this mid-section, which is probably preventing a complete breach of the jetty.

Along the ocean-side of the landward section, the jetty is experiencing many moderate and minor scallops due to slope sloughing and stone cascading. A large amount of wood debris is stacked along the shoreline area of the jetty, where the jetty crest elevation appears to be lower than offshore jetty crest elevations. The specific minor, moderate and major damage areas along the length of the jetty observed during the 2010 inspection are noted below:

Minor damage

a. Ocean-side sloughed slope stone adjacent to stacked slope stone; Submaterial visible beneath the armor stone: Sta. 81+97 to 82+32.
b. Narrow, ocean-side slot forming from the toe to the crest: Sta. 79+22 to 79+48.
c. Ocean-side area of stone loss and lower slope shifting: 66+75 to 66+94.
d. Ocean-side scallop with toe stone loss and slope shifting extending to edge of crest: 65+73 to 66+44.
e. Ocean-side scallop extending to edge of crest: 63+57 to 63+99.
f. Crest elevation lowers by 1-2 stone diameters: There is a large amount of wood debris stacked along this section: Shoreline to 50+31.

Moderate damage

a. River-side scallops forming from the erosion of, and movement of, toe stone. Steep slopes above; sub-material is exposed where armor stone has cascaded: 84+00 to 84+91.
b. Large slope stone has cascaded down to toe; steep slopes and perched large stone above: 83+06 to 83+66.
c. Ocean-side location of a length of settled slope stone extending 5’ into the crest stone; lower elevations throughout the damage area: 77+75 to 79+07.
d. Narrow crest width and up to 1 stone low: 69+66 to 69+81.
e. Narrow crest width (2 stone diameters wide). Ocean-side mild slope due to stone slumping. Jumbled and settled crest stone: 67+66 to 68+92.
f. Narrow slot forming a scallop; low stone perched over moved toe stone. Slope stone movement is affecting the crest stone: 66+99 to 67+51.
g. Ocean-side sloughing and cascading of mid-slope stones. One section has formed a scallop with vertical faces at the upper slope stone and crest stone: 61+31 to 63+22.
h. Several ocean-side scallops with damage encroaching crest by 1 stone width: 53+83 to 58+36.
i. Crest breach with jumbled crest stone. New crest elevation is 1 to 2stones low and damage to both side slopes: 54+63 to 55+43.
j. Ocean-side scallop forming, encroaching into jetty crest stone: 50+64 to 53+39.

Major damage

a. Jetty head becomes increasingly narrow: 87+00 to 87+80.
b. Ocean-side scallops forming: 86+00 to 86+80 and 85+16 to 85+56.
c. River-side section of nearly vertical side slopes. Slope stones have cascaded down exposing sub-material beneath: 85+56 to 86+31.
d. River-side sloughed toe stone and side slope leaving steep, perched stone above: 85+00 to 85+40.
e. Ocean-side scallop between76+77 and 77+04.
f. Area of jetty breaching between Sta. 70+60 and 76+52. Significant narrow crest widths and lower crest elevations throughout. Complete jetty breach between Sta. 71+96 and 73+13 with only a few stones remaining above high tide.
g. Major damage is observed offshore of the existing 2010 head location. This represents a total of 966' of head loss from the original constructed length.

b. South Jetty Inspection

In 2010 the South Jetty was inspected from shoreline (Sta. 189+00) to the existing jetty head (~Sta 312). Two areas recently repaired (2006 and 2007), and some minor-moderate damage has appeared within the repaired areas. Areas that were not repaired recently are experiencing increased (continual) deterioration. The range of damage observed was from minor to major. These areas should continue to be monitored frequently to observe if any active change is threatening the function of the jetty. The specific minor, moderate and major damage areas along the length of the jetty observed during the 2010 inspection are noted below. Areas shown in **bold** designate damage that has been realized since the last jetty inspection in 2009:

Minor damage

a. Ocean-side location that is potentially forming a scallop; mild slope with some cascaded stones, some stones have been knocked back up onto the crest: 299+30 to 300+50.
b. Ocean-side narrower crest width possibly due to slope sloughing; there is a mild slope between wider crests and some perched stones adjacent to mild slope: 294+00 to **299+30**.
c. Ocean-side low to mid-slope slough leaving upper stone perched: 284+60 to **286+00**.
d. Ocean side armor stone popping off slope, coming to rest along lower slope (below water level); general steepening of slope due to armor displacement along lower slope: 282-30 to 284+60.
e. Ocean-side over-steepened slopes and perched stones: 279+00 to **280+00.**
f. Ocean-side 2-3 large perched stones (including one green colored stone from the 2007 repair stone); toe stone movement: **279+00** to **280+00.**
g. Ocean-side slope; armor along lower slope missing leaving oversteepened slope ready for washout to crest: St 271+80 to

275+80

h. Ocean-side section of lower stone sloughing; some toe stone holes: 269+20 to 269+60.
i. Ocean-side section of low and toe stone movement (including some green-colored stone); perched and steeper slopes above: **264+00** to 267+70.
j. Ocean-side large green-colored stone knocked nearly vertical to the crest stone: 258+60.
k. Ocean-side slope slough leaving some adjacent perched stone; mild low slope as stones bunch at toe: 257+80 to 258+20.
l. Channel-side slope slough: 257+50 to 257+80.
m. Ocean-side steep side slope and perched stone; some low slope movement: 255+30 to 255+80.
n. **Ocean side damage (chute) extending from lower slope to crest: 246**.
o. **Ocean-side damage to slope, armor zone blow leaving upper slope unstable, susceptible to slope failure extending to crest: Sta 39+30 235+70, and 233.**
p. **Ocean-side damage to side slope extending from lower slope to crest, armor rolling off side slope: 223- 226.**
q. Ocean-side 'slot' scallop: 216+80 to 217+20.
r. Ocean-side scallop forming affecting slope up to crest stone: 205+60 to 206+00.
s. Ocean-side toe stone holes with steep slopes above; some adjacent slope slumping: 203+50 to 203+90.
t. Ocean-side toe stone hole: 201+80.
u. Low crest elevation possibly from loss of haul road material. In addition, ocean-side slough of slope stone: 193+30 to 193+70.

Moderate damage

a. Ocean-side scallop affecting side-slope stone: 309+20 to 309+80.
b. Ocean-side narrowing of crest width and several scallops in a row: 306+30 to 306+80; 305+70 to 306+10; 304+80 to 305+30.
c. Ocean-side mild slope and narrow, jumbled crest: 304+30 to 304+70.
d. Lower crest elevation (by 1-2 stone diameters); wave overtopping has potentially knocked stones towards channel-side; potential to breach in the future: 303+90 to 304+30.
e. Ocean-side scallop encroaching into crest stone: 302+90 to 303+90.
f. Ocean-side scallop encroaching into crest stone: **291+00** to 292+80.
g. Ocean-side section of low stone slump (including some new repair green-colored stone); upper slope stone is perched, some precariously; upper slopes are steep: 281+30 to 282+30.
h. Ocean-side slope slump with some perched stone and steeper slopes: 280+00 to 280+60.
i. **Ocean-side significant damage along lower slope affecting upper slope areas. Large scallops though most of slope; will affect crest:**

275+80 to 279.

j. Ocean-side scallop with steeper slopes and settlement of low slope stone: 218+00 to 218+50.
k. Ocean-side long section of sloughing slope stone, narrow crest and perched stone: 214+60 to 216+30.
l. Ocean-side scallop encroaching into crest stone; mild slope from stone settlement: 213+80 to 214+40.
m. Ocean-side scallop encroaching into crest stone: 213+20 to 213+60.
n. Lower crest elevation (10-15') from loss of haul road material ocean-side sloughing of slope stone, general blow-out of armor stone along base of active wave slope, damage extending to crest: 192+60. In 2008, this area was noted as "minor damage"
o. Lower sections of crest stone (2'-4' lower than surrounding crest stone), general blow-out of armor stone along base of active wave slope, damage extending to crest, local crest washouts: 191+00 to 191+40; 189+00 to 189+40. In 2008, this area was noted as "minor damage"
p. Sand erosion from backside of jetty. At higher water levels, wave action overtops the jetty and water passes through the jetty to the backside and erodes from the sand dune: 160+00 to 164+60.

Major damage

a. Crest stone is narrow (2-3 stones wide): 311+00 to 313+00.
b. Toe stones are jumbled on both ocean- and channel-side: 311+00 to 313+00.
c. Ocean-side steeper slopes: 311+00 to 313+00.
d. Several dislodged crest and upper slope stone: 311+00 to 313+00.
e. Large ocean-side scallop encroaching halfway into crest stone: 310+00 to 311+00.
f. Ocean-side scallop immediately inshore of 2006 repair area, encroaching halfway into crest stone: 222+40 to 222+90.
g. Ocean-side scallop encroaching halfway into crest stone; steep slopes and perched stone with some cascading stone down-slope. Crest is 10' wide at the smallest width; there is some associated crest stone settlement: 221+00 to 222+40.
h. Ocean-side scallop encroaching halfway into crest stone; steep slopes and perched stone with some cascading stone down-slope. Crest is 15' wide at smallest width; there is some associated crest stone settlement and some channel-side stone cascading that has occurred: 218+70 to 219+80.
i. Two locations of ocean-side scallops encroaching halfway into crest stone; steep upper slope, mile lower slope; some associated channel;-side slumping: 212+20 to 213+00 and 210+90 to 211+60.
q. Major damage is observed offshore of the existing 2010 head location. This represents a total of 3038' of head loss from the 1942 head repair.

c. North Jetty Inspection

In 2010 the North jetty was inspected Sta 60+00 to the jetty head. During 2010 inspection, access to the north jetty was limited due to the WALDR dredged material pump ashore operation. There were some isolated areas of damage noted along the western-most area of the 2005 repairs (Sta 73, 82, & 85). In general, the area offshore of the 2005 repair area is in a severe state of disrepair. The deterioration is accelerating. The crest is narrow and jumbled; the peak of the crest is not coincident with the jetty axis, but, rather, varies location along the jetty axis. There are several areas of lower crest elevation than surrounding crest elevations.

In-shore of Sta 81+00, the 2005 repairs are performing very well. The repair area is in good condition with only a small number of minor damaged areas observed. The length of jetty inshore of the 2005 repair area has never been repaired and continues to show signs of deterioration. The crest width is narrow and jumbled. The channel-side slope is mild. The land-side slope is steep. Water freely passes through this section of the jetty to a backside embayment, which has been created from the erosion of the backside sand. The specific minor, moderate and major damage areas along the length of the jetty observed during the 2010 inspection are noted below. Areas shown in bold designate damage that has realized since the last jetty inspection in 2009:

Minor damage

a. Ocean-side steep upper slopes and mile low slopes: 84+50 to 85+20.
b. Ocean-side chute (stone missing along slot from water line to crest): 82+00 to 82+50
c. Missing toe stone channel-side: 81+60.
d. Ocean-side jumbled side slope; some cascading slope stone and non-interlocking stone: 72+50 to 73+30.

Moderate damage

a. Ocean-side lower crest elevation from side-slope sloughing. Channel-side narrower crest width due to slumping side slope, characterized by a mild low slope and steep upper slope at the crest stone. Channel-side sloughing slope, cascading crest stone, steep upper slope and mild lower slope: 92+40 to 96+30.
b. Jetty is in a varied state of deterioration resulting from no repair since original construction: 10+00 (shoreline) to 56+00.

Major damage

a. Jetty crest width is narrow with steep surrounding upper slopes to mild low slopes; the toe is wider at the base from cascading or moving toe stone: 98+00 to **99+74**
b. Large ocean-side scallop with more encroachment into the jetty stone towards the offshore side than the onshore side; nearly vertical faces at

the upper slope; toe stone has moved away from the jetty creating a low shelf of stone: 96+00 to 98+00.

c. Lower crest elevation (6'-8') than surrounding crest elevations with intermittent large armor stone left perched or sliding. Low slope has slid out from toe: 91+40 to 92+40.
d. Very narrow and meandering crest peak (1 stone diameter wide). Both sides' exhibit signs of slope sloughing, some perched stone near the crest; many smaller stone comprise the remaining stone near crest (1'-2' and 3'-5'): 88+20 to 91+40.
e. Lower crest elevation by **10'** with slope sloughing on both sides: 87+60 to 88+20.
f. Very narrow crest width (1 stone diameter) with steep slopes on both sides: 86+70 to 87+60.
g. Major damage is observed offshore of the existing 2010 head location. This represents a total of 993' of head loss from the 1965 head rehabilitation.

6. Conclusions. The jetty system at MCR is subject to annual stormy weather conditions and large wave activity. The entrance to the Columbia River is also subject to large tidal currents superposed on large river currents. The combination of all these factors makes for a challenging environment in which to sustain protective structures that can maintain stability through strong climatic events.

Both the North and South Jetties have undergone repairs along specific reaches within the last 3 years. Recently repaired areas of both jetties are already showing signs of minor to moderate damage, at isolated locations. The 2005 North Jetty repair and the 2007 South Jetty repair are exhibiting signs of minor-moderate damage in 2010. Areas of each jetty that have not undergone recent repair are experience continued deterioration.

The South Jetty, although suffering no additional loss in length from 2009, has many locations of varying degrees of damage that have formed since 2009. Other damage areas are expanding in along and through the jetty cross-section. Some of these damage areas encroach well into the jetty crest, leaving as little as a 10' wide crest before a breach will occur. The nominal crest width should be 30 ft. In addition, some of these same damage areas are exhibiting crest lowering and channel-side damages (due to wave overtopping and re-distribution of armor stone). This type of damage is occurring both offshore and inshore of the recent repair areas. The area of the jetty inshore of Sta. 182+00 consists of a narrow crest width and more jumbled stone than what is visible offshore of this point. This area is typically within the breaking wave region of the surf zone and exposed to the energy breaking waves frequently. Near the beach between Sta. 160+00 and 164+00, over topping waves and storm surge has eroded sediment to the point that the water passes freely through the jetty stone at higher water levels, allowing access to the backside sand dunes, where more sand is eroded by the water. This location has been monitored for several years, and should continue to be monitored closely for damage advancement of the erosion line. A foredune that intersects the south jetty root near Sta

155+00 serves to prevent overland surge from the ocean that would otherwise lead to breaching of Clatsop Spit between Trestle Bay (estuary) and the ocean. The south jetty foredune is currently in a threatened condition; more than 2/3's of the foredune has been eroded and the dunes' crest elevation has been reduced from +40 ft MLLW to +25. The progressive erosion of the foredune is being driven by a receding foreshore morphology, with storm waves and surge eroding the face along the ocean side toe. Abatement and remediation of the erosion along the south jetty foredune should be undertaken as soon as practicable.

The North Jetty sections offshore of the 2005 repair area appear to be in a severe state of disrepair. Much of this region consists of very narrow crest widths, with a meandering crest peak. Many locations have lower crest elevations than surrounding cross-sections. The narrow crest is fronted often by a low shelf of toe stone from sloughed or cascaded slope stone. Steep upper slopes leave many stones perched, if they have not cascaded down-slope already. The wave heights increase tremendously immediately offshore of the jetty head, as the submerged relic jetty stone causes abrupt changes in water depth. Waves frequently break on the jetty head stone and, when waves approach from the north, the ocean-side of the jetty undergoes significant wave attack.

The shortening of the jetty is believed to be directly responsible for the shoreline recession immediately north of the jetty (Benson Beach). For several years, dredge disposal has occurred in the Shallow Water Site (SWS) which extends offshore from the western tip of the North Jetty. Sediment is transported north from the SWS and transports or deposits naturally along the near-shore region. This process supplies sediment to the spit in an attempt to stabilize the beach and cause sand to accrete. A breach through the North Jetty trunk would potentially destabilize the jetty rapidly as well as the adjacent shoreline. Sand would be transported into the navigation channel causing additional shoreline recession and navigation hazards in an already dangerous navigation channel. This jetty should be monitored closely, as well, for further destabilizing damage.

Jetty 'A', though still performing well according to its purpose, is exhibiting signs of severe damage along its length. The head continues to recede, losing approximately 80 additional feet since the 2007 inspection. Various scallops are forming on both sides of the head, with the smaller, sub-material stone exposed in these areas. There was only one layer of armor stone placed when this section was constructed or repaired. Once the armor stone is removed, the sub-material is not interlocked sufficiently to prevent further erosion.

The mid-section of the jetty suffers from a narrow crest of jumbled stone and lower crest elevations. Several locations exhibit signs of jetty crest breaching to various degrees. In one location, the breach is clear down to the layer of sand. The stone remaining in this breach is low in elevation, potentially underwater during extreme high water level events. During the inspection, the water level was approximately 5.7' MLLW and was approximately 2.0' below the top of stone through the breach. If this continues to grow, or any of the other breaches continue to deteriorate, flow may be allowed to pass through the jetty, further destabilizing the jetty and surrounding regions (e.g. the Ilwaco, WA channel that it serves to protect). If further breaches are allowed to form or deteriorate, the jetty will not be effective in re-directing the river flow towards the south jetty. The result of this would be potential destabilization of the North Jetty, as the river current will be allowed to scour the adjacent toe sediment.

The ongoing MCR Major Rehabilitation Study will attempt to look at all consequences of various repair strategies. The objective is to produce the most holistic, cost-effective, long-term maintenance and repair plan for the MCR jetty system.

MCR Jetty System Major Rehabilitation Evaluation Report

Appendix A5

Historical MCR Morphology Change

Appendix A5

Bathymetry Surfaces

This appendix contains thirteen bathymetric surfaces created from bathymetry and shoreline data sets. Bathymetric surfaces were created using a TIN model that incorporated high-water shoreline positions as landward boundaries for bathymetry. Three-dimensional perspectives also are provided for each surface.

Source: Regional Sediment Transport Patterns Relative to Engineering Activities at the Mouth of the Columbia River, Washington/Oregon, 2006.

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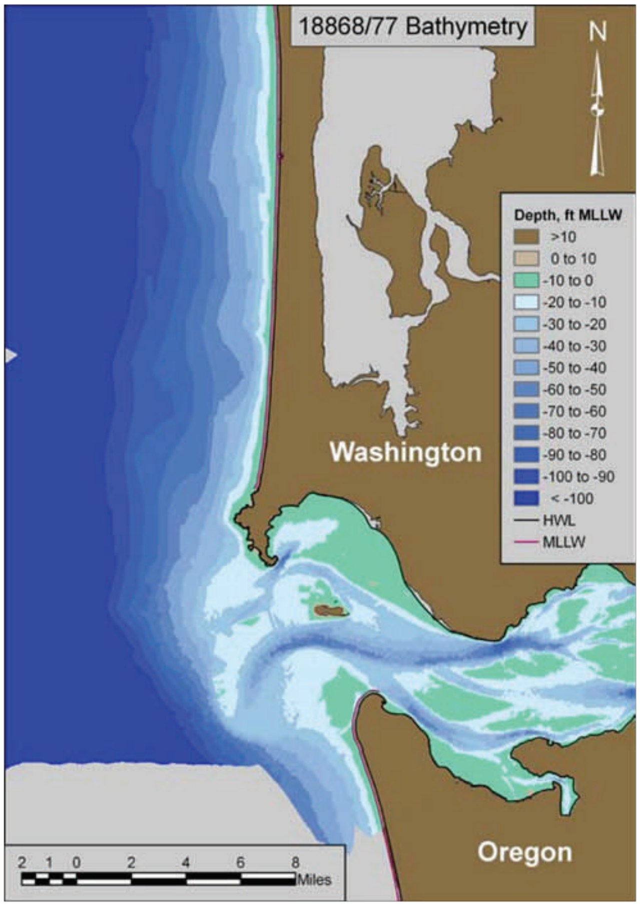
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-90 to -80
-100 to -90
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MLLW
Washington
Oregon
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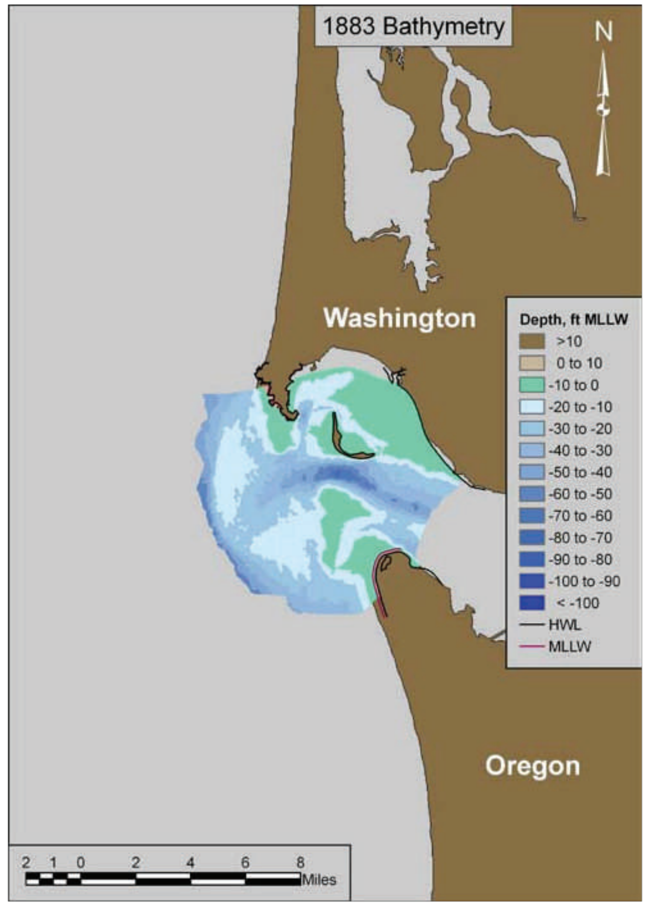
Miles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-60 to -50
-70 to -60
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-90 to -80
-100 to -90
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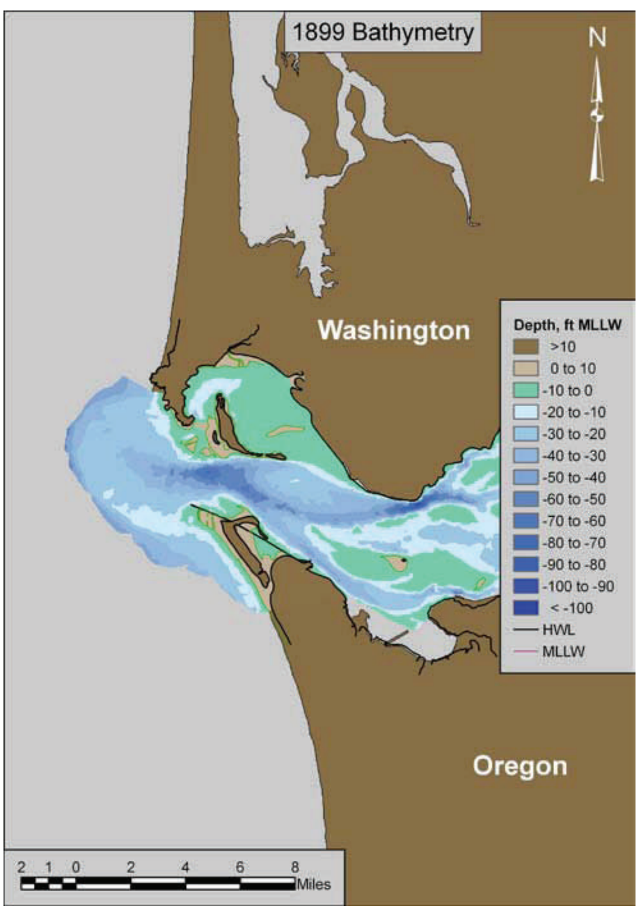
HWL
MLLW
Oregon
2 1 0 2 4 6 8
Miles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-60 to -50
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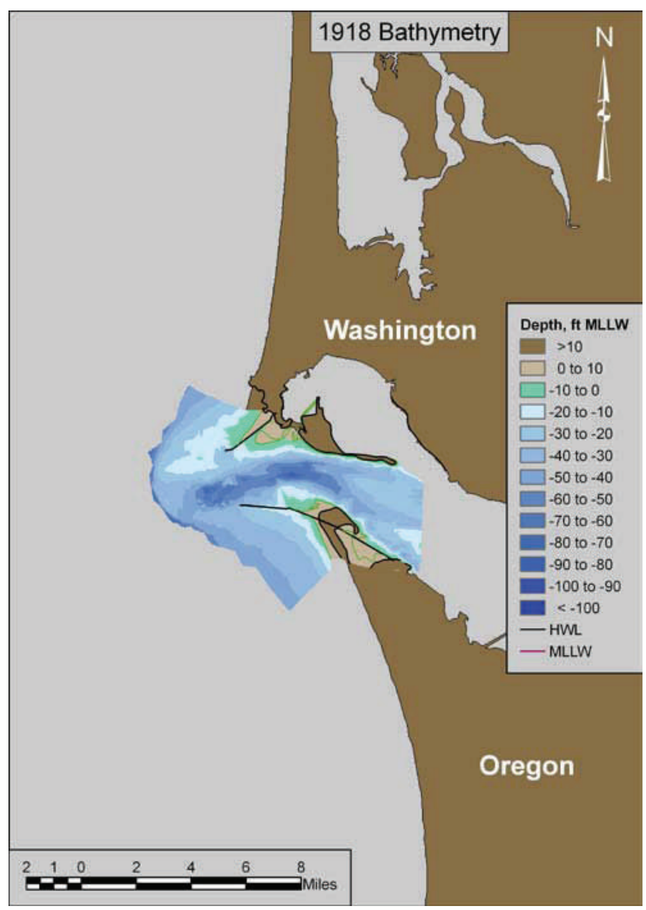
HWL
MLLW
Oregon
2 1 0 2 4 6 8
Miles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Depth, ft MLLW
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-60 to -50
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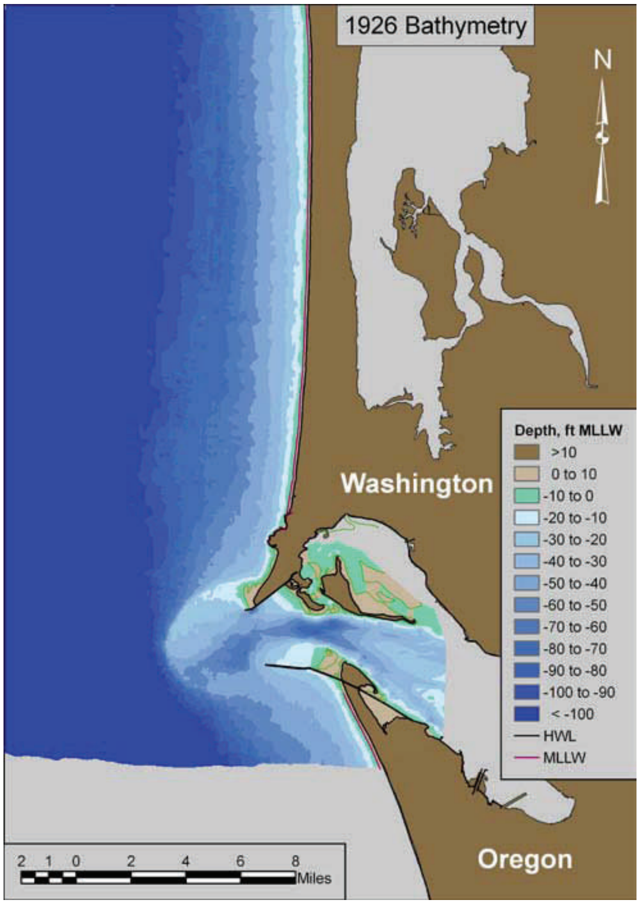
HWL
MLLW
Oregon
2 1 0 2 4 6 8
Miles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Oregon
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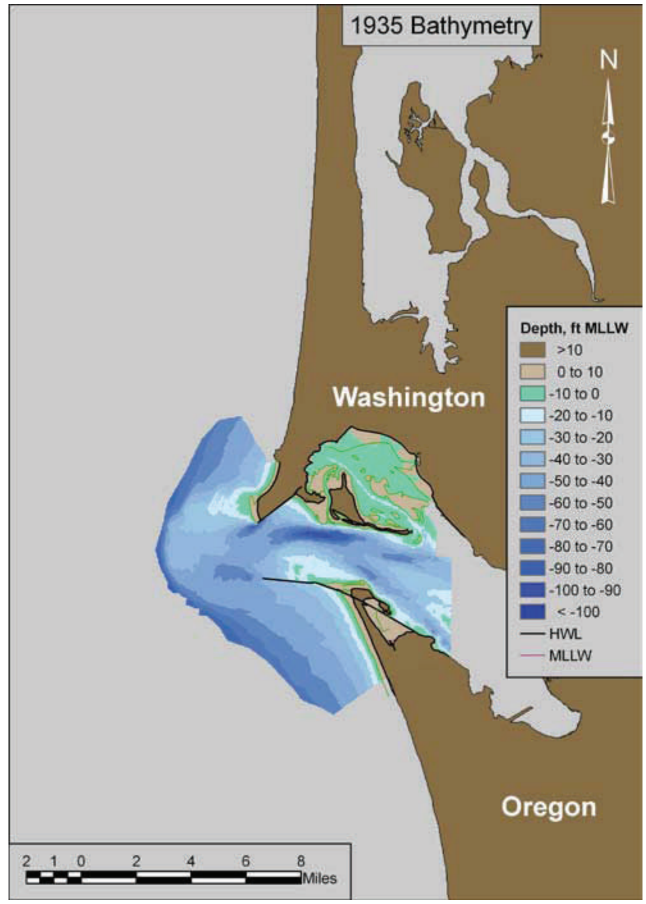
2 1 0 2 4 6 8
Miles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Washington
Oregon
Depth, ft MLLW
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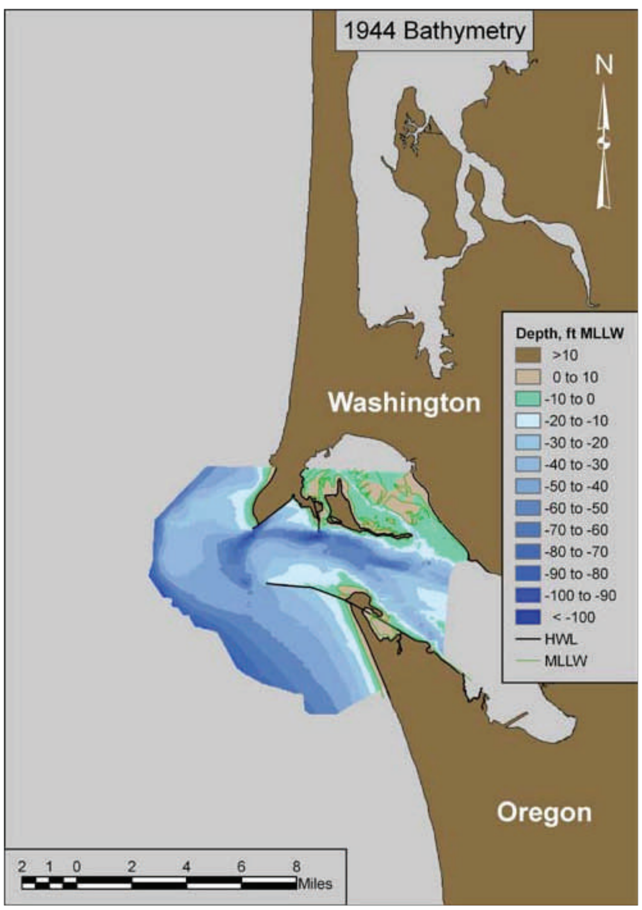
2 1 0 2 4 6 8
Miles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Washington
Oregon
Depth, ft MLLW
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-20 to -10
-30 to -20
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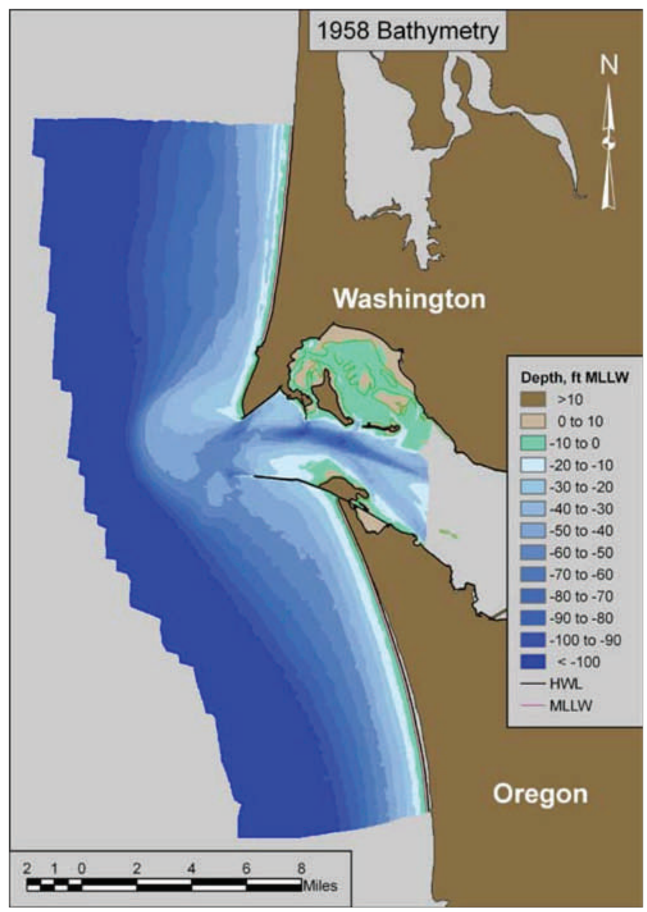
2 1 0 2 4 6 8
Miles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Washington
Oregon
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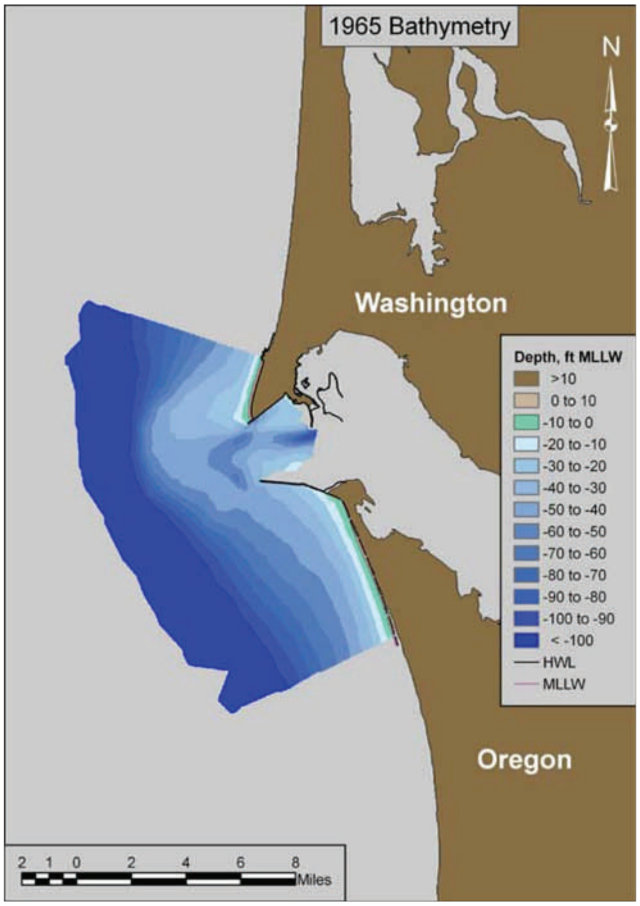
2 1 0 2 4 6 8
Miles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Washington
Oregon
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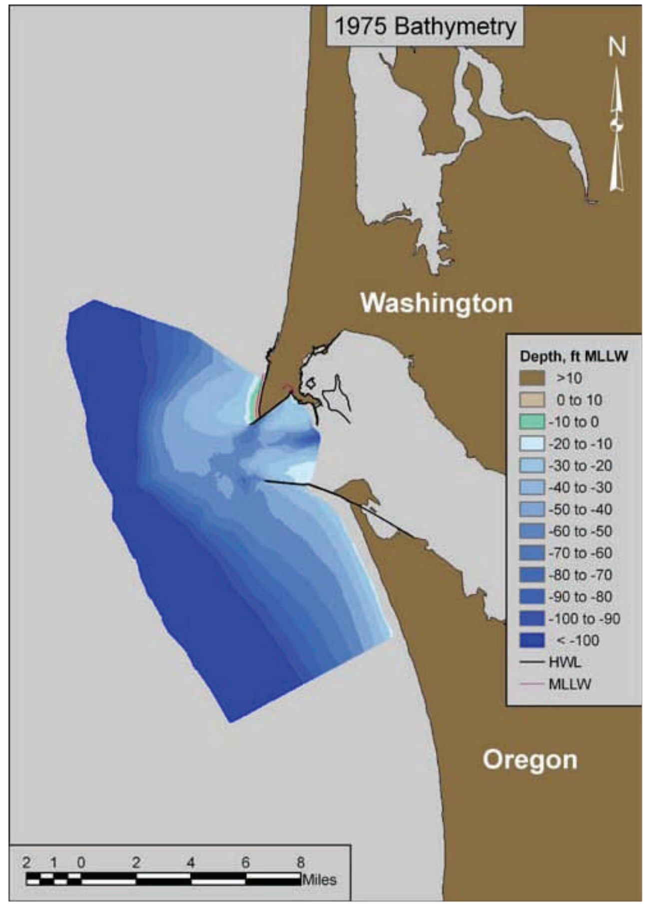
HWL
MLLW
2 1 0 2 4 6 8
Miles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N
Washington
Oregon
Depth, ft MLLW
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0 to 10
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-20 to -10
-30 to -20
-40 to -30
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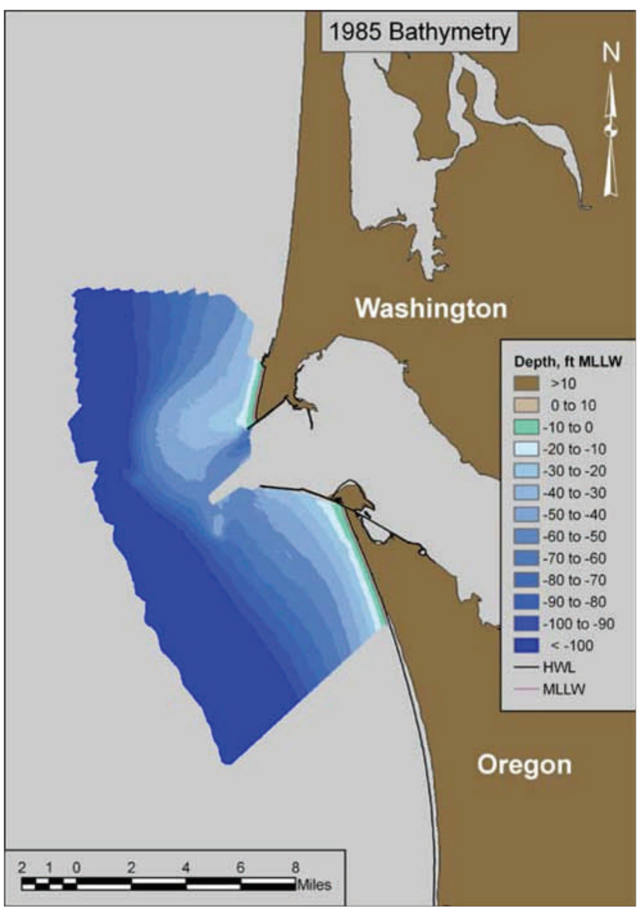
2 1 0 2 4 6 8
Miles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Washington
Oregon
Depth, ft MLLW
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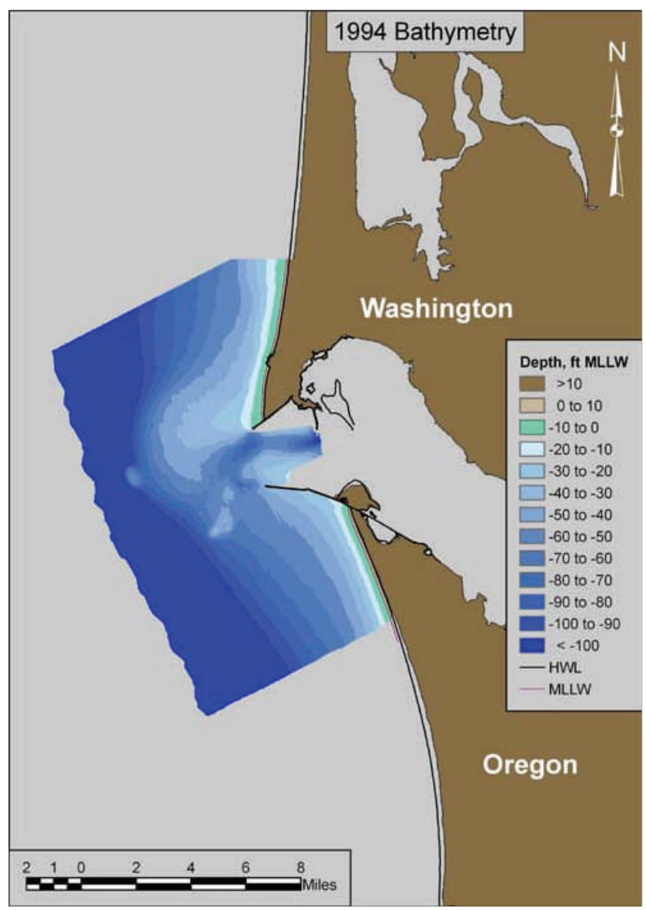
2 1 0 2 4 6 8
Miles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N
Washington
Oregon
Depth, ft MLLW
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-30 to -20
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-60 to -50
-70 to -60
-80 to -70
-90 to -80
-100 to -90
< -100
HWL
MLLW
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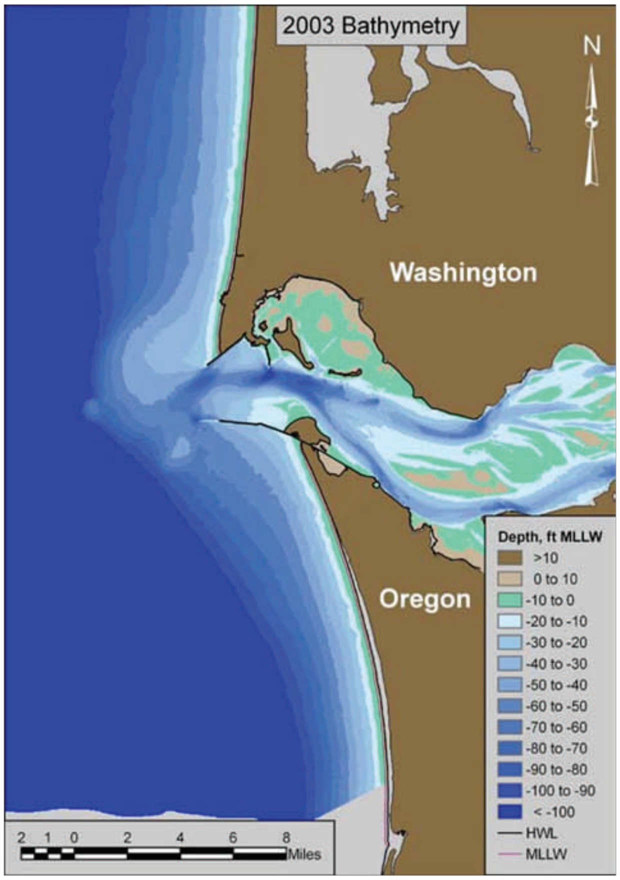
Miles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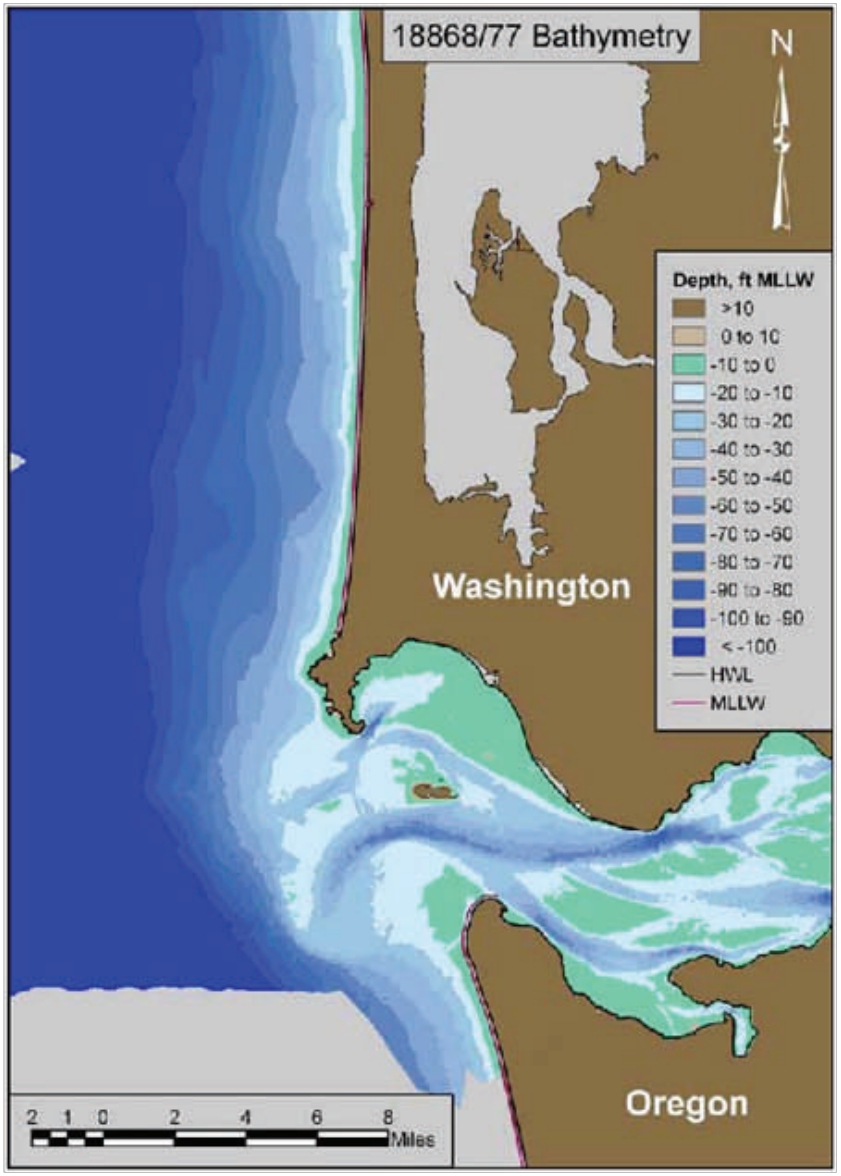
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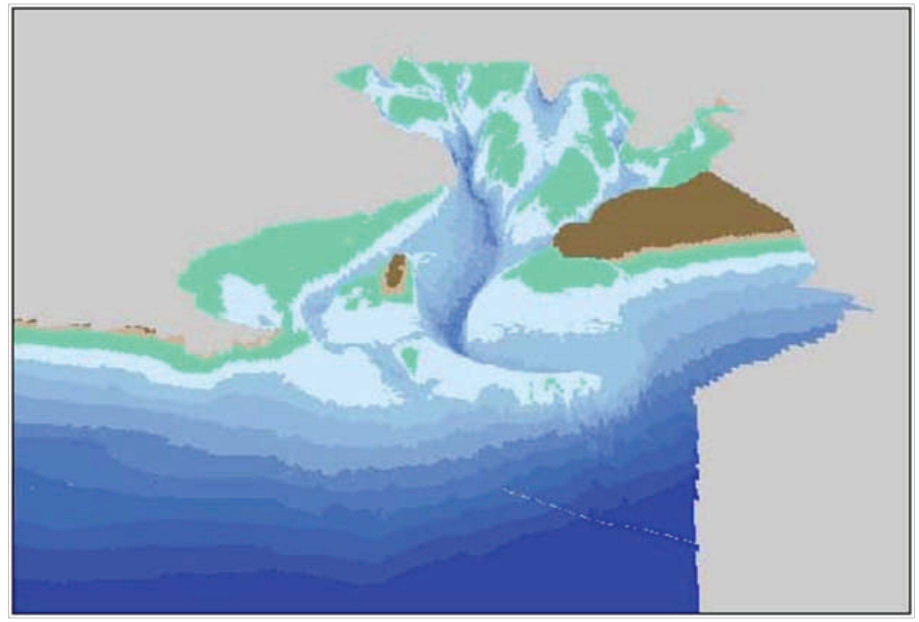

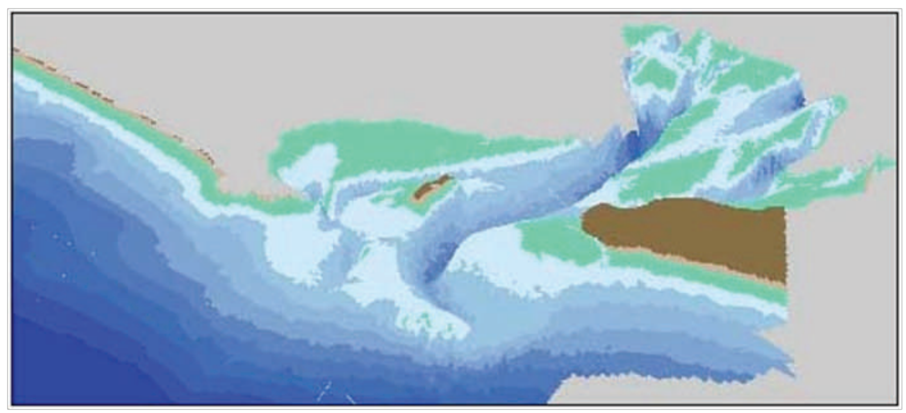

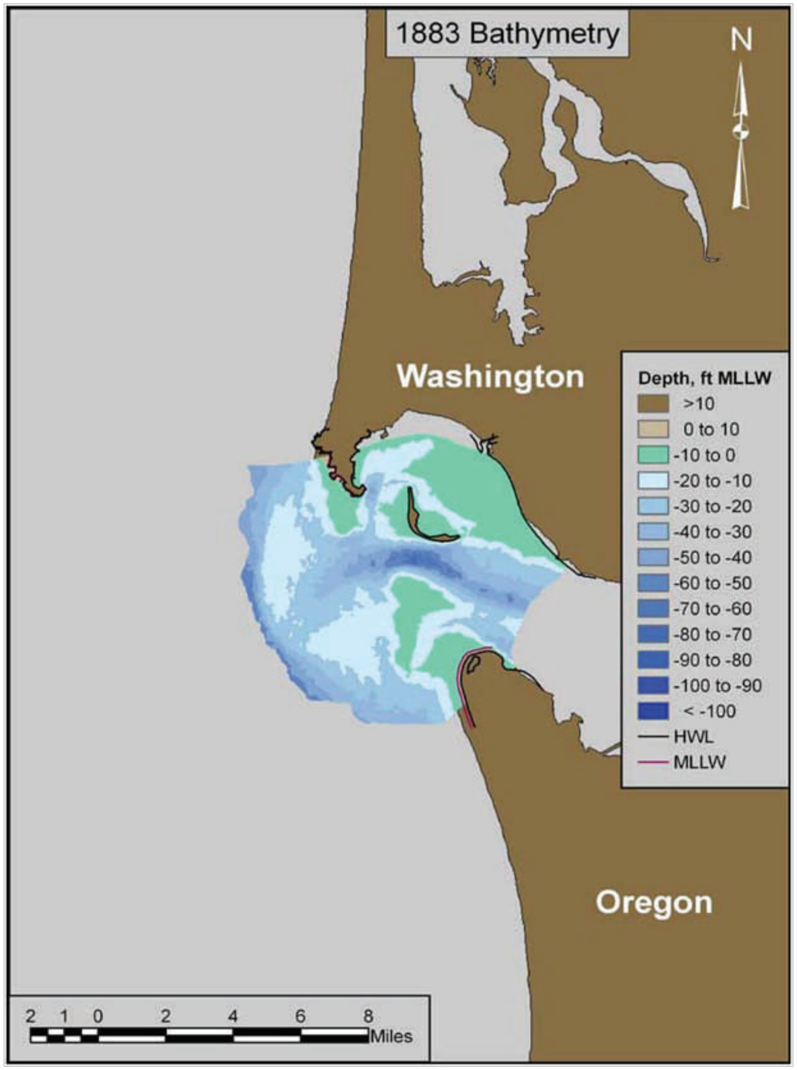
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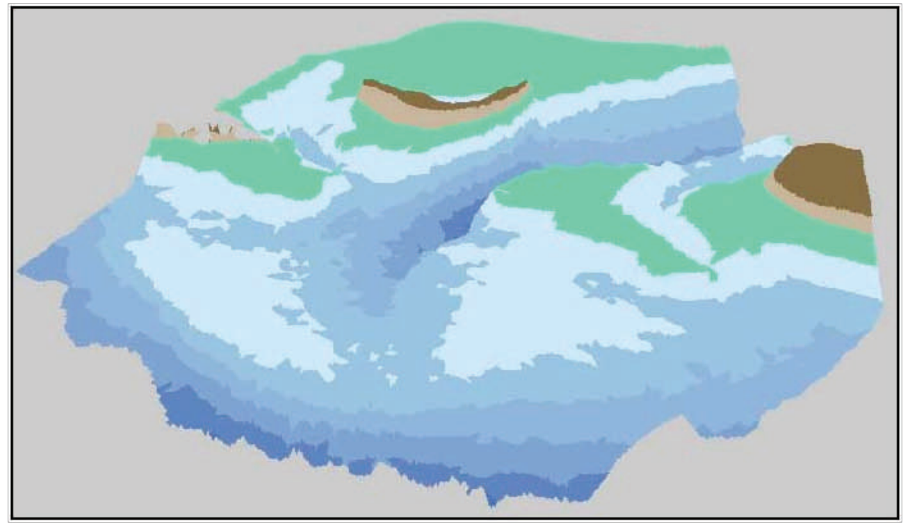

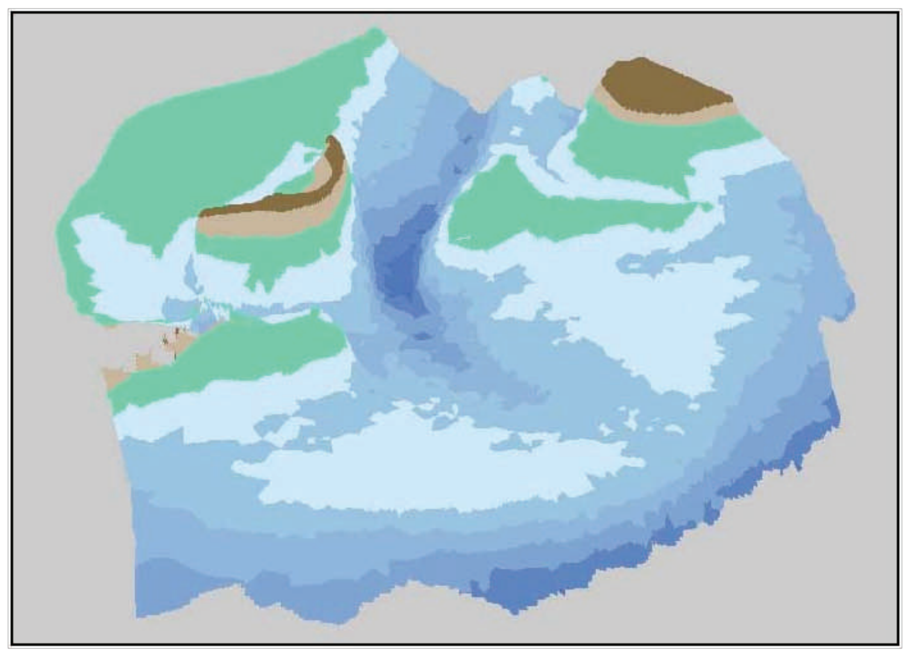

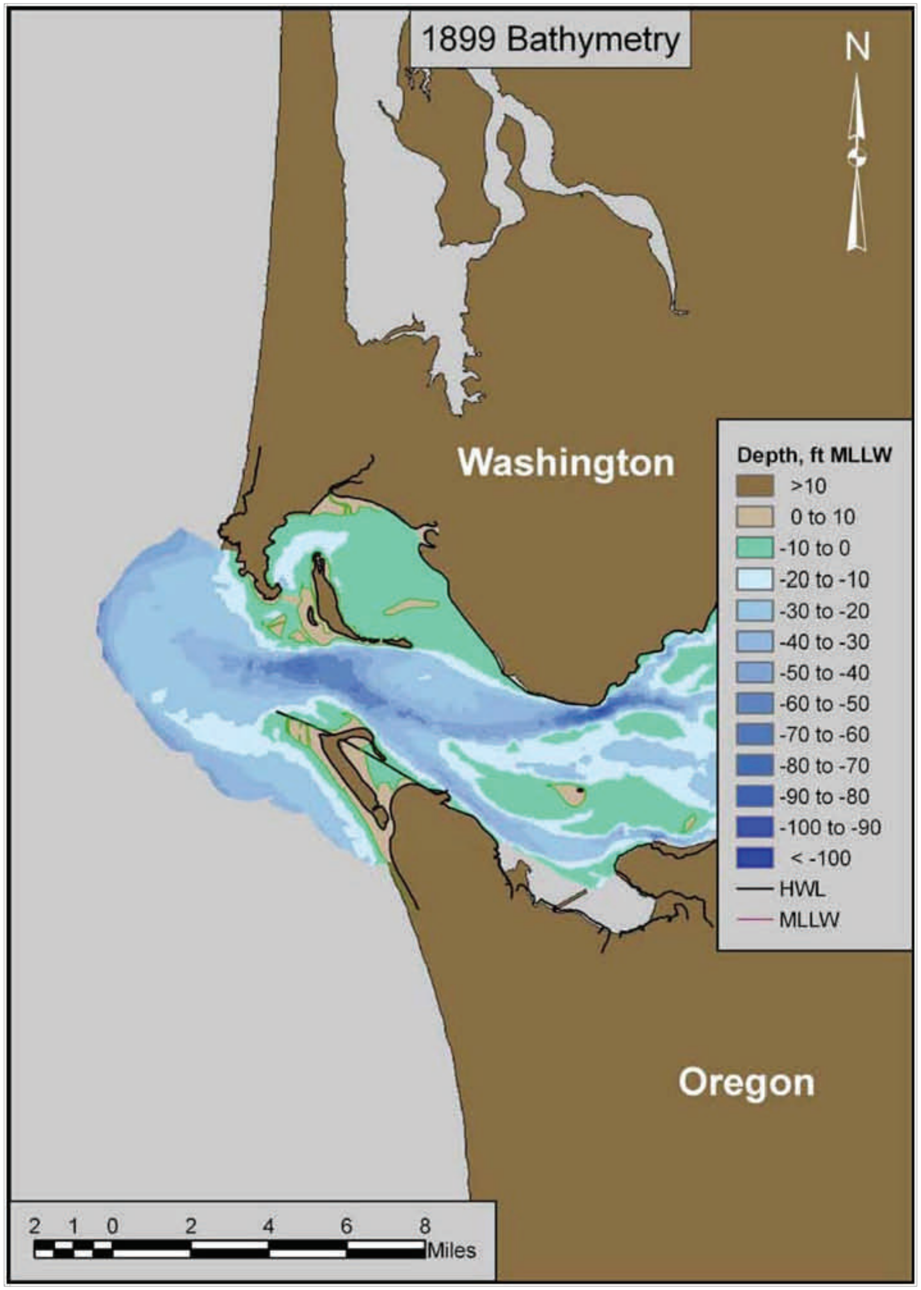
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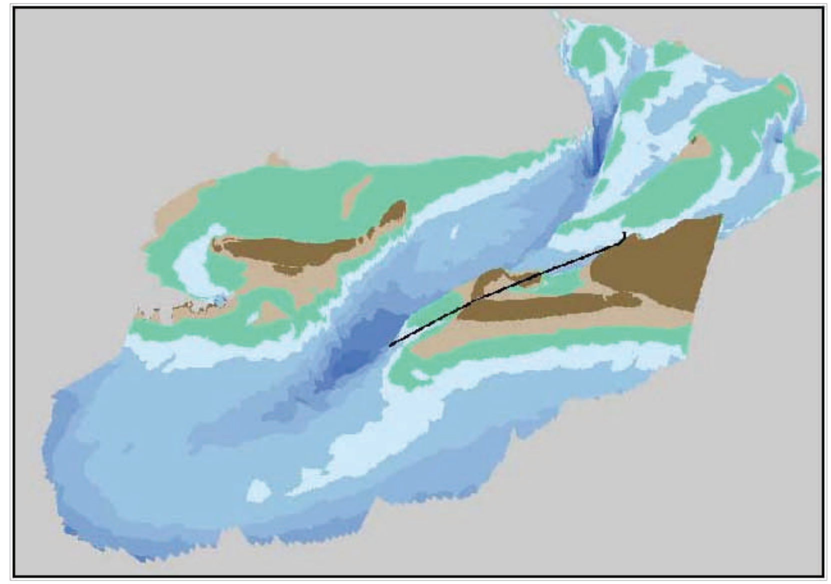

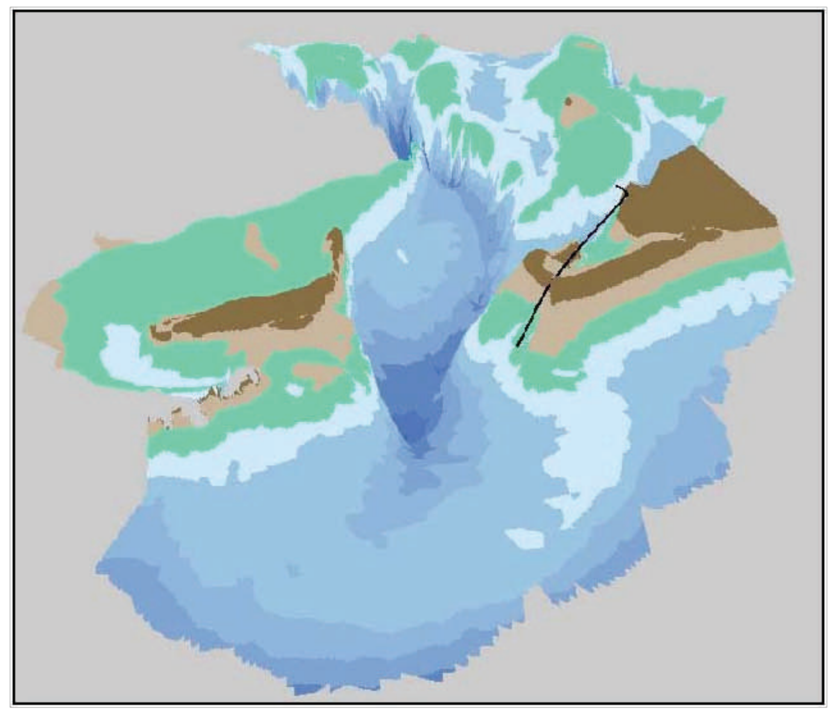

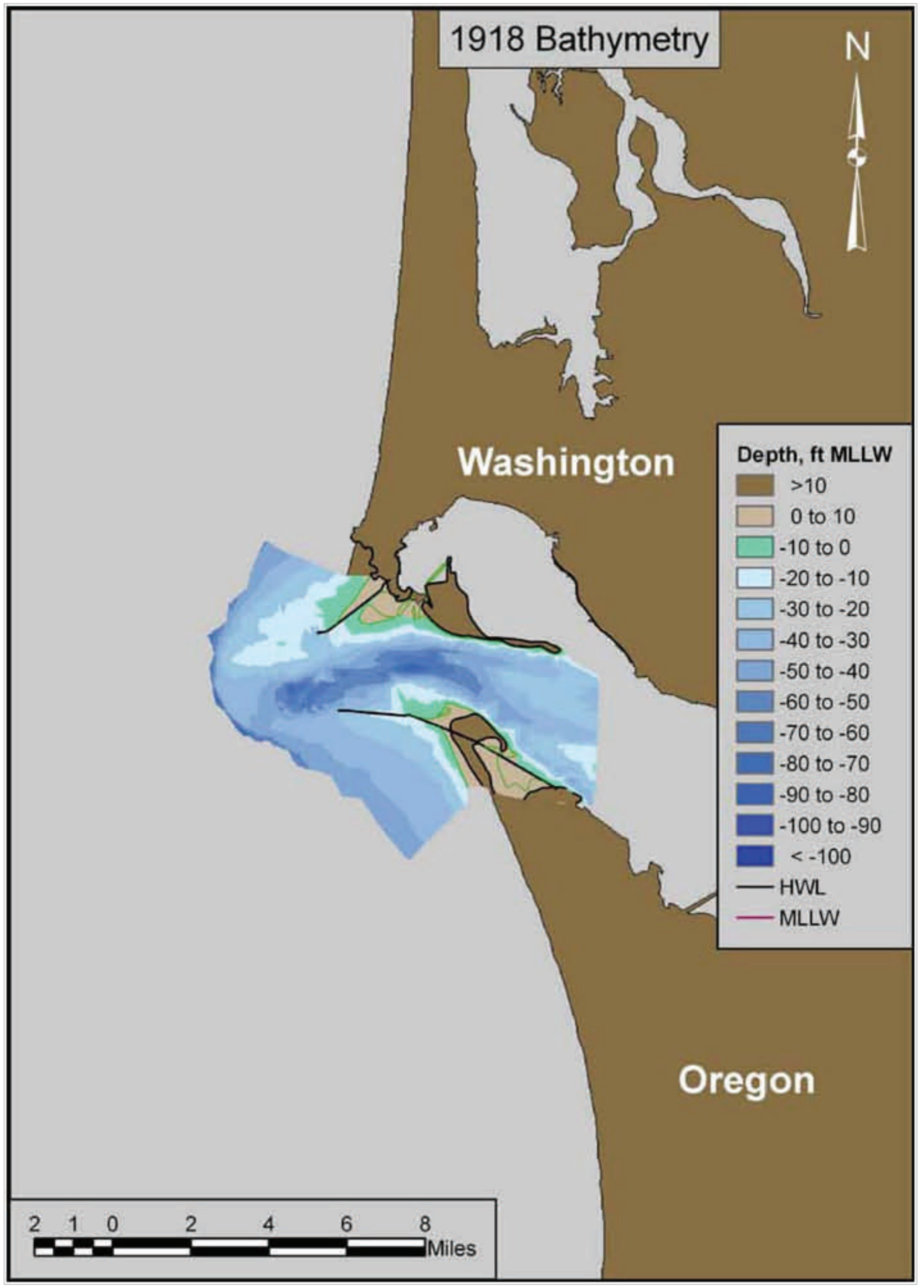
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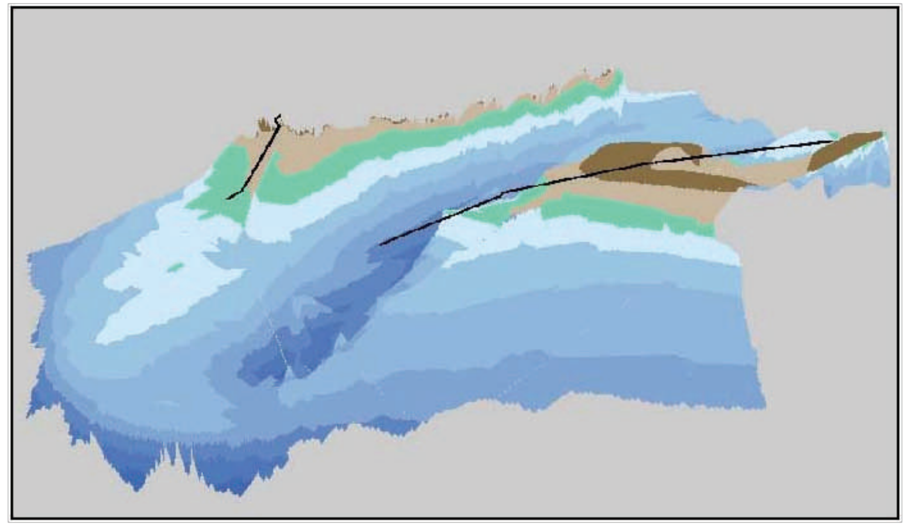
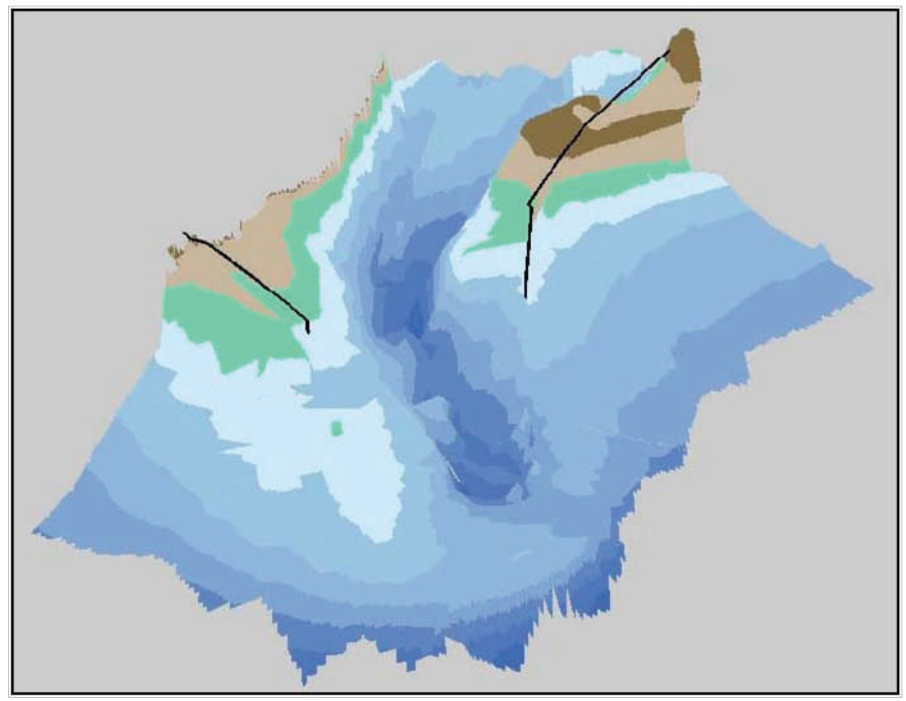

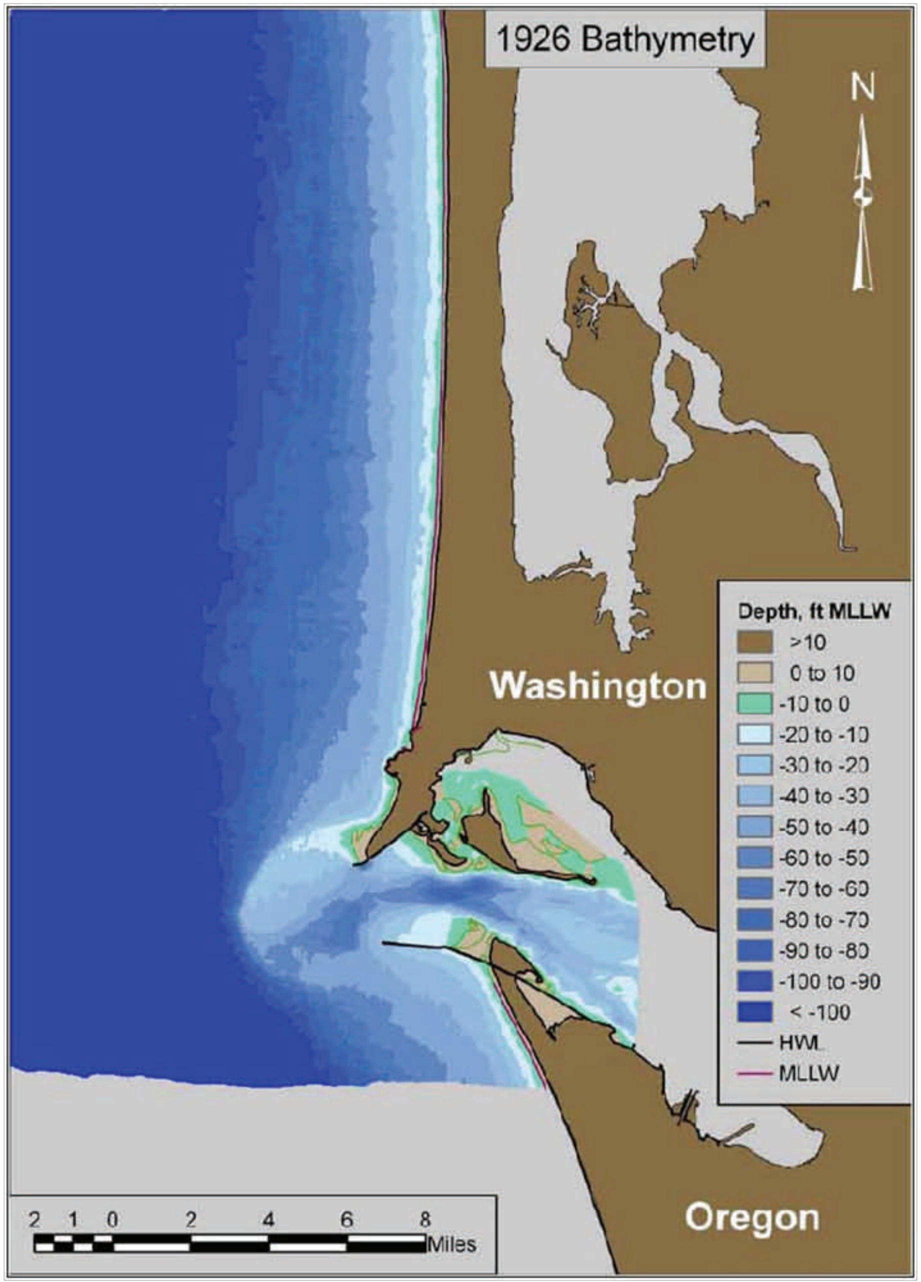
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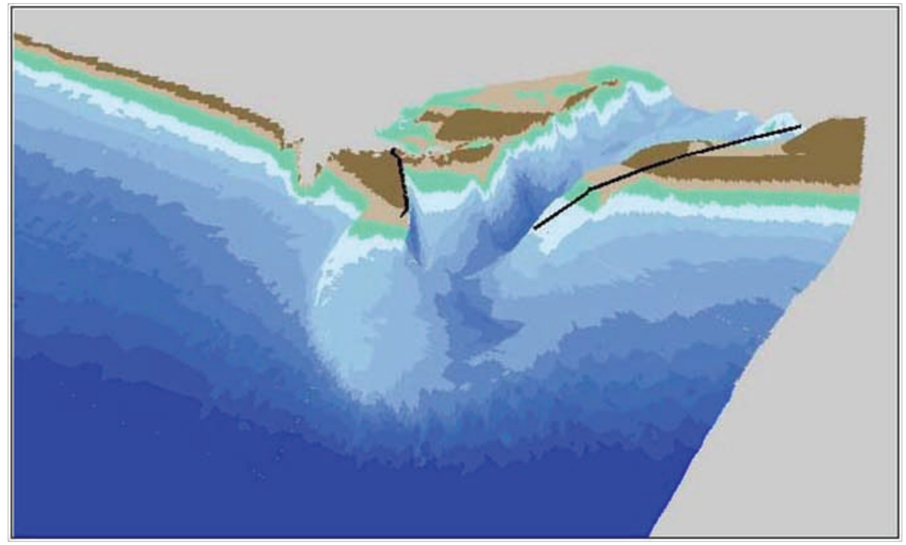

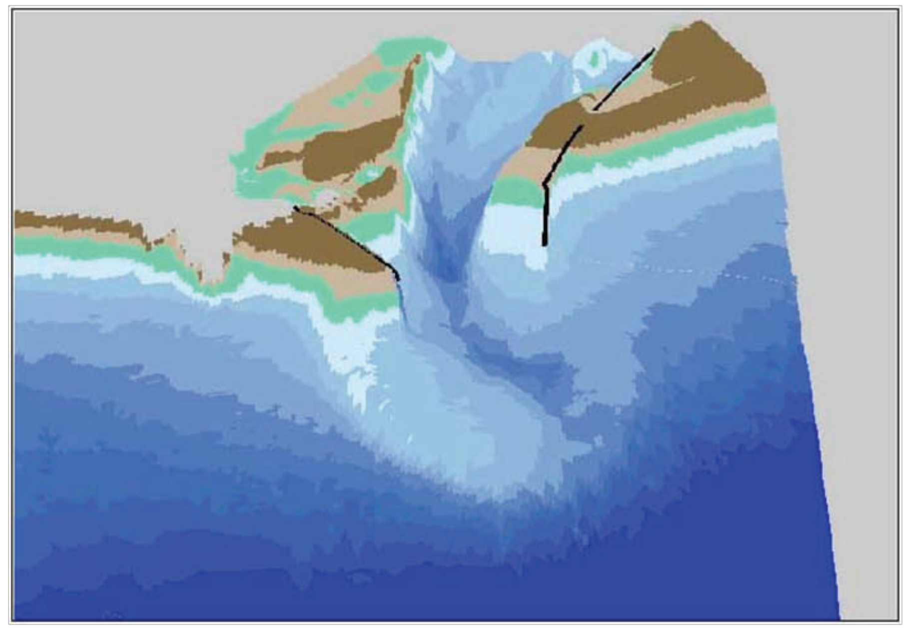

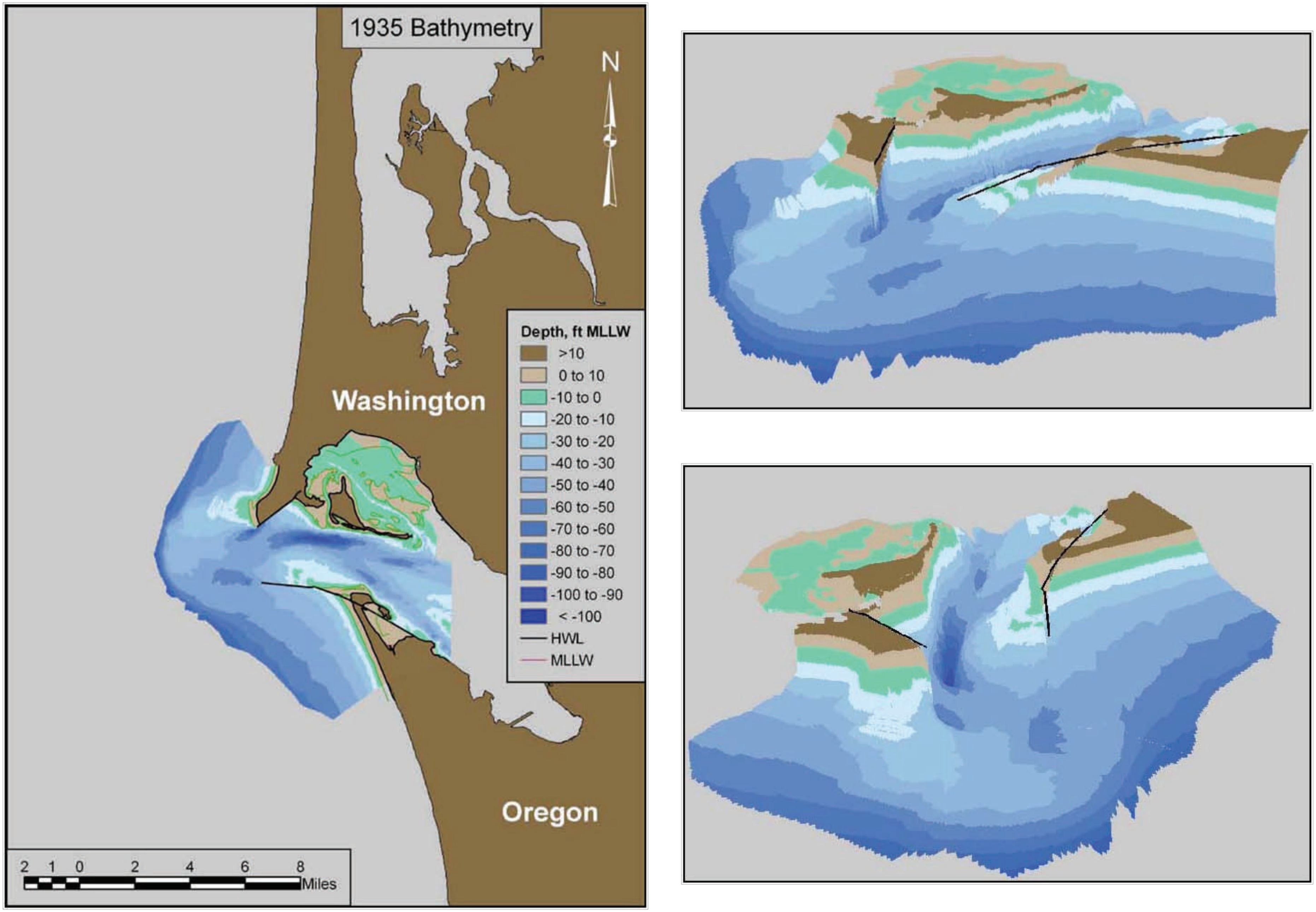
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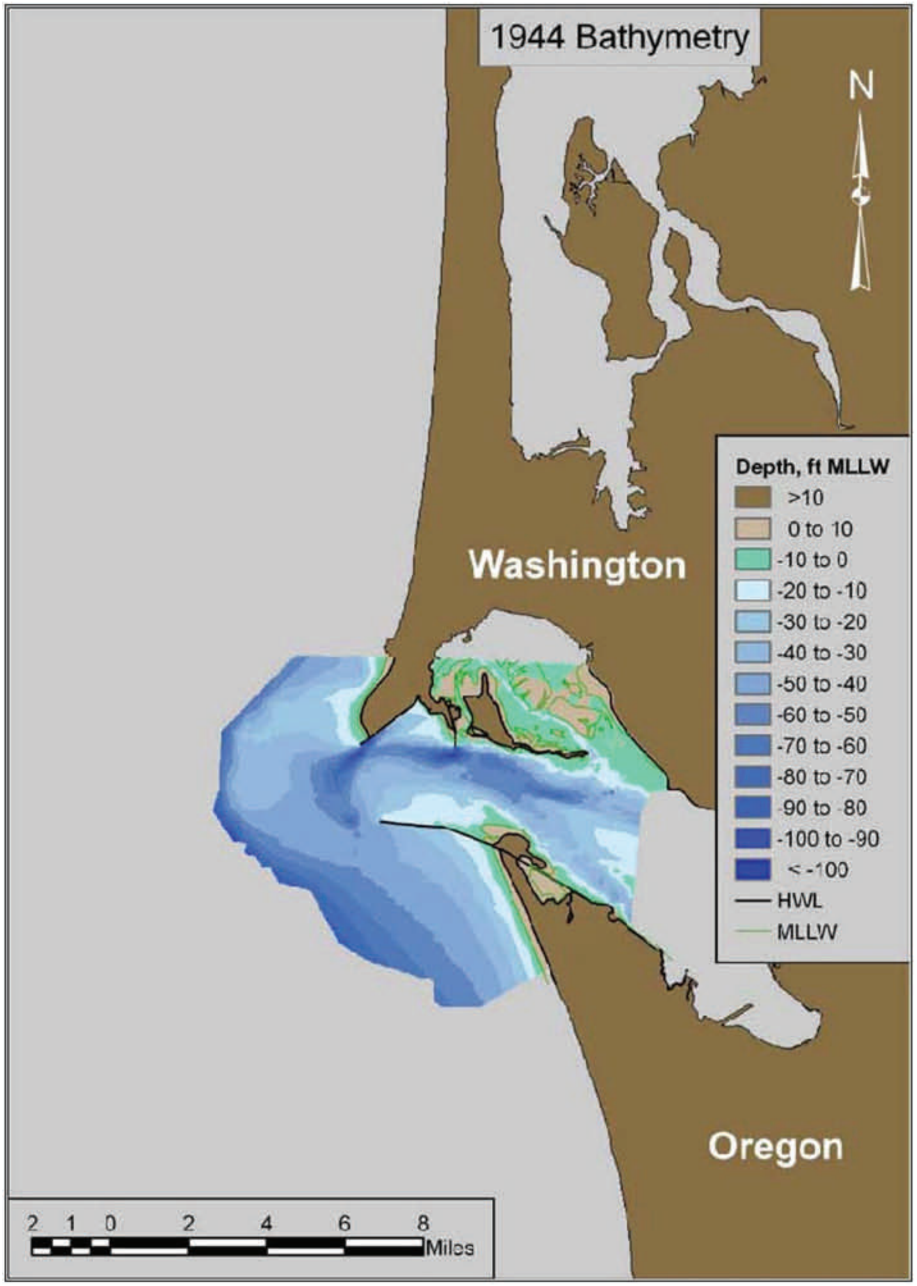
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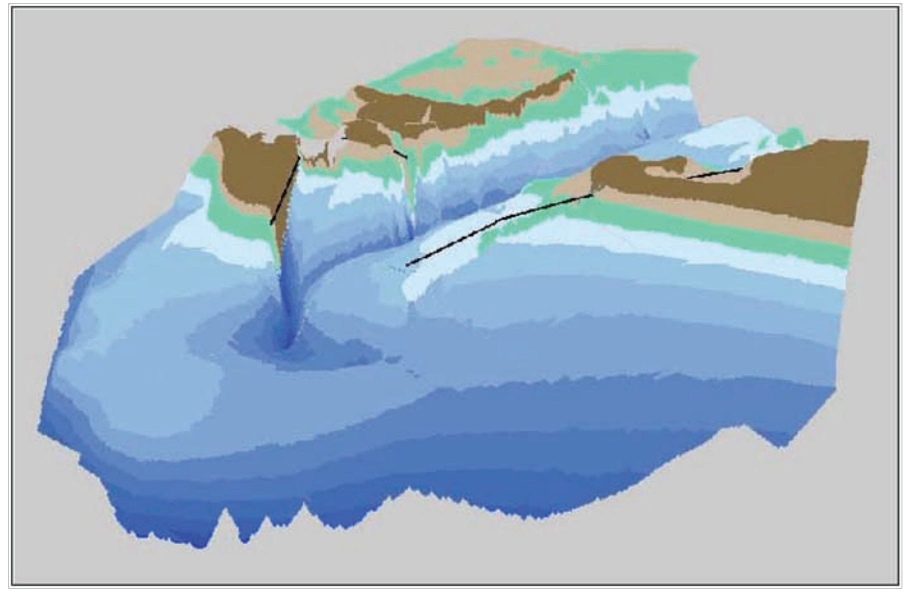

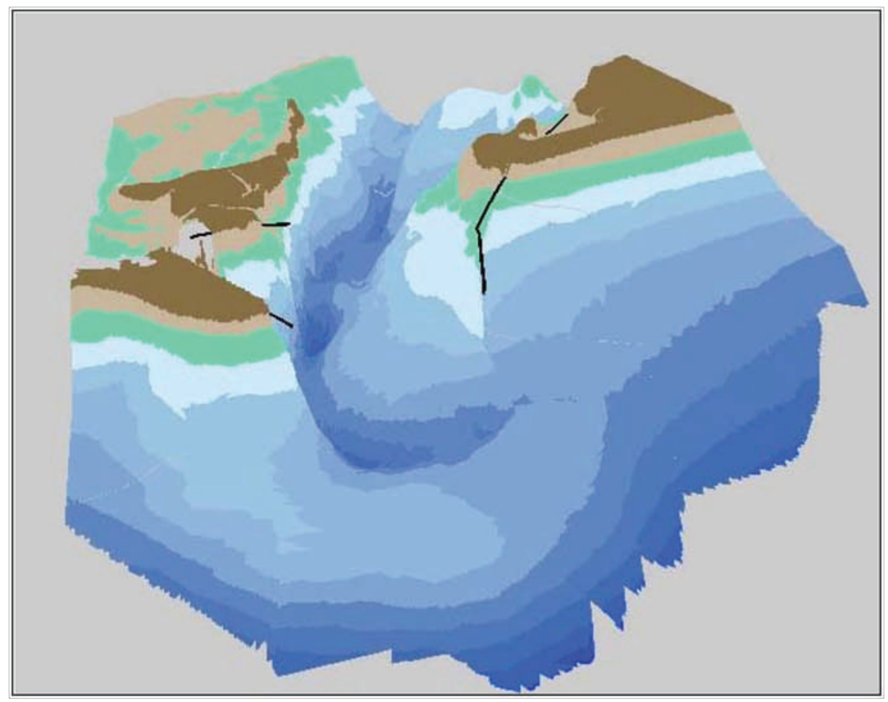

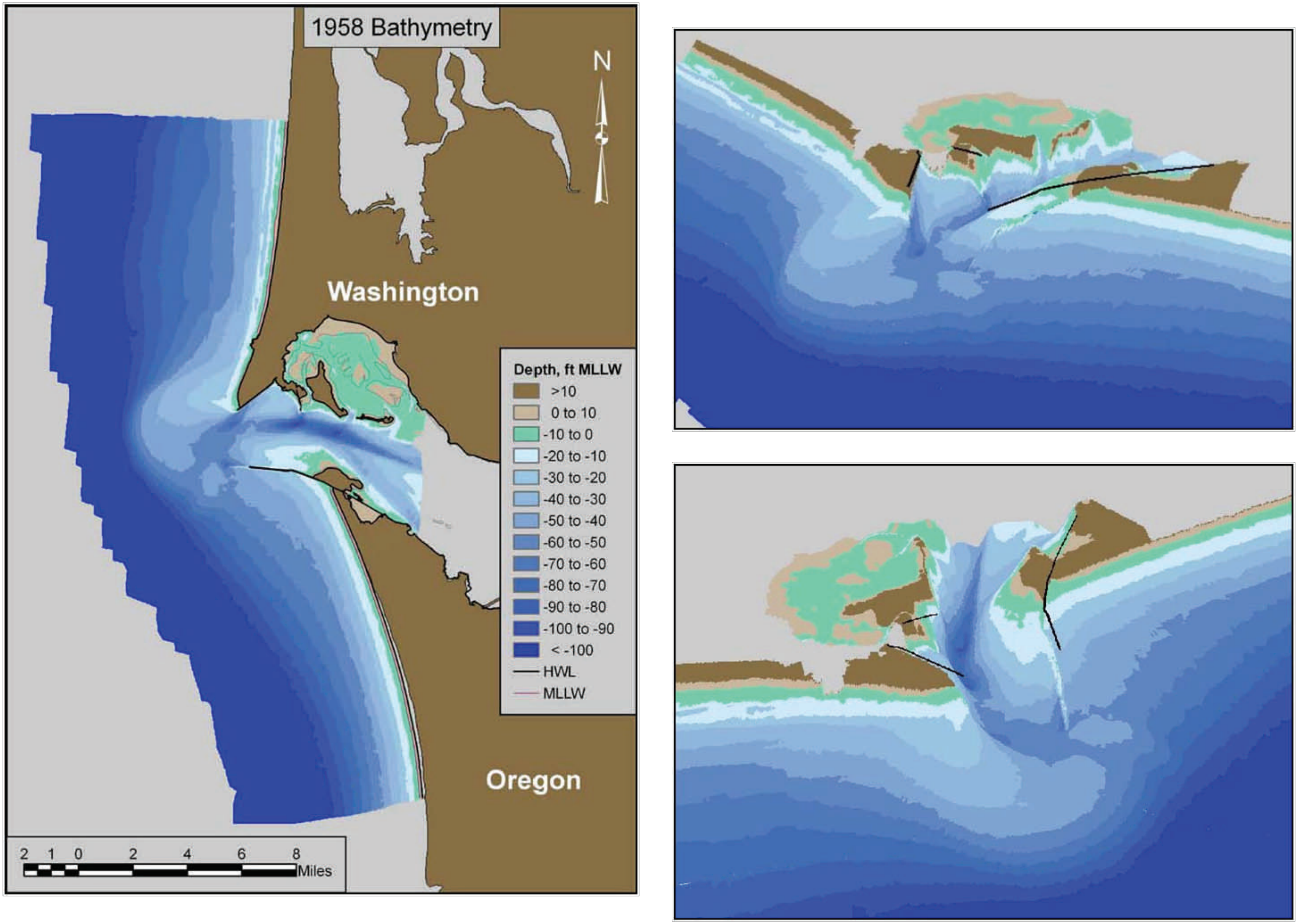
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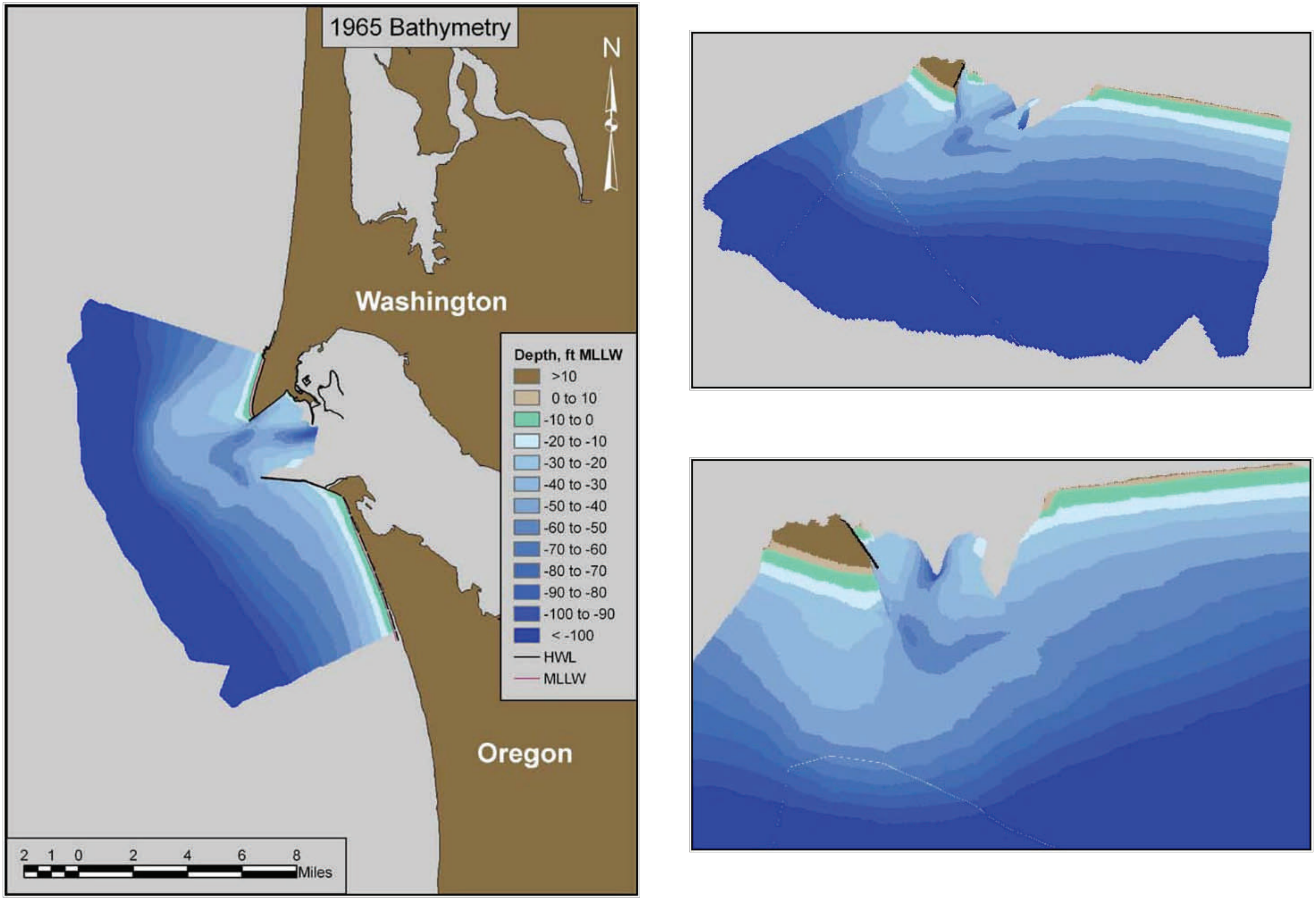
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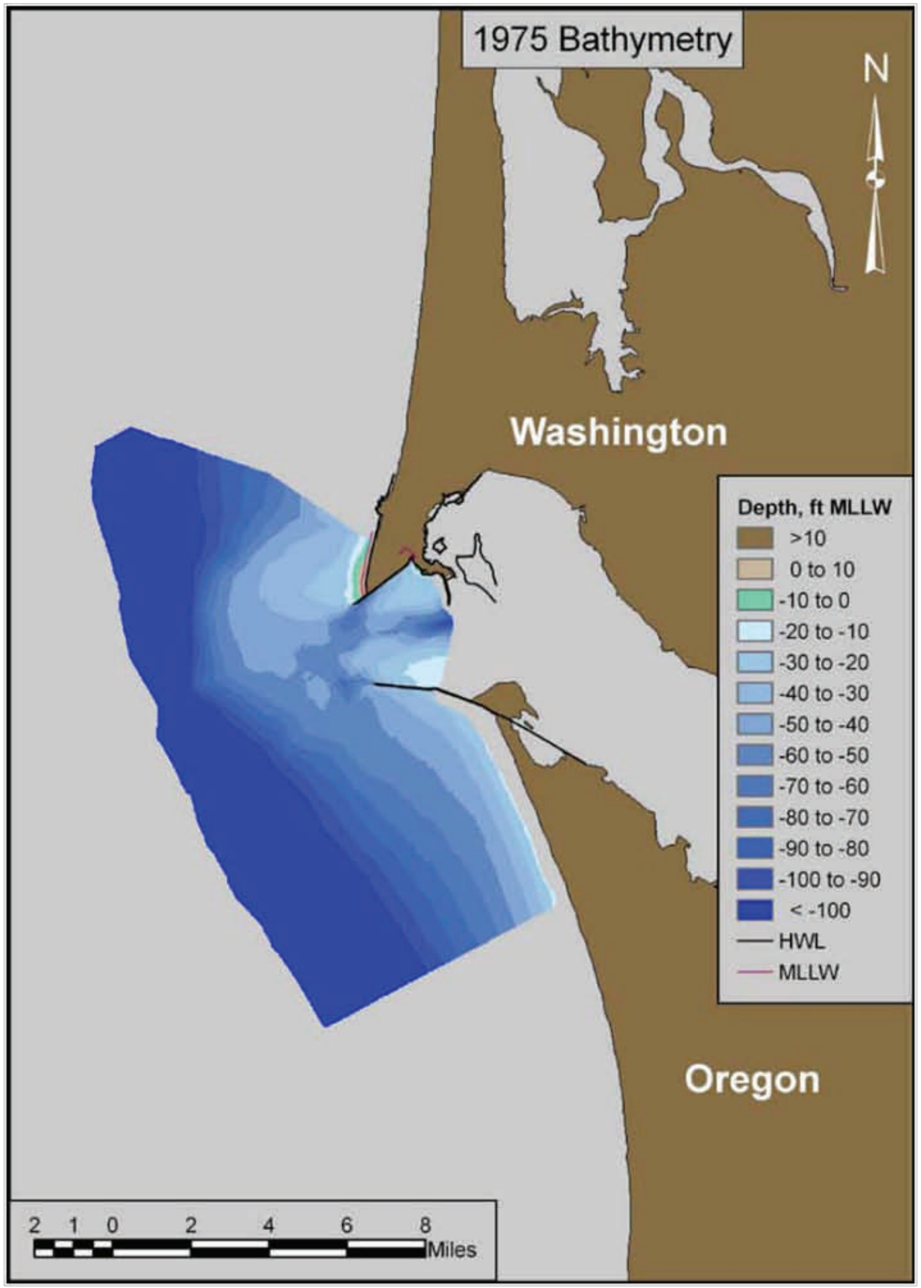
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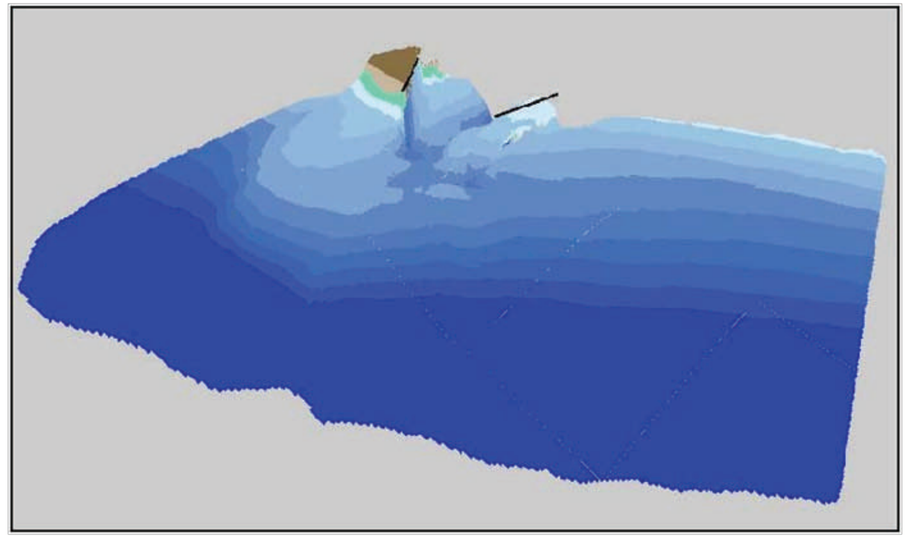

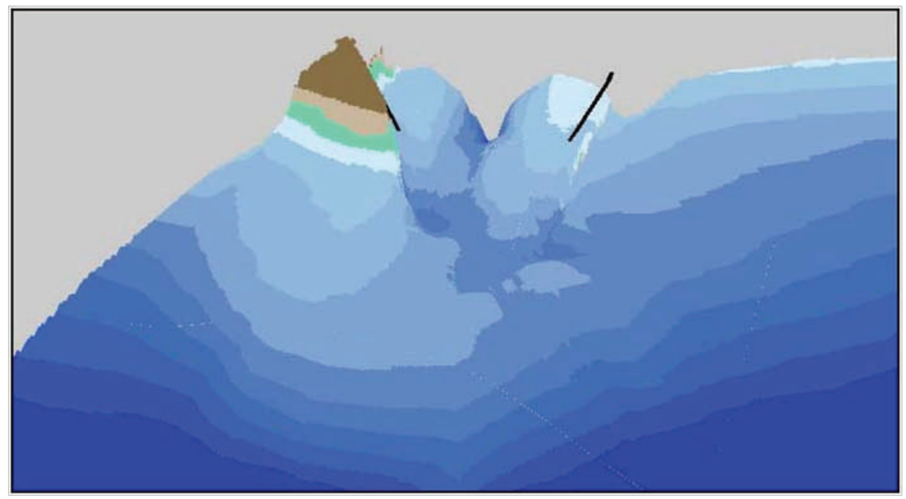

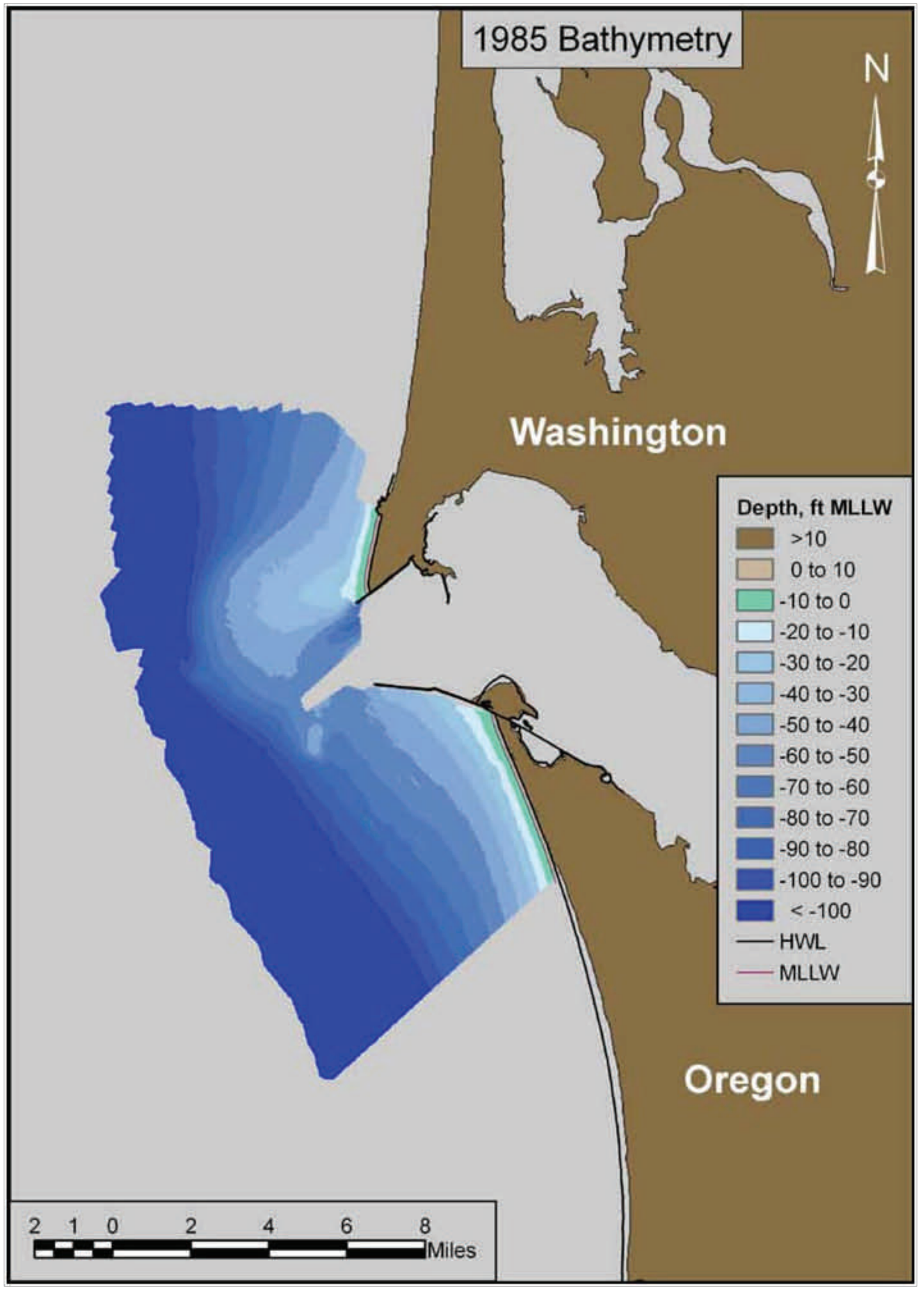
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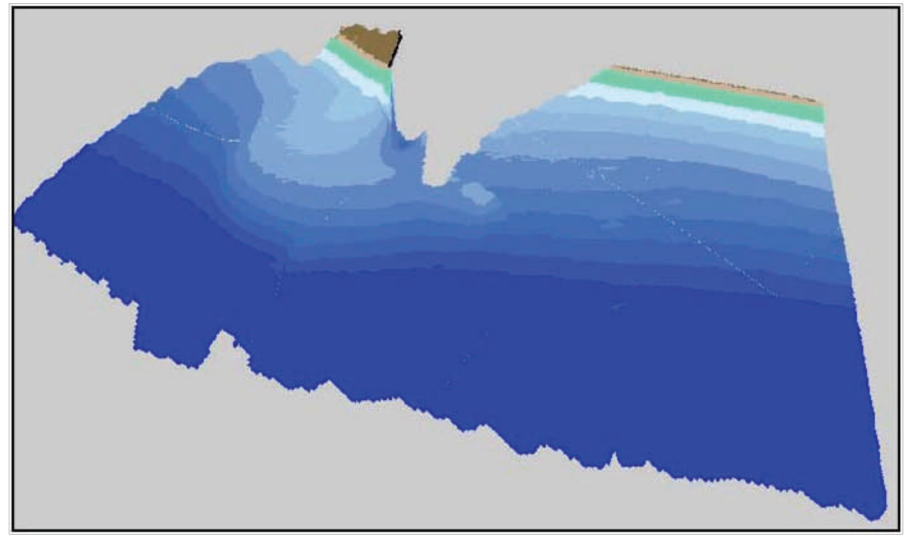

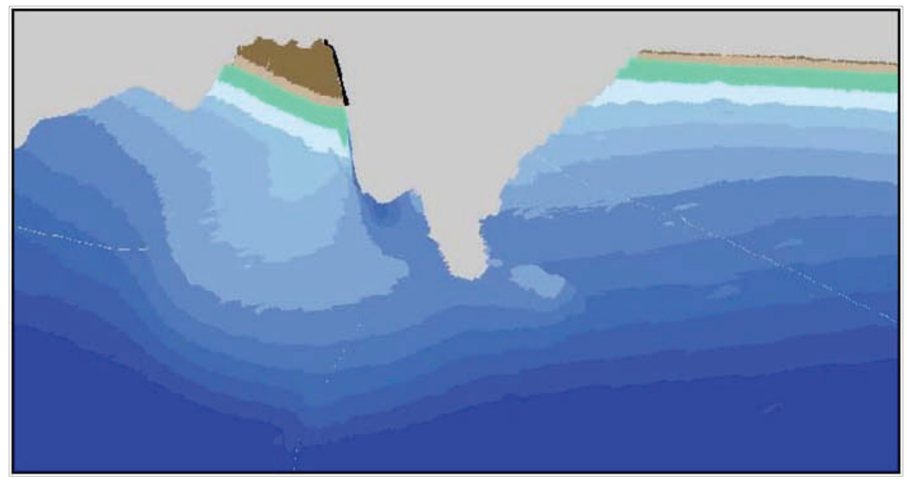

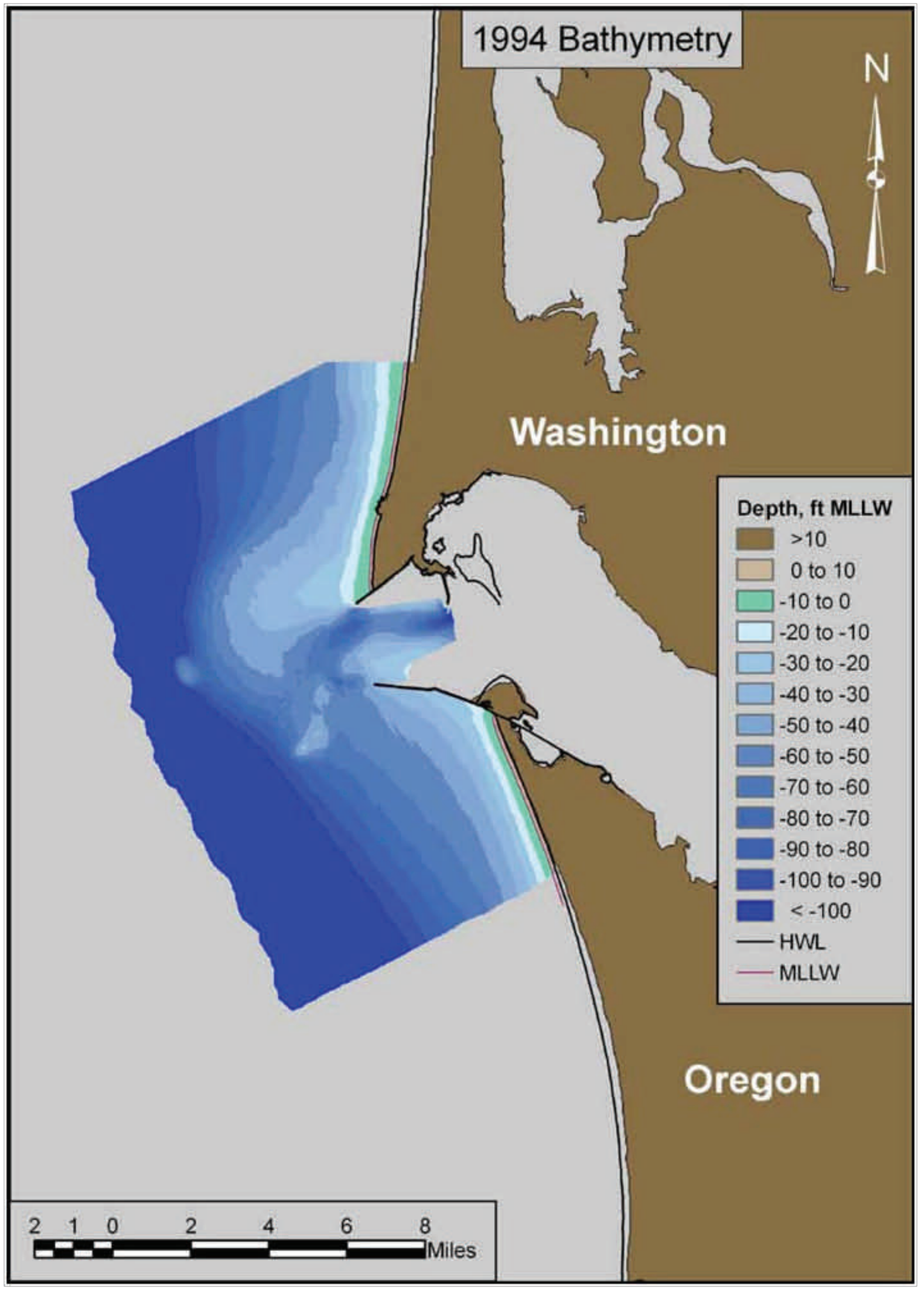
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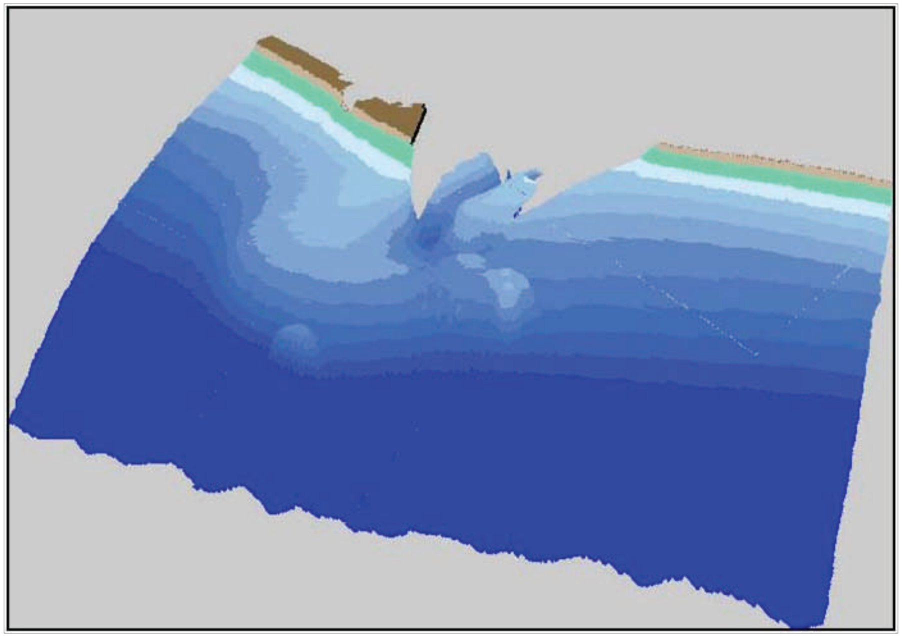

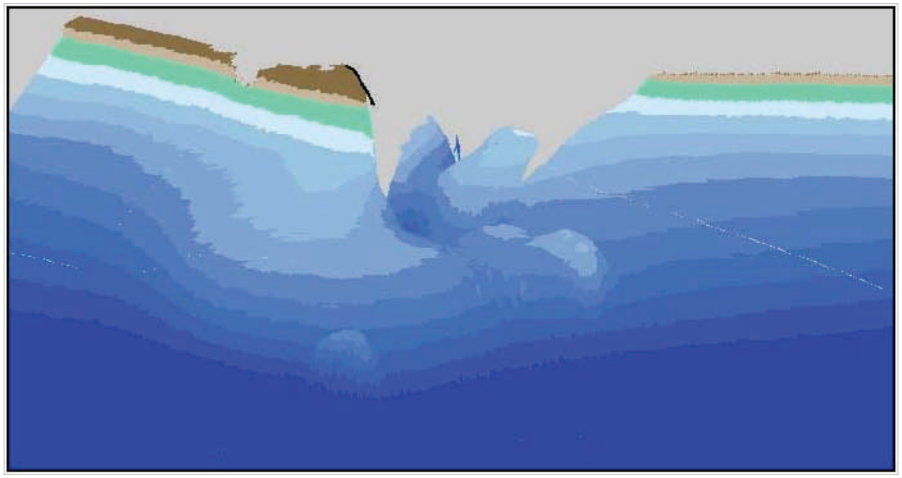

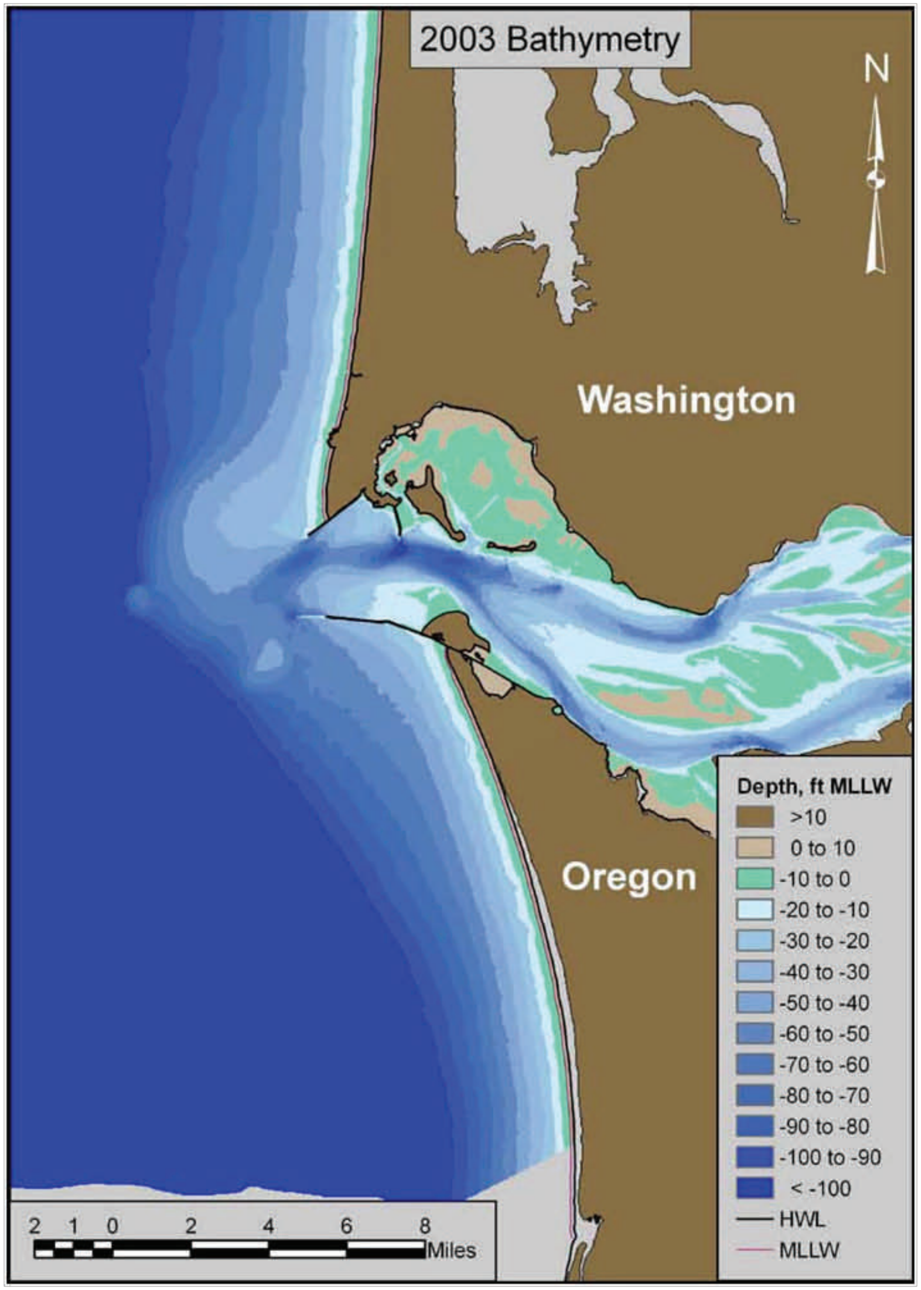
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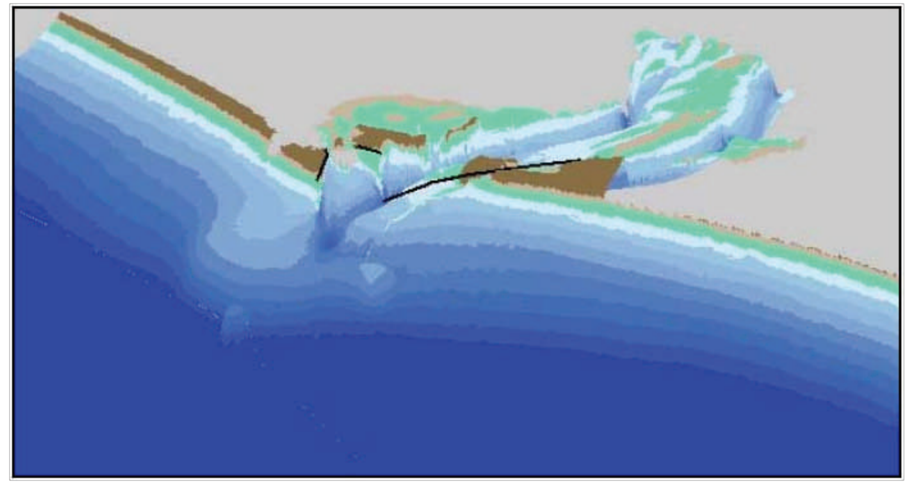

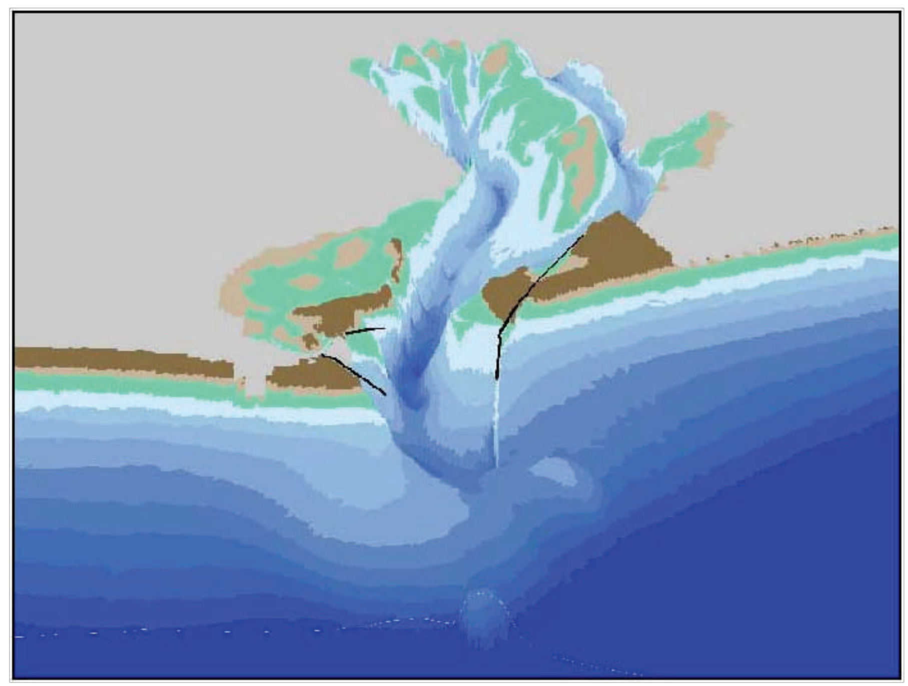

MCR Jetty System Major Rehabilitation Evaluation Report

Appendix B

Geotechnical Studies

Appendix B - Geotechnical Studies

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Appendix B - Geotechnical Studies

1. BACKGROUND

The jetties adjacent to the mouth of the Columbia River (MCR) at Astoria, Oregon are under study for a major rehabilitation action to repair them back to a 50-year design life. All three jetties have been experiencing damage from winter storms and each has lost significant amounts of material from the head and trunk sections over the past several years. Designs resulting from numerical and physical modeling require very large amounts of jettystone to be placed on the relict stone base as well as the adjacent sand foundation.

Project Description

The North and South jetties at MCR are located at the mouth of the Columbia River in northern Oregon and southern Washington. Jetty A is located at approximate river mile 3 and extends south from Cape Disappointment towards the navigation channel. All jetties were built on sand foundations. The North Jetty was constructed to a length of 12,408 feet from 1913-1917. It has had four repairs to the outer trunk and head section culminating with interim repairs to the trunk section in 2005. The first 22,440 feet of the South Jetty was constructed from 1885-1896. It was repaired and extended by 12,514 to the currently authorized length from 1903-1914. The South Jetty has had eight repairs to the head and trunk section since it was extended, with the last interim repair occurring in 2006-2007. Jetty A was constructed in 1939 to a length of 10,000 feet and was repaired four times before a repair and 3,806 foot extension in 1958. The last repair occurred to the trunk and outer end in 1961. All three jetties have experienced significant damage to the trunk and head sections in the last several years.

2. GEOLOGICAL FRAMEWORK

The coastal area of Oregon has been influenced by a combination of tectonic forces and glacial effects during the past few million years. Regional uplift, coupled with a fluctuating sea level, are shown by marine terraces up to 100 feet above present sea level and Astoria Canyon, more than 300 feet below sea level. Beneath deposits of recent sands are rocks up to 40 million years old. These are mostly marine deposits with volcanic outcrops forming such features as North Head, Tongue Point, and Tillamook Head. About 20 million years ago these rocks were uplifted and deformed into a “trough” along the course of the present river. Erosion as uplift occurred produced massive sedimentary deposits that were subsequently partially eroded and overlain by younger deposits. Volcanic activity associated with the uplift produced submarine basalt deposits and intrusions intermingled with the sedimentary deposits.

Beginning about 2 million years ago, glacially-induced sea level fluctuations were superimposed upon the continued regional uplift. At the maximum extent of the continental glaciers sea level was as much as 400 feet below present and the MCR was up to 10 miles offshore. During this time a series of shelf-edge canyons were formed, including Astoria Canyon, which channeled sediments into deeper water. Delta-like features formed from massive amounts of sediments, estimated up to 10 times present volumes (Nelson 1968). The Astoria fan is one such feature, shown on Figure B-1. As the glaciers retreated, sea level rose up to 100 feet above its present elevation. Coastal forces extensively reworked unconsolidated sediments and formed marine terraces during relative still-stands. The last episode of glacial retreat began less than 20,000 years ago with sea level rising rapidly until 5,000 to 6,000 years ago. Estuaries at the MCR and elsewhere are "drowned" river valleys, and coastal features such as extensive sand spits and dune complexes resulted from marine forces reworking sediments relict from earlier times.

Figure B-1. Columbia River Drainage Basin and Adjacent Pacific Ocean Floor

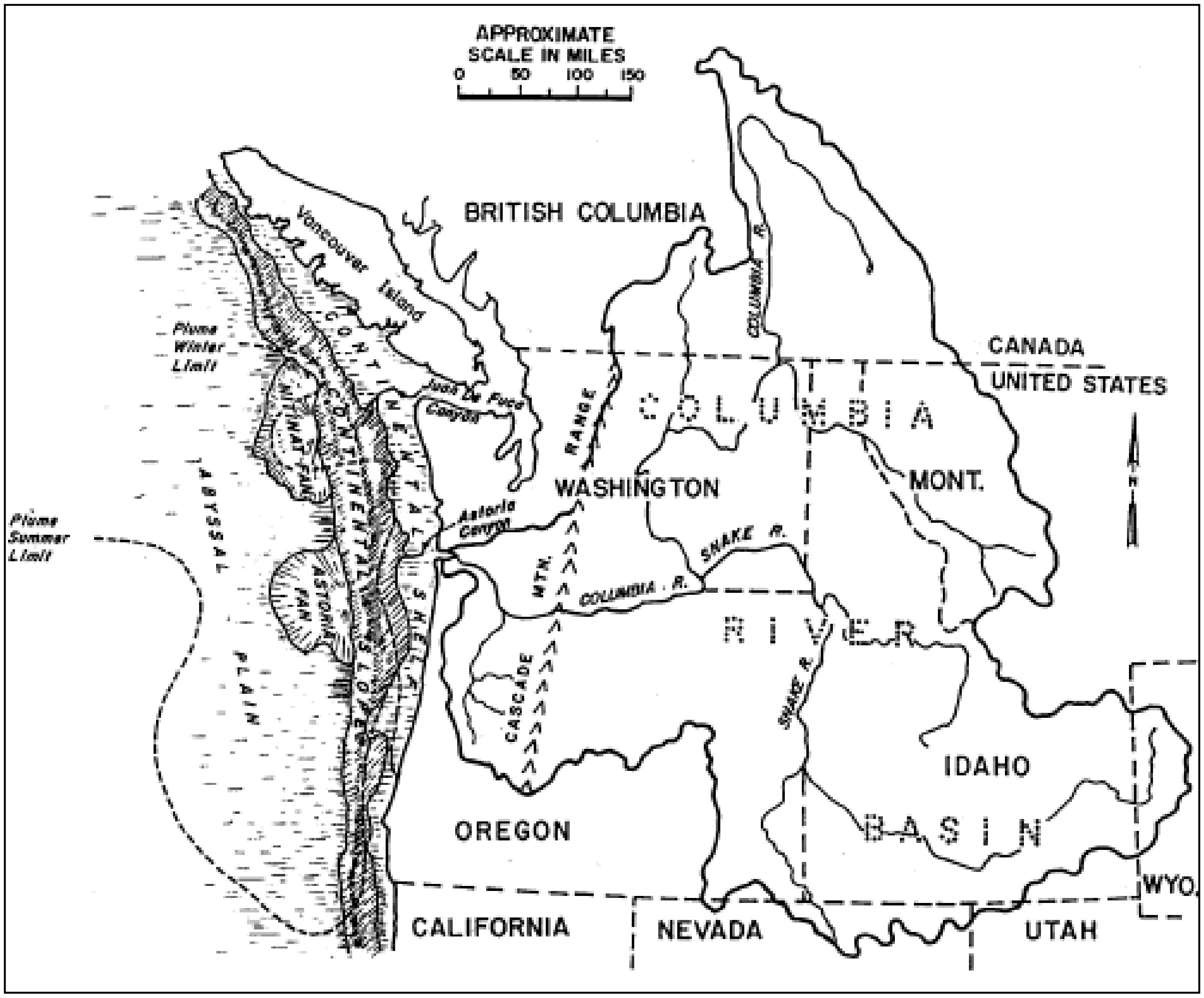


Figure B-2 shows the general geology of the area around the MCR. Upland areas are mostly older sedimentary rocks that are intercalated basalt flows that are folded and faulted. Overlying these rocks are occasional remnants of once extensive Pleistocene marine terraces. Filling the valley bottoms and the estuary are modern river sediments. These sediments grade into marine sands near the river mouth that continue offshore. Extensive coastal dunes and beaches have been formed in modern times by wind forces acting upon river/marine sands. Figure B-3 presents two cross sections of the study area based upon onshore drilling. These sections are displayed on Figure B-2. Section A-A runs north-south along Clatsop Spit and Section B-B runs perpendicular to the shoreline near Gearhart. These sections demonstrate the extent of the sediment layer above bedrock, averaging 100 feet near Gearhart and thickening to over 200 feet at the MCR.

Figure B-2. Coastal Geology near the MCR

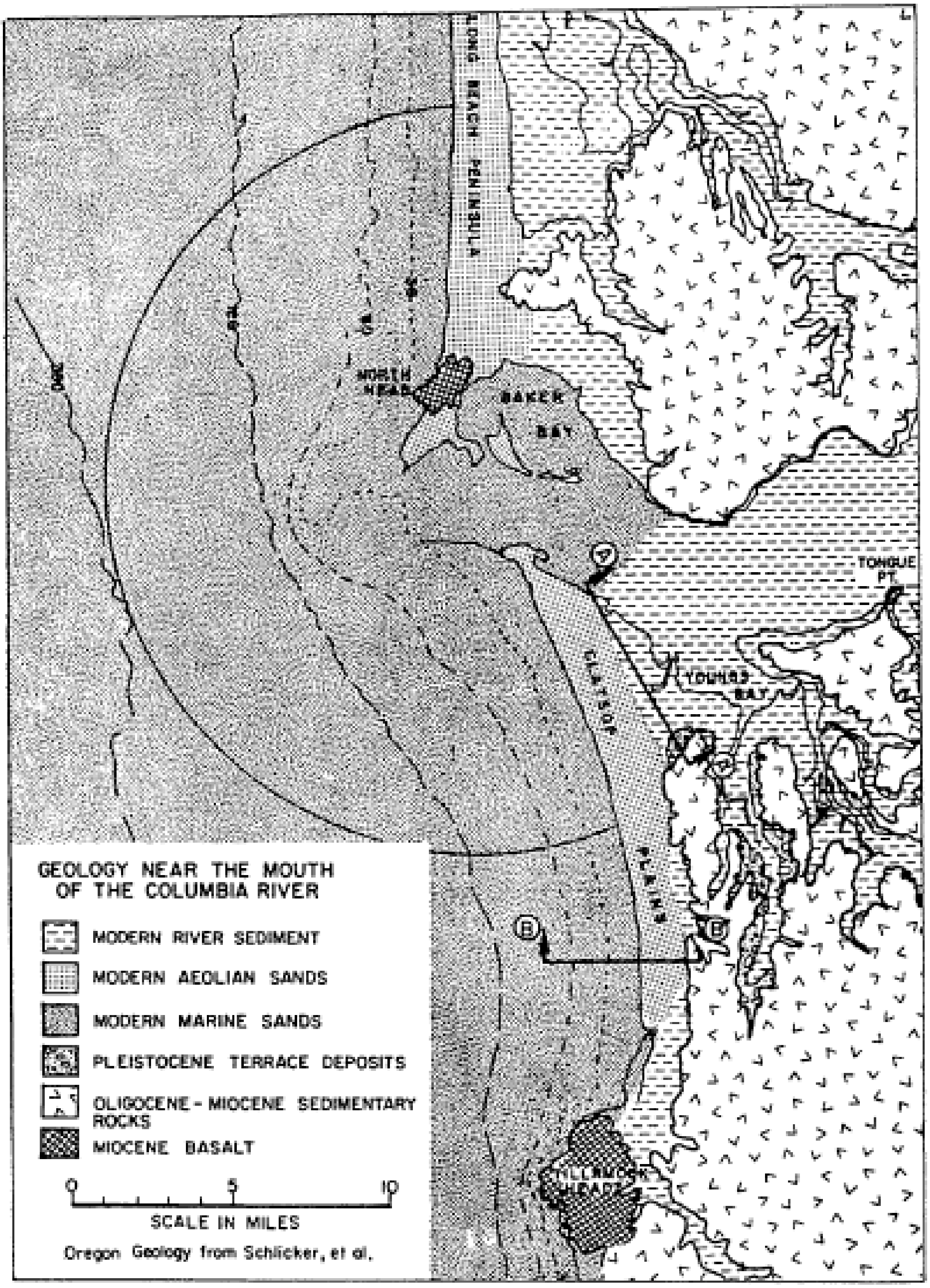
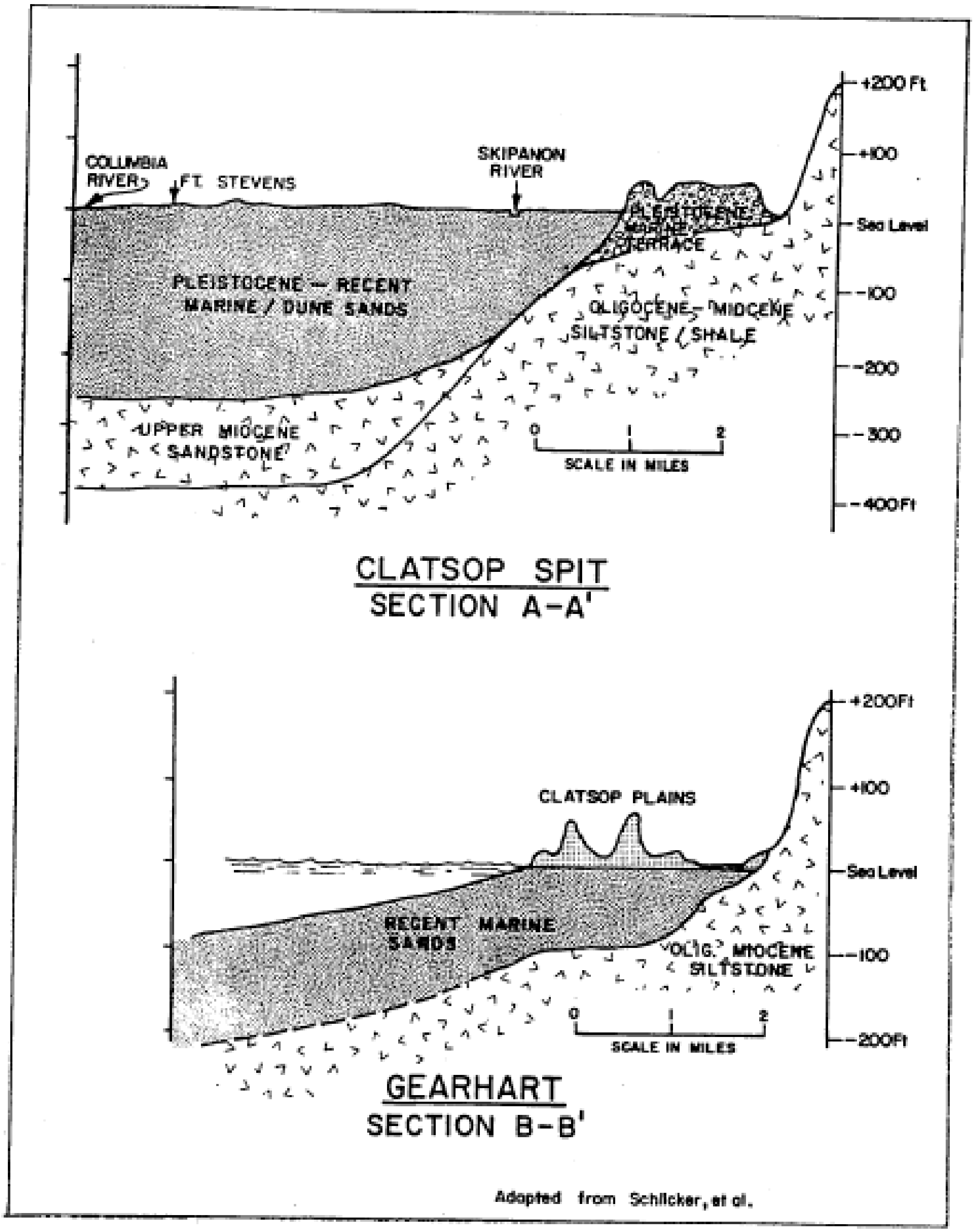


Figure B-3. Cross-sections of Coastal Areas near the MCR (sections are shown in Figure B-2)



Geologic Units beneath the MCR Study Area

No bedrock outcrops were found during USACE investigations within the MCR study area. Snavely and Wells (1996) indicate that Pleistocene and Holocene sediments extend across the entire continental slope and are exposed on the sea floor only on large banks such as Heceta and Nehalem, which are south of the study area. By projection of bedrock units mapped in the Astoria 15' Quadrangle by Schlicker and others (1972), it appears that the study area is underlain by an undifferentiated sequence of sedimentary rocks of Oligocene to middle Miocene age. These beds are estimated to be approximately 5,000 feet thick and consist of thin-bedded to massive tuffaceous siltstone and clay stone with lesser amounts of sandstone and shale locally. These beds are mildly deformed, typically dipping 40 degrees or less. No known faults mapped on land project into the study area. A west-trending strike slip fault through the Columbia River mouth and extending offshore is known from either aeromagnetic data or seismic reflection profiling. It occurs in the older rocks, being concealed by the younger strata.

Several wells have been drilled in the Clatsop plains area south of the South Jetty within a few miles of the study area (Frank 1970). Near the surface, these wells encountered a variety of unconsolidated dune, beach, and shallow marine sands interbedded with alluvium, all of Pleistocene and Holocene age. These young deposits extend to depths of between 250 and 300 feet below sea level and rest unconformably on a sandy unit that extends to depths of approximately 400 feet below sea level. This second unit was tentatively identified as Astoria Formation by Frank (1970), but has subsequently been called Upper Miocene Sandstone by Schlicker and others (1972). This unit is typically buff-colored, medium- to coarse-grained, semi-consolidated sandstone of marine origin. The Oligo-Miocene beds that are part of the Astoria Formation underlie the Upper Miocene Sandstone.

Seismic Conditions

The site is located within the Cascadia Subduction Zone where very large magnitude earthquakes are expected to occur. Earthquakes between magnitude 8 and 9+ occur on average about once for 450 to 500 years. The last event occurred 311 years ago and was at least a magnitude 9. A subduction zone earthquake will result in at least a one to three foot subsidence of the sea floor and jetty, liquefaction and lateral spreading of loose sediments, and a large tsunami (a series of long wave length, 20 to 50 foot waves) that will overtop the jetties.

Recent Geophysical Investigations

Geophysical investigations consisting of side scan sonar and sub-bottom profiling, have been conducted for the USACE at the mouth and offshore of Columbia River since at least 1982 (Northern Technical Services). This initial investigation provided information related to sub-bottom conditions present in the entrance and lower navigation channel, including the identification of potential areas of harder dredging related to an early study to deepen the navigation channel in this area. Subsequent vibracoring operations (L.R. Squier 1984 and Dames & Moore 1986) in these potential harder areas identified the material types and properties up to 20 feet and 30 feet respectively, beneath the existing channel bottom.

The study of the Columbia River mouth area in 1985 by Earth Sciences Associates and Geo Recon International utilized both side scan and sub-bottom profiling techniques. Figure B-4 shows a geologic map of the 1985 study area produced by side-scan sonograph records. The sub-bottom data, such as that shown in Figure B-5, provided a clear differentiation between the unconsolidated fine to medium sand of the present sea bottom and underlying semi-consolidated to consolidated material beneath.

The top layer of sediment defined between the base of the water column and the first sub-bottom reflector has a variable thickness averaging from 20 to 40 feet thick. This material is of Holocene age with the upper part consisting of the sediment currently being deposited by the Columbia River and subsequently redistributed by oceanic currents. The basal reflector of this unit is very irregular, suggesting that the underlying unit might be large scale sand waves or dunes. This unit averages 90-120 feet thick and is thought to consist of unconsolidated and semi-consolidated sand with minor silt and clay. This correlation is based solely on depth and geometry of these contacts with those found in nearby wells. The lowermost unit identified on the profile represents the Upper Miocene Sandstone Formation which is one of the bedrock formations found in the area. Side scan data from 1985 revealed a general uniformity of the sea floor, which appears to be composed of silty sand to sandy silt. No rock outcrop exposures were found in the area surveyed. Small east-west trending ripple marks were consistently apparent over the entire area surveyed, decreasing somewhat north of the river mouth. The extreme northern portion of the study area showed a notable increase in bottom debris and bottom growth. At and south of the river mouth there was a marked absence of typical sea floor growth and debris. Sand waves were noted south of the active disposal site A. Long period sand waves with wave lengths of up to 500 feet, crest to crest, and heights of up to five feet, trough to crest, were noted on the fathometer records and located where indicated on the side scan map. The wave crests parallel the east-west axis of the local grid. These long-period sand waves were practically invisible on the side scan records due to their long wave length and small wave height.

Side scan data from 1996 (Northwest Geophysical Associates) was collected from areas not covered by the 1985 survey. Data from the combined surveys provides fairly complete coverage out to about 5 miles from the river mouth with overlap noted primarily in the river mouth area (Figure B-6). Figure B-7 shows the majority of the material in the 1996 coverage area is interpreted to be sand/silt which is equivalent to the fine to medium sand identified in the earlier survey. A large area between the jetties and immediately offshore shows numerous sand waves. Beyond that is a large area described as possible scour/ submerged rock, however, rock is not likely to be found within the study area. A few large unidentifiable objects were found on the bottom. None of these targets exhibited a shadow indicating there was little bottom relief. These are located in a table on Figure B-7.

Figure B-4. 1985 Sub-bottom Profile Plan Map Showing Geology

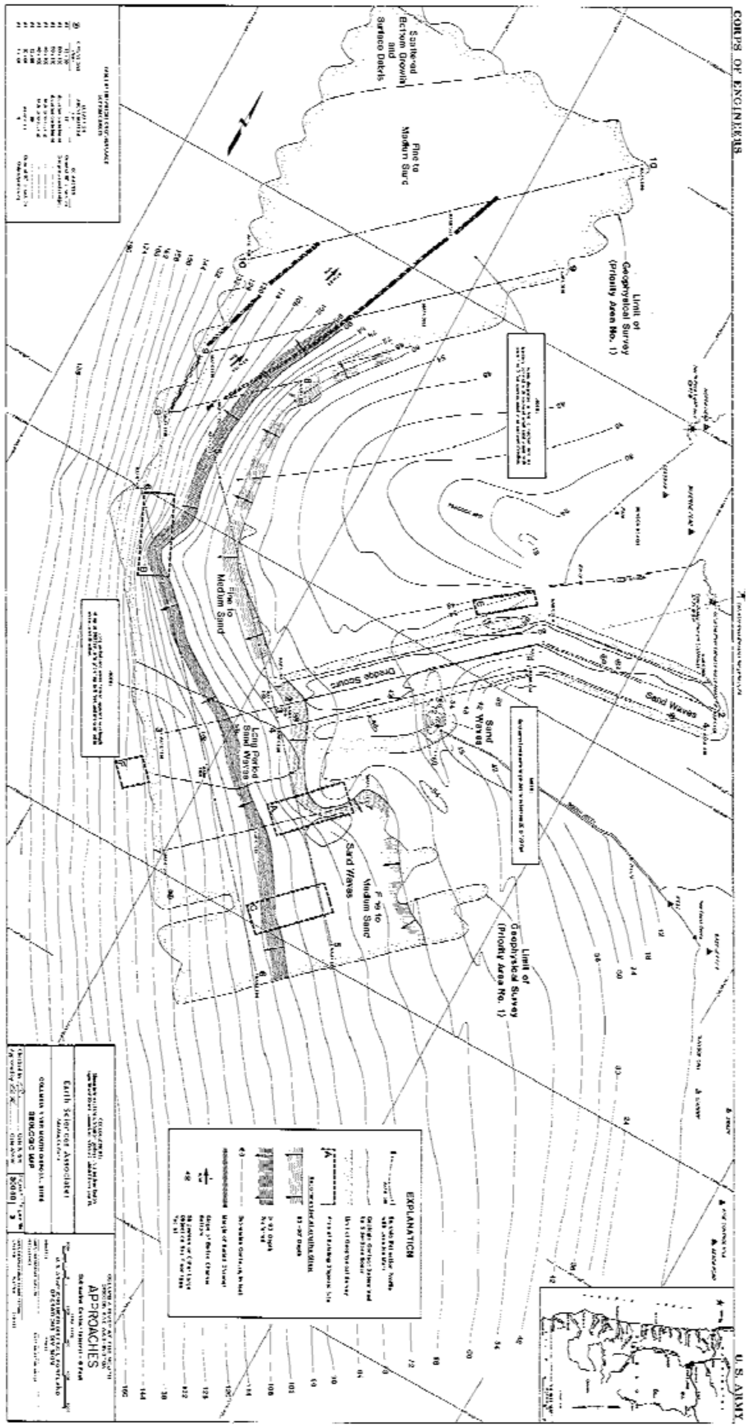


Figure B-5. Geologic Section through 1985 Sub-bottom Profile, Trackline 2

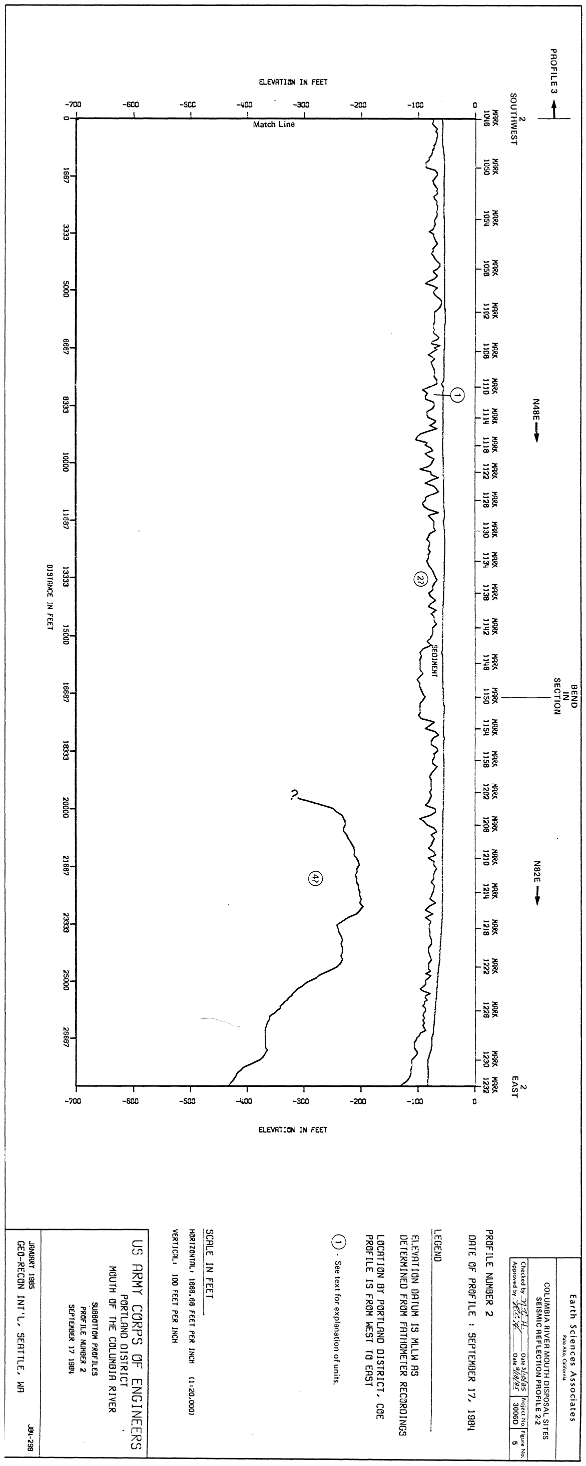


Figure B-6. 1996 Side Scan Plan Map Compared with 1985 Coverage

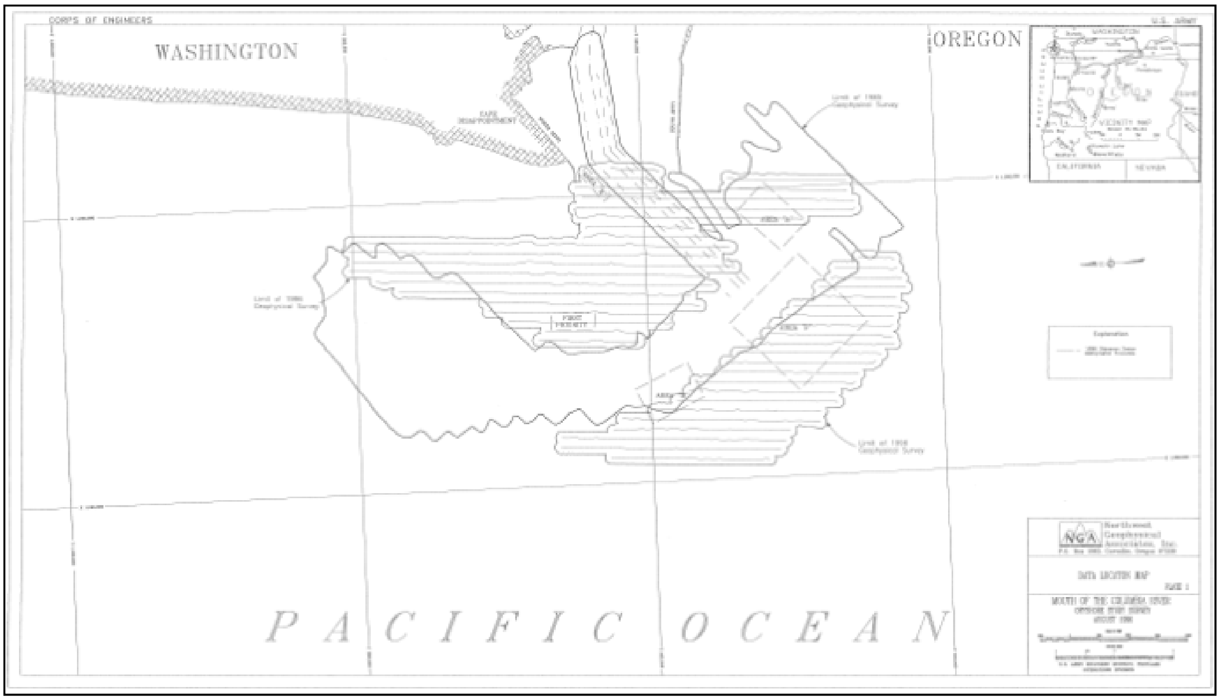


Figure B-7. 1996 Side Scan Survey Results

Bottom Changes Noted between the 1996 and 1985 Surveys

Most of the area of overlap between the 1985 and 1996 surveys appears to be unchanged. The major differences found between the two studies are as follows:

- Sand waves are no longer present in Area “F.”

- Less scour was observed in the channel between the jetties and was replaced by sand waves.
- More scour was observed west of approximately X=1,090,000. Bathymetric changes show the removal of one to two feet of material in the scoured areas.
- Five "other submerged targets" were detected at the mouth of the jetties and do not appear in the 1985 study.
- Three objects shown in the 1985 study as "shipwreck or other large object on sea floor" were not detected by the 1996 survey.
- Significant amounts of material have been added to Areas "B", "F", and "A." Area "B" appears to be as much as 25 feet shallower in 1996 than in 1985.

Other Studies

A side scan sonar survey with accompanying seismic reflection, along with a surface sediment sampling program was undertaken by the USGS in 2000 (Twichell et.al.) to map the distribution of Recent sediment in the Columbia River littoral cell. The study also identified the surficial geology of the inner continental shelf area of southwestern Washington, including the area around the mouth of the Columbia River and adjacent to the north and south jetties. This study confirmed that the inner shelf and lower beach face in the study area around the Columbia River mouth is comprised of between 10 and 50 meters of Holocene sediments with no rock outcrops present anywhere within the study area. Surface sediments were shown to be comprised of fine sand in water depths less than 15 meters depth grading to very fine sand in water depths of 15 to 25 meters.

Information obtained from a Sediment Trend Analysis (STA®) and Acoustic Bottom Classification (ABC) conducted in 2000 (McLaren and Hill) was used to develop an understanding of the mechanisms of sediment transport and inter-relationships among sediment sources and sinks associated with the Columbia River mouth, primarily related to offshore disposal sites. The study, through the tracking of relative changes in grain-size distribution of the bottom sediments, was able to identify areas of net erosion, net accretion, or dynamic equilibrium. Information from the sediment sampling program and acoustic data used with STA technique identified sediment transport pathways in the study area including adjacent to the north and south jetties. Results indicate that net erosion is occurring near both the north and south jetty; however, dynamic equilibrium is present along the inner portion of both the north side of the south jetty and the south side of the north jetty. Seismic reflection lines were run in 2003 in the area between the North Jetty and Jetty A to identify subsurface materials adjacent to the North Jetty for use as a possible sump location for dredged material for eventual distribution onto Benson Beach (David Evans and Associates 2003). Comparing records with vibracore samples taken shortly after the survey (Kaminsky 2003) showed that the entire area was comprised of very fine to medium grained sands with little or no internal structure evident. The top of bedrock dropping away from Cape Disappointment was also identified in the records, and detectable to an elevation of -175 feet MLLW at a distance of almost ½ mile west of the headland.

The lower 6 miles of the MCR and the adjacent offshore dredged material disposal sites were mapped in 2005 as part of a detailed study. The maps created by these multibeam investigations accurately produced bathymetric imagery with contours, along with backscatter imagery (Global Remote Sensing 2005). The resulting bathymetry was used to create an accurate depiction of bottom conditions for numerical models related to this rehab study. The maps created from these investigations have not been compared with the 1996 surveys to identify changes that may have occurred since that time.

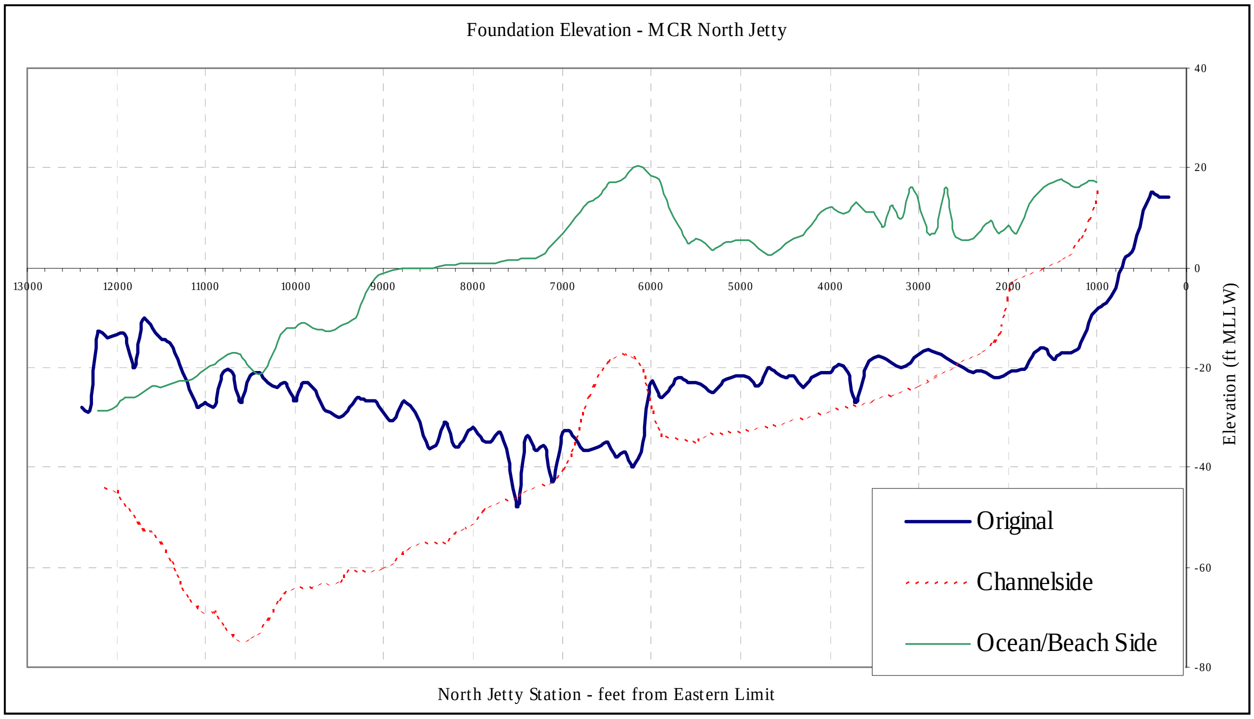
3. FOUNDATION CONDITIONS

No known subsurface explorations have been conducted by the USACE in conjunction with jetty construction. Vibracoring operations have been conducted, however, adjacent to the jetties (Kaminsky and others 2005) for the purpose of evaluating a proposed dredged material re-handling area adjacent to the North Jetty. Information from these cores as well as from cores obtained near the South Jetty during the same study has provided a look at the subsurface materials present adjacent to each jetty. The foundations for original construction of both the North and South jetties consisted primarily of recently deposited fine sand with some mud/sand interbeds. Bedrock is anticipated to occur at depth and is not believed to have been encountered during original construction. Conditions within the current footprint have been interpreted from analyzing multibeam fathometer surveys completed in 1999. The conditions surrounding each jetty foundation are discussed below.

North Jetty

The North Jetty is anchored to the western side of Cape Disappointment, which is a hard, basaltic headland. Bedrock quickly drops beneath the ocean floor and was not encountered during construction. Figure B-8 shows that stone placement during original construction encountered the ocean floor at approximately El. –20 feet MLLW over the majority of the area from Sta. 12+00 to Sta. 60+00. Stone placed at Sta. 60+00 drops to near El. –40 MLLW, then transitions gradually back to near El. –20 by Sta. 108+00. It is not known how much stone settlement has taken place after initial placement, but Figure B-8 indicates that the toe of the jetty is now up to 10 feet deeper than it was during original construction. This is most likely to have occurred from stone displaced from the jetty side slopes and crest having settled along the margins of the jetty slope, rather than from actual settlement from the jetty. Vibracores taken adjacent to the North Jetty indicate that the foundation is primarily well-sorted very fine to fine grained sand with only thin interbeds of laminated mud, silt and sand, interpreted to having been deposited during floods. Radiocarbon dating indicates that the sediment pre-dates jetty construction by at least hundreds of years, indicating that any settlement of the layers had likely taken place long before jetty construction. As a result, this material is less susceptible to compaction upon loading and was shown during vibracoring operations to be dense and hard to penetrate, especially along the inner portion of the jetty.

Figure B-8. North Jetty Foundation Grade during Original Construction

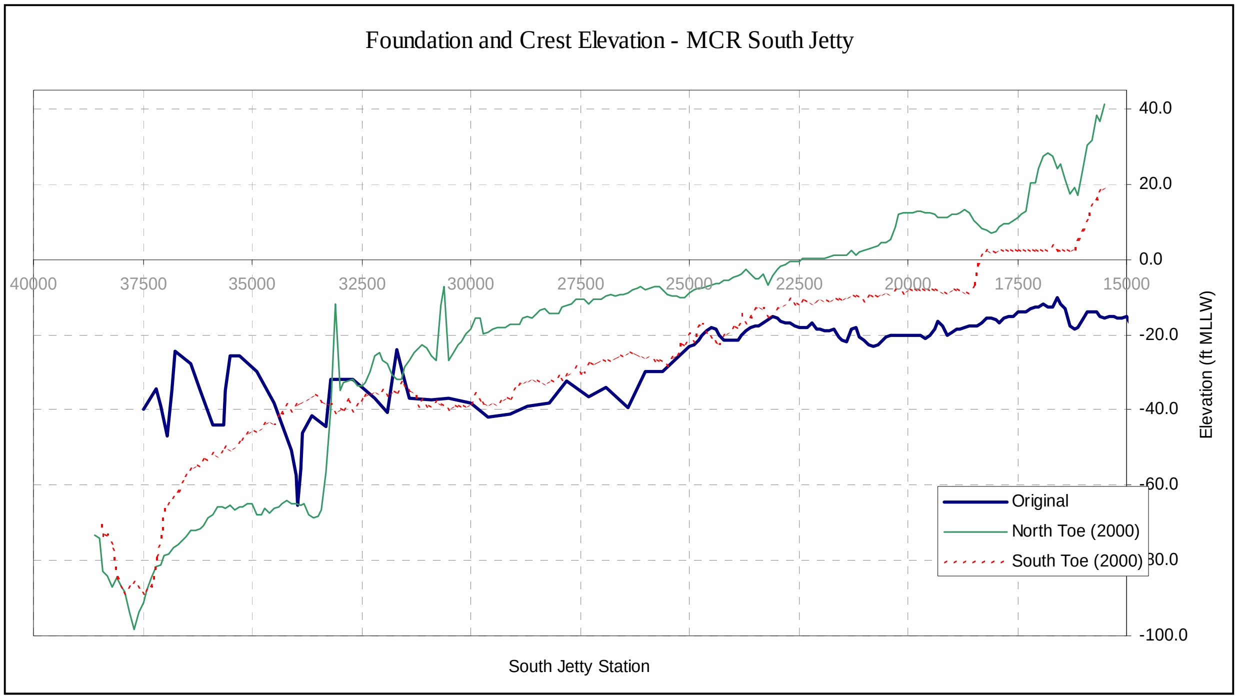


Much of the area within this study has not been repaired since original construction ended in 1917. Stone was dumped from railway cars from the jetty tramway and placement was mostly random. Migration of the channel northward and adjacent to the North Jetty caused undercutting of the stone base, and resulted in side slope failures along a significant portion of the reach under study. The outer edge of exposed rock on the channel side is fairly consistently located approximately 90 feet from the centerline of the jetty between Sta. 40+00 and Sta. 59+00 at an elevation of -30 feet MLLW. Shoaling occurs adjacent to the jetty between Sta. 59+00 and Sta. 70+00. In this area, the exposed edge of the rock side slope disappears beneath the sand approximately 60 feet from jetty centerline at an elevation of about -6 feet MLLW. Side slopes below MLLW are a fairly consistent 1V on 2H from Sta. 40+00 to Sta. 70+00, and then increase to approximately 3V on 4H to Sta. 80+00. Small, localized areas of steepening up to 1V on 1H are present throughout the study area.

South Jetty

Construction of the South Jetty commenced in 1885 at Point Adams, near Ft. Stevens, which is comprised of recent sand deposits. No bedrock is present in the area, and is anticipated to occur at greater depth than the North Jetty. Construction was directed seaward across Clatsop Spit, which is an extension of Point Adams. Figure B-9 shows that the ocean floor was encountered between elevations of -10 and -15 feet MLLW from near the start of the jetty to Sta. 180+00. Between Sta. 180+00 and approximate Sta. 250+00, the ocean floor averaged El. -20 feet MLLW. Jettystone was placed to elevations averaging between –30 and –40 feet MLLW from Sta. 250+00 and Sta. 330+00 for this report. The remainder of jetty construction seaward of this section placed stone at elevations varying between -25 to over -60 feet MLLW. Figure B-5 shows that stone was originally placed at a depth shallower than bottom conditions encountered now from Sta. 330+00 seaward. Analysis of historical bathymetric data adjacent to the South Jetty (Kaminsky and others 2005) indicates that a deeper channel existed beneath the jetty just landward of the knuckle a few decades before jetty construction. Vibracores suggest that thicker mud deposits are present in these buried channels, and since they only predated construction by a few years, it has been hypothesized that dewatering of these mud deposits by loading from jetty construction may have contributed to settlement, translating to recurrent damage to the jetty at this point.

Figure B-9. South Jetty Foundation Grade during Original Construction

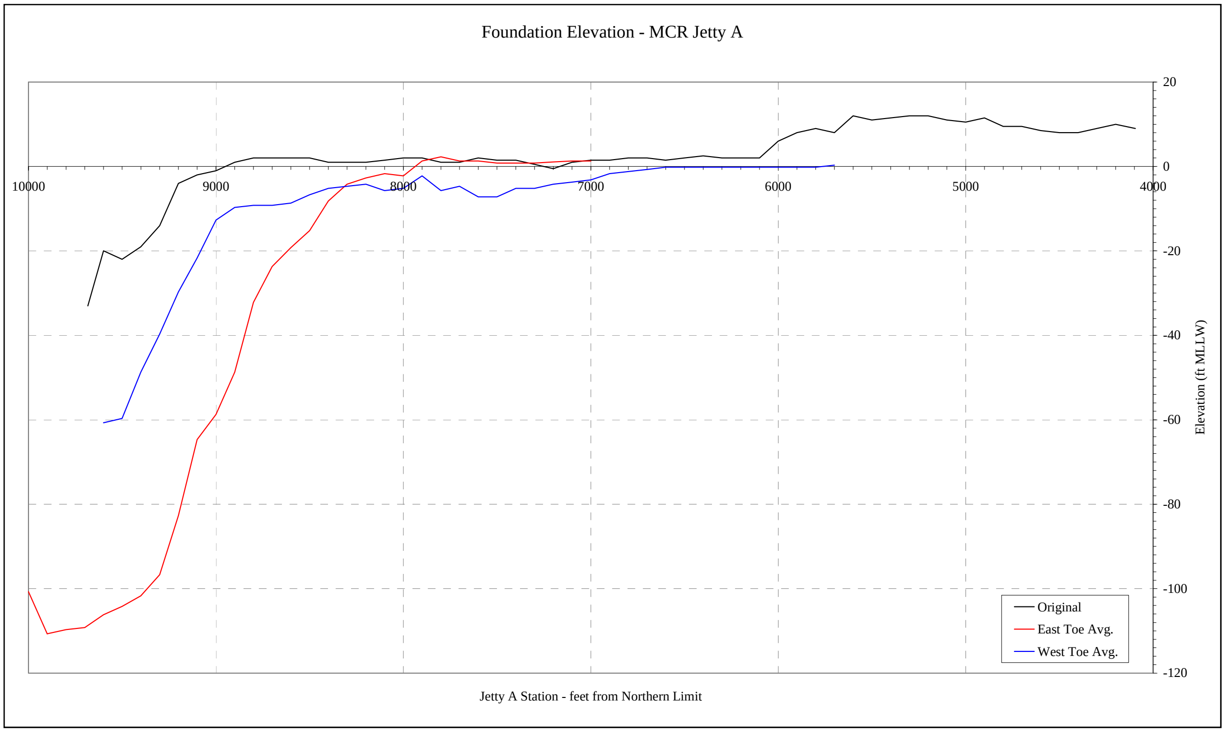


Repeated failures of the South Jetty have distributed a large quantity of stones primarily to the sea side of the jetty. The current jetty cross-section within the study area has been constructed on a relict stone base that has been dispersed between 150 feet to over 220 feet from jetty centerline. The outer edge of relict rock is not always obvious in the survey plots due to lack of data adjacent to the below water slope between the shoreline and Sta. 242+00. While settlement may have occurred along this and potentially other sections of the South Jetty, the numerous repairs provided stone for a substantial relict base and along with over 100 years of foundation loading having occurred, little to no additional settlement is expected along the jetty.

Jetty A

Construction of Jetty A commenced from the southeastern side of Cape Disappointment and was built on an existing sand spit that extended south into the Columbia River. The jetty is anchored to the basaltic headland and was initially constructed above the high tide mark for the first 6,000 feet. At this point, as Figure B-10 shows, the sand spit dropped to an approximate elevation of +2 feet MLLW that extended an additional 3,000 feet to the south. At this point, the sand spit ends and water depths increase dramatically to the south with the end of the jetty founded on sand at El. -30 MLLW.

Figure B-10. Jetty A Foundation Grade during Original Construction



The root of Jetty A remains landlocked on both sides from near the Coast Guard Station to approximate Sta. 50+00. From this point, the western, or sea side of the jetty is exposed to wave action, and the jetty toe has scoured below original foundation grade to an elevation averaging MLLW to approximate Sta. 67+00. The jetty toe beyond this point continues to scour below grade at a fairly consistent slope from MLLW to El. -10 to Sta. 90+00, which is beyond the current head of the jetty. A scour hole occurs just south of Sta. 90+00 on the west toe and drops off to an elevation greater than -60 feet MLLW. The eastern side of the jetty (Baker Bay side) has an above water berm extending from the shoreline to approximate Sta. 79+00. The height of this berm equates to the original jetty foundation grade through this area. Southward of this point, the same scour hole at the end of the jetty is encountered, achieving an elevation of approximately -110 feet MLLW.

No vibracoring operations have been conducted adjacent to Jetty A, however, a geophysical investigation consisting of acoustical sub-bottom profiling and side scan sonar investigation was accomplished in the adjacent Baker Bay channel in 1983 (Northern Technical Services). Results of seismic reflection sub-bottom profiling indicated that bedrock occurred at a depth greater than 150 to 200 feet below the channel bottom. Subsurface materials in the channel adjacent to the jetty section were interpreted to consist of 5 to 10 feet of fine sand overlying a uniform, thick sequence of medium-grained sand probably in excess of 70 feet. Side scan sonar provided data out to 300 feet on each side of the trackline and results also indicate a uniform surficial layer of sand adjacent to the jetty. No evidence of mud interbeds, although found in areas further inland of the jetty, were found in this reach. This indicates that Jetty A is likely founded on fine to medium-grained sand that would provide for a uniform, more solid base that is not susceptible to settlement.

Foundation Design Considerations

While no known foundation borings have been conducted by USACE in conjunction with construction of these jetties which began over 100 years ago, USACE does have a good understanding of the foundation in relation to jetty performance. The original foundation conditions are identified through repeated geophysical testing and subsequent vibracoring operations in the vicinity of the jetties as being comprised of a thick deposit of sands with some minor localized interbeds of mud. These original foundations have been modified and strengthened through the years as a result of jetty stone movement by waves from severe winter storms widening the foundation footprint and have been supplemented with additional material from several repairs to create a significant relict stone base beneath and around the jetties upon which most of these new repairs will be founded.

Repairs to the MCR jetties have occurred multiple times since original construction. Repairs have taken place along most reaches of the jetties with the exception of the root of the north jetty. All areas currently impacted by the most severe conditions have seen repairs. The result of these repairs has strengthened the foundation under and adjacent to the jetties multiple times through successive loading by not only added stone mass but also by land-based repair equipment delivering stone along the jetty to the repair area. Planned repairs to the MCR jetties are not occurring on new, unknown foundations. Foundation borings are not required, as would be performed if these were new foundations. These are existing performance-tested jetty structures with performance-tested foundations. The stability of the jetties were modeled and analyzed for a range of geometries and geotechnical parameters to identify the sensitivity of factors of safety against failure for each various parameter. The likely failure modes identified for these structures have been verified from observing over 100 years of jetty performance.

The predominant failure modes for the jetties, as identified from modeling and discussed in the sections below, have been stone movement due to wave loading and foundation scour impacting the jetty toes. Large waves from winter storms dislodge stones from the upper exposed portions of the jetty and move them down the slope to a more stable configuration. Holes created from dislodged stones effectively destabilize adjacent stones and make them and deeper stones in the slope vulnerable to hydraulic forces. Larger stone size utilization and higher degree of interlocking is seen as the solution to this problem. The scour of sediments at the toe of the side slope is seen as the other major failure mechanism. Lower submerged slopes are most susceptible to failure when they are steeper than 1.5H to 1V and have been subjected to 5 meters or more of scour. Most side slopes are flatter than this though due to dislodged slope stones present on the lower slopes. A short apron of stone placed at the base of the exposed slope would act as a preventative measure to support the slope in areas where accumulated stone at the base of the slope is not already present. Deep-seated foundation failure, such as noted in landslides, has not been observed over the lifetime of the jetties and is not considered a concern. This makes sense from a soil mechanics point of view: deep-seated foundation failures do not occur in granular, free-draining foundation materials that gain strength with increasing depth and effective stress. In addition, the proposed jetty repair sections are no higher in top elevation and no steeper in side slope than the existing jetty sections, which mean they will not produce higher-than-already-experienced shear stresses in the foundation. Results of the analysis presented in the Stone Stability Analysis section below recommends a design foundation shear strength of ϕ' = 34 degrees. Foundation design parameters are identified in Table B-1.

Existing Foundation Stone Stability

Stone present below MLLW throughout the original footprint of the jetties should be fairly well stabilized. Various sizes of rock material within the original footprint, along with sand infilling, have probably created a hard, sound base for future construction. This is based on tough digging conditions encountered during a rock removal project at the outer end of the Yaquina North Jetty at Newport, OR in 1999. That Contract removed rock that had wrapped back around the channel side of the jetty as a result of jetty destruction by waves from winter storms. This "wing" of rock extends below water and encroaches on the navigation channel providing a rougher wave climate in that area. The Contractor had difficulty removing these stones, especially as they proceeded deeper, and in many areas was unable to make the design grade established by that Contract.

Most stones comprising the relict base are fairly well-keyed in, will provide a sound and stable base, and will see little to no additional settlement upon reconstruction. The existence of a relict stone foundation can be verified during construction by "feeling" the bottom with the stone placement equipment. The North Jetty and Jetty A reconstruction will take place primarily on relict stone foundations. Some areas may be at the margin of the relict stone, and other areas may encounter sand overlying the relict base. The South Jetty reconstruction is anticipated to be entirely on the relict stone foundation on the south side of the jetty, with sand foundations occurring on the margins of the north side if flatter slopes are attained. Spur groins placed on the south side of the North Jetty and the north side of the South Jetty will likely encounter a sand foundation except where it ties to the jetty. While these structures are located entirely beneath the water surface and quite small in comparison to the main jetties, it is important that any area encountering sand be prepped with a bedding layer prior to placement of the armor stone to ensure a stable foundation exists.

Deep seated slip surface failures are not likely to occur at the MCR jetties. One main reason that this type of failure is not likely is based on past performance of the jetties, where catastrophic damage involving a significant portion of the side slope and crest has not been observed in over 100 years since original construction. This makes sense from a soil mechanics point of view: deep-seated foundation failures do not occur in granular, free-draining foundation materials that gain strength with increasing depth and effective stress. Damage has been noted to primarily progress through time from the outer slope inward to the center, typically involving a single armor layer at a time. A second reason this type of failure is unlikely is that the original sand foundation underlying the jetties is protected from undermining and subsequent failure by an armored outer slope created by jettystone displaced during failure of original and subsequently repaired sections of the jetty.

Stone Stability Analysis

Stability of the MCR jetties was analyzed for a range of geometries and geotechnical parameters presumed to be representative of existing jetty conditions. Parameters used are listed in Table B-1. For each parameter, minimum likely, most likely, and maximum likely values were developed. There is insufficient information to develop a standard deviation. The range of values developed is based on judgment. Because of the extensive nature of the jetties, there are numerous combinations of possible geometries and uncertainties in parameters; analyses were done with a range of values to determine the sensitive of the factor of safety against failure for various parameters.

A significant aspect of this analysis was to develop a reasonable estimate of the internal hydraulic pore pressures within the jetty mass; in particular, the excess pore pressure between the stones as the ocean wave recedes after impact. This pore pressure is required to do the computations. However, the pressure distribution during storm events within the jetty is unknown. To provide this required parameter, a transient seepage analysis was conducted using the finite element software product SeepW, developed by GEO-SLOPE. The model is shown in Figure B-11. This analysis used one-half of the height of a storm wave train measured offshore of the jetties and modified to convert wave velocity to equivalent pressure as input into the seepage model. The output results from this seepage model were examined, and the highest positive pressure differential between the pressure beneath representative jetty stones and the ocean was used as the maximum likely excess pore pressure. The most likely pore pressure was taken as one-half of this value and minimum likely pore pressure was taken as zero differential pressure.

Stability analyses were accomplished using SlopeW - a limit equilibrium slope stability program developed by GEO-SLOPE. Geometry of the model is shown in Figure B-12. The model considered the geometry of the slope; materials weight and shear strength, estimates transient excess pore water pressures due to wave impact, and recession. The model took into account partial submergence of the jetties. Seawater was modeled as a force acting normal to the surface of the jetty and seabed. This representation was done to eliminate problems associated with inter-slice forces when modeling water as a zero strength material.

The factor of safety against failure of the jetty was calculated for the most likely condition. In addition, the factor of safety was calculated for each case where only one parameter was changed to minimum and maximum likely values while holding the others unchanged from the most likely value where possible. A few cases where depth of seabed was changed required other changes in geometry as well. The results of the analyses are also shown in Table B-1. Sensitivity of the various parameters is shown in Figure B-13. The results suggest that the stability of the jetties is sensitive to three primary parameters. These are in order of importance: the internal pore pressures (effects of waves impact and recession), shear strength of the mass of stones (quality of stacking or construction), and amount of exposed sediments below the base of jetty due to scour.

Table B-1. Geometrical, Mechanical, and Hydraulic Parameters used in Analysis and Results

Parameter	**Description**	**Adopted Range of Values & Factor of Safety**		
		Minimum Likely (FS)	**Most Likely (FS)**	**Maximum Likely (FS)**
Jetty Slope	Most likely value represents design above water surface, 1V:1.25H represents oversteepened or eroded condition, 1V:1.75 H represents flattened slope below water and degraded slopes.	1V:1.25H **FS=0.87**	1V:1.5H **FS=1.06**	1V:1.75H **FS=1.28**
Jetty Stone Mass Weight	Most likely value is based on laboratory tests of typical basalt used in construction of the jetties (165 pcf ±5 pcf). Mass weight of the jetty was then adjusted to reflect that the most likely jetty mass is estimated to be 75% stone and 25% voids. For the low end lower stone weight (65%) and voids (35%) was used and for the high end heavier jetty stone weight (85%) and voids (15%) was used. Unsaturated weight above and saturated weights below ocean level were used. Jetties are partially submerged so that sea-water (1.026x fresh water) was represented using a hydrostatic force applied to seabed and jetty.	Unsaturated 17.8 kN/m^3 Saturated 20.9 kN/m^3 **FS=1.01**	Unsaturated 19.7 kN/m^3 Saturated 22.3 kN/m^3 **FS=1.06**	Unsaturated 21.6 kN/m^3 Saturated 23.7 kN/m^3 **FS=1.10**
Jetty Stone Mass Shear Strength	Shear strength of the mass jetty stone is based on judgment. Most likely value is assumed to be 45° with a range between minimum and maximum values of 30° and 60°. A low value of 30° would represent poorly stacked stone that would tend to slide easily. This value is slightly lower than typical natural angle of repose for dry granular material and maybe reasonable for submerged conditions. High end represents well-stacked stones interlocking that would stand as very steep walls.	30° **FS=0.63**	45° **FS=1.06**	60° **FS=1.53**
Base Depth of Jetty (Original Depth of Water)	Most likely value is assumed to be -8 m with a range between minimum and maximum values of 6 m. Thickness of jetty stones varies with original depth of water that jetty was built on. Jetty is thinner near shore and becomes thicker as progresses in deeper water further off shore. This parameter captures the effects along the length of jetty. There is some overlap with Depth to Seabed parameter. In this model, minimum likely value (high base of jetty) is similar to having 5 m of seabed scour.	-5 m **FS=0.82** **FS=1.26 w/ debris apron**	-8 m **FS=1.06**	-11 m **FS=1.10**

Table B-1 (continued). Geometrical, Mechanical, and Hydraulic Parameters used in Analysis and Results

Parameter	Description	Adopted Range of Values & Factor of Safety		
		Minimum Likely (FS)	**Most Likely (FS)**	**Maximum Likely (FS)**
Underlying Marine Sediments Mass Weight	Most likely value is assumed to be 19.7 kN/m^3 with a range of 0.9 kN/m^3 (125 ±5 pcf). Based on typical values for unconsolidated saturated sediments.	19.7 kN/m^3 **FS=1.05**	20.6 kN/m^3 **FS=1.06**	21.4 kN/m^3 **FS=1.06**
Underlying Marine Sediments Shear Strength	Based on judgment. Most likely value is assumed to be 32° with a range of 4° - typical value and range for unconsolidated silty fine sand. There should be a correlation between underlying marine sediments mass weight and shear strength. As the density of the sediment increases the shear strength would increase.	32° **FS=1.04±**	34° **FS=1.06**	36° **FS=1.08**
Ocean Surface (Tide Level)	Most likely value is taken as 0 m with a range of 2.4 m. Most likely value represents mean sea-level and the extremes represent high and low tide conditions.	-1.2 m **FS=1.04**	0 m **FS=1.06**	1.2 m **FS=1.10**
Depth to Seabed (Current Elevation)	Most likely value is 10 m and represents the depth to base of jetty. There is some overlap of this parameter and base depth of jetty. Depth of seabed becomes deeper as scour occurs and amount of the underlying marine sediments is exposed. This parameter captures the effects of seafloor scour at any given stationing.	-5 m **FS=1.07**	-10 m **FS=1.06**	-15 m **FS=0.95**
Impact of Storm Waves	Parameter represents hydraulic impact of storm waves on stability of jetty stones. Value is very uncertain and conceptually based on estimating the differential hydraulic pressure that develops within the jetty using a simplified seepage model that accounts for transient pressure flow conditions. Estimated peak positive differential pressure (acting outward) is 1.6 m. This occurs during rapid wave recession of water as it drains. Conceptually, greatest pressure may not correspond to highest wave but would occur during a rapid recession following a long period of high water such that may occur with two interfering wave patterns with two waves nearly coinciding in time. This could result in longer period of time to drive water into the jetty that fills more voids. This larger quantity of water cannot drain in the short period during a rapid recession and, thus, result in higher differential pressure.	0 m **FS=1.44** (Instant free-draining)	0.8 m **FS=1.06** (0.5 x estimated hydraulic pressure due to 32 foot maximum wave)	1.6 m **FS=0.53** (Estimated hydraulic differential pressure due to maximum wave)

Figure B-11. Storm Waves Model Internal Jetty Pore Pressures

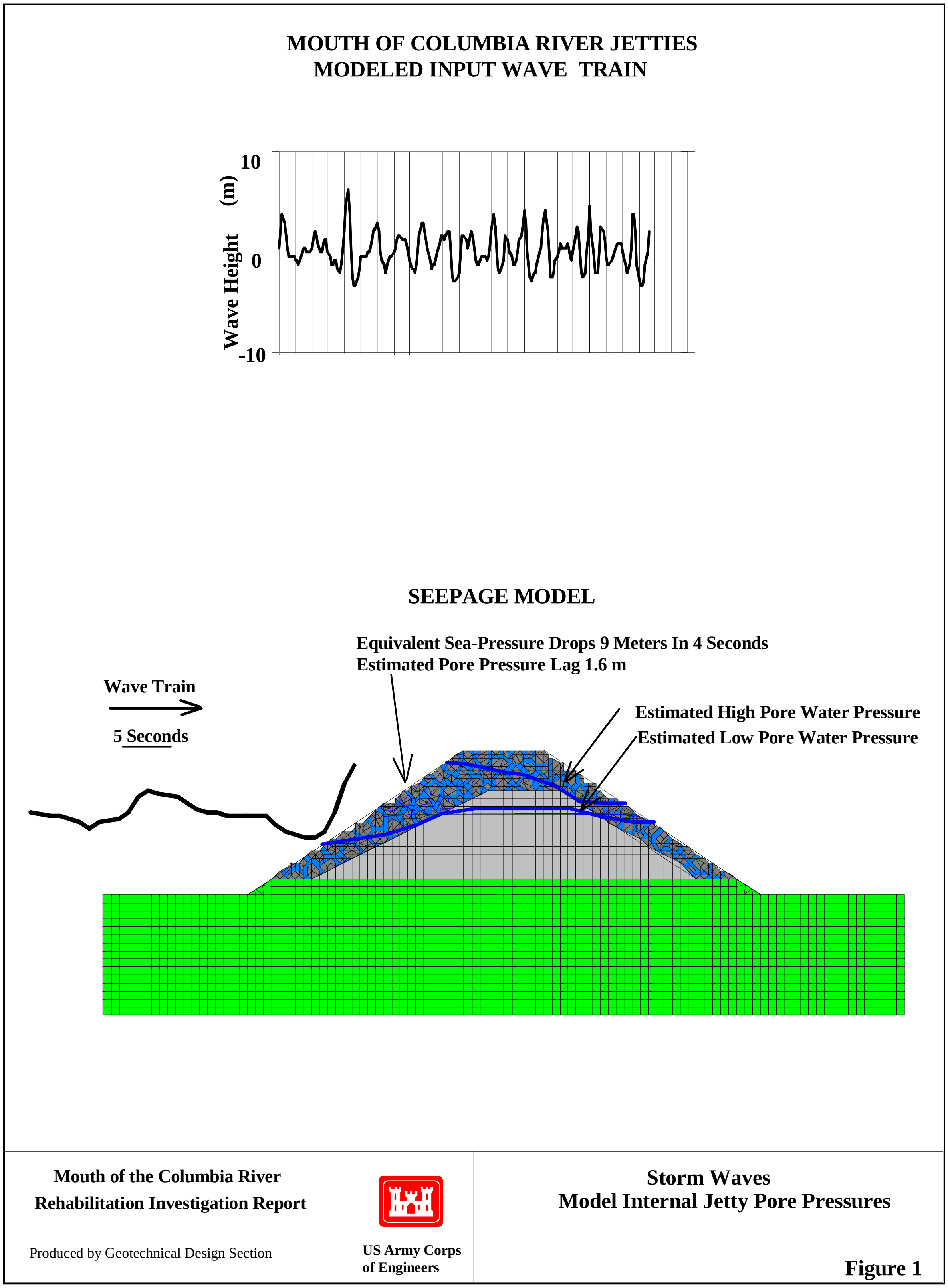
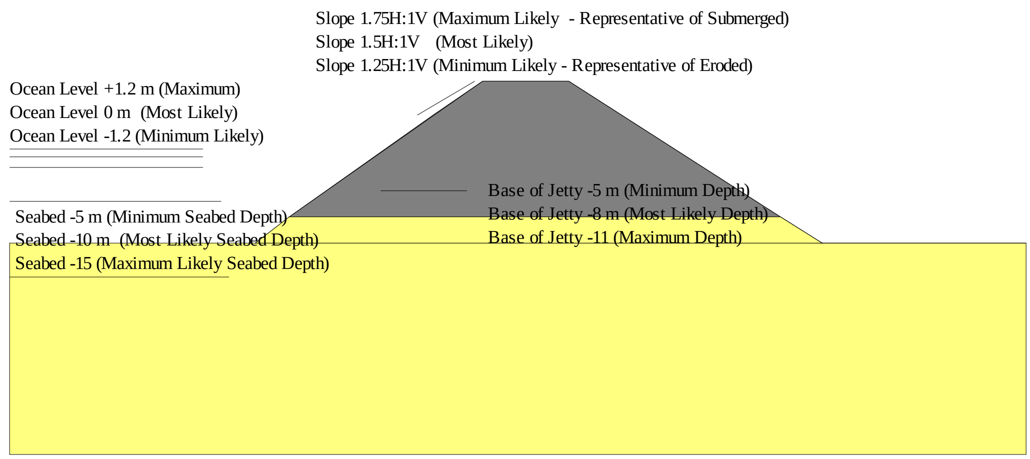


Figure B-12. Stability Model



STABILITY MODEL

Mouth of the Columbia River
Rehabilitation Investigation Report

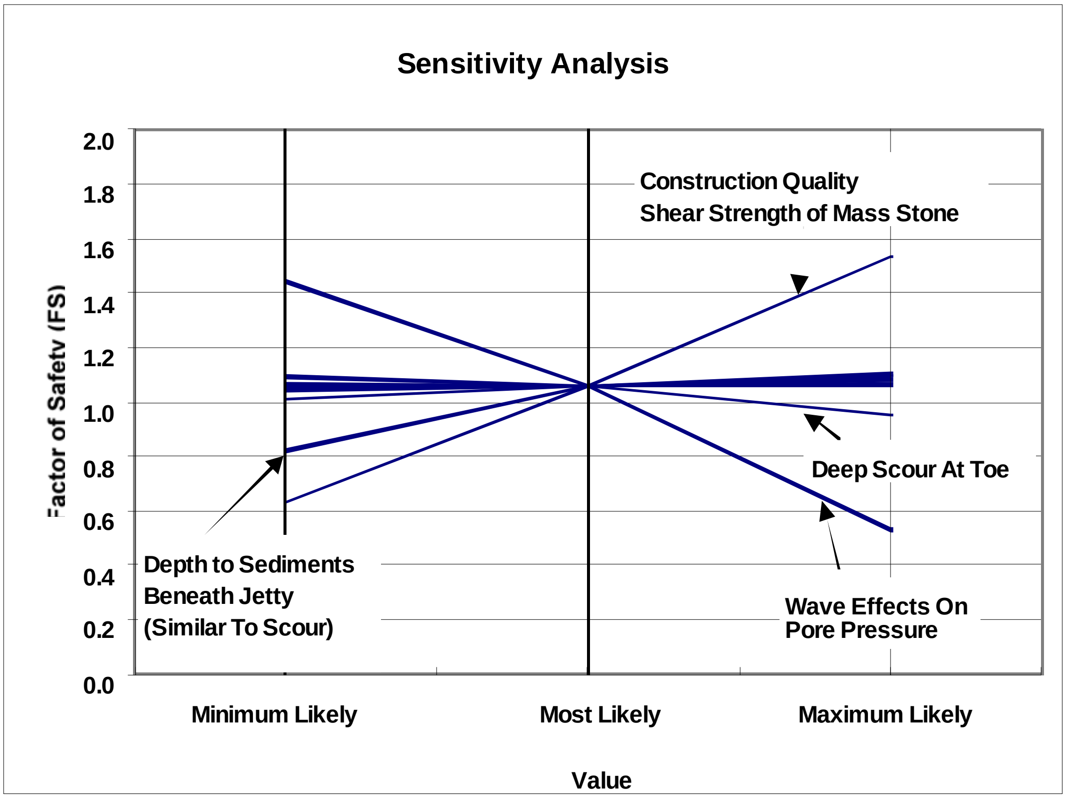
Produced by Geotechnical Design Section

US Army Corps of Engineers

Stability Model

Figure 2

Figure B-13. Sensitivity Analysis



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Sensitivity Analysis

Figure 3

Transient internal hydraulic effects of wave impact may be the most important parameter in the stability of the jetties. However, it is the least certain of all of the parameters. Internal hydraulic pressures in jetties have not been measured. In addition, it is extremely difficult to model, as there is nothing to calibrate a model against. Intuitively, period of excess pore pressure acting outwards occur during the period of most rapid wave recession. Slower wave recession or smaller waves do not generate as large of excess pressures. Stability analysis indicates that the outer layer of stones is least stable (shallow failure planes) with factors of safety dropping significantly below one (below point of stable equilibrium). Even though a factor of stability of less than one indicates that a stone can move, other factors are involved such as interaction with neighboring stable stones. Once all of the conditions are met, a stone will begin to move. However, movement may be restricted to a short period when factor of safety is less than one and all other conditions are met. Consequently, because of the large mass and inertia of a stone, it may only move a small amount before it comes to rest. Therefore, failure may be more in the form of gradual "walking" of the stone out of position and slow degradation of the jetty during periods of intense wave activity. Once one stone is removed, the neighboring stones may become less stable and susceptible to movement. Stones would accumulate at the toe and, thus, flatten the lower submerged slope of the jetty. Once a stone or layer is removed then hydraulic forces will increase their effects on to the exposed deeper stones. This may lead to continued progressive erosion and degradation of the upper or exposed portion of the jetty.

The second major factor is the shear strength of the mass of jetty stones. This factor represents the stone shape and how well stones are placed. Zones of low mass shear strength can occur where individual stones may form a smooth outward sloping surface or internal plane due to the way stones were placed. Internal planes may result from placing stones on a previously eroded and repaired erosion surface with little interlocking between the new stones and the older mass. Failure again would probably be progressive with small incremental movements occurring during recession of storm waves. Conceptually, continued movement of stones will gradually flatten the slope, which would result in slowing and self-arresting of failure by this mechanism.

The third major factor is scour of the sediments at the toe of the jetty. Analyses suggest that 5 meters of scour will decrease factor of safety sufficiently to lead to failure of 1.5H to 1V slopes. However, most slopes below the water surface are flatter than this and, consequently, this may not be as important of a factor as the analyses suggest. Analyses suggest that the lower toe of the slope where sediments have been exposed are most susceptible. Failures tend to daylight at the toe of the slope. Hence, a short apron of stone placed as preventative measure or as the result of movement and accumulation of moved stones would reduce the risk of this failure mechanism.

4. STONE REQUIREMENTS

Stones to be utilized for repair for the MCR jetties will need to meet the Portland District's minimum requirements for jetty stone as shown in Table B-2. Supplemental test requirements that may be required by the Government based on visual analysis also are shown in the table. Laboratory test data, or service records from previous contracts, will be necessary for approval. The largest hurdles for quarries to pass for providing stones for this job will be the size of the stones required. Depending on the repair templates for various reaches on each of the jetties, stone gradation will range from 5 to over 40 tons. Due to increased wave climate realized along the coast since original construction, larger stones will be needed to provide the necessary stability factor. Few quarries are available to produce the stone size necessary for this job. The other hurdle is the sheer volume of material required to repair the jetties. Estimates range into the millions of tons of jetty stone needed to repair the jetties to the recommended design templates.

Table B-2. Portland District Minimum Lab Testing Requirements for Jetty Stone

PRIMARY TESTS	REQUIREMENT
a) Unit Weight	Minimum of 165 lb/ft^3 but may vary per job
b) Absorption	Not more than 5.0 percent
c) Abrasion-500 revolutions	Not more than 20.0 percent loss (by weight)
d) Magnesium Sulfate Soundness -5 cycles	Not more than 15.0 percent loss (by weight)
e) Accelerated Expansion	Not more than 15.0 percent breakdown (by weight) or piece count

SUPPLEMENTAL TESTS	REQUIREMENT
f) Wetting and Drying - 80 cycles	Not more than 15.0 percent loss (by weight)
g) Freezing/Thawing - 100 cycles	Not more than 15.0 percent loss (by weight)
h) Petrographic Examination	Absence of weakness or materials that could result in significant stone alteration and reduction in durability
i) X-Ray Analysis (Spectrographic and Diffraction)	Absence of deleterious clays or other minerals that could result in significant deterioration of rock quality

It has been observed that armor stone damage through time has not been an issue relating to jetty damage. Portland District has strict armor stone quality requirements that have been in place for more than 50 years which provide for a more durable stone in the coastal environment. The very nature of the stones, being volcanic and metamorphic, has been demonstrated through time on the jetties as not being susceptible to much wear or breakage. Most existing broken stones found on the jetties were damaged during original placement with very little additional damage noted in later years. Broken stones account for probably less than 1% of the total jetty volume and do not impact the overall structural integrity of the jetty. Wear depends on the particular stone used and where in the template it is used (lower slope vs. crest). Most stones conforming to the 50-year old test requirements show minor wear to the point that they don’t impact the interlocking or cohesive nature of the jetties. A large percentage of the stones used during the original construction of the MCR jetties conformed to these current quality standards and are still performing adequately to this date.

5. QUARRY MARKET SURVEY

A quarry market survey was undertaken to help identify potential quarries that could supply stone for the jetty repairs. The primary purpose of this study was to identify potential quarries that have the capability to produce large-sized jettystone for upcoming jetty rehab work. With a projected 1.3 million tons of stone required for both North and South jetties and Jetty A, significant investigations will be required by the Government to verify that sufficient quantities of stone exist and are capable of being mined for full stone repair alternatives. The survey consisted of contacting potential stone suppliers in the anticipated market from Oregon, Washington, northern California, and southern British Columbia, usually within 200 miles of the Pacific Coast as identified in Figure B-14. Owners were questioned about their rock sources concerning the size of stone able to be produced from the quarries, type of rock, laboratory testing done, size of quarry and potential minable reserves. A few of the larger potential quarries that had not been previously visited were then investigated for the potential to produce stones for these repairs. Based on the large amount of stone needed for the repairs, it is anticipated that no single quarry will be used for producing the amount of material we’ve identified, but more likely a combination of quarries over multiple years will be necessary to produce the stone required in the timeframe needed.

Stone Sources for Jetty Repairs

Given the large amount of stone required for rebuilding the jetties, it is conceivable that several quarries may be utilized to produce and deliver the amount of stone needed within the time frame required. The majority of stone may likely be supplied by sources in northwestern Washington or one or more of several potential sources that exist in Canada, on or adjacent to Vancouver Island in British Columbia. Smaller amounts of stone may also be supplied by any number of local sources in Oregon and Washington within 100 miles of the MCR jetties, and by quarries near Eureka in northern California. Only quarries actually investigated for this study, or visited by Portland District personnel in the past, are presented here. Locations of the quarries discussed in the following sections are shown on Figure B-15 and described in Table B-3.

Figure B-14. Potential Quarry Areas by Region

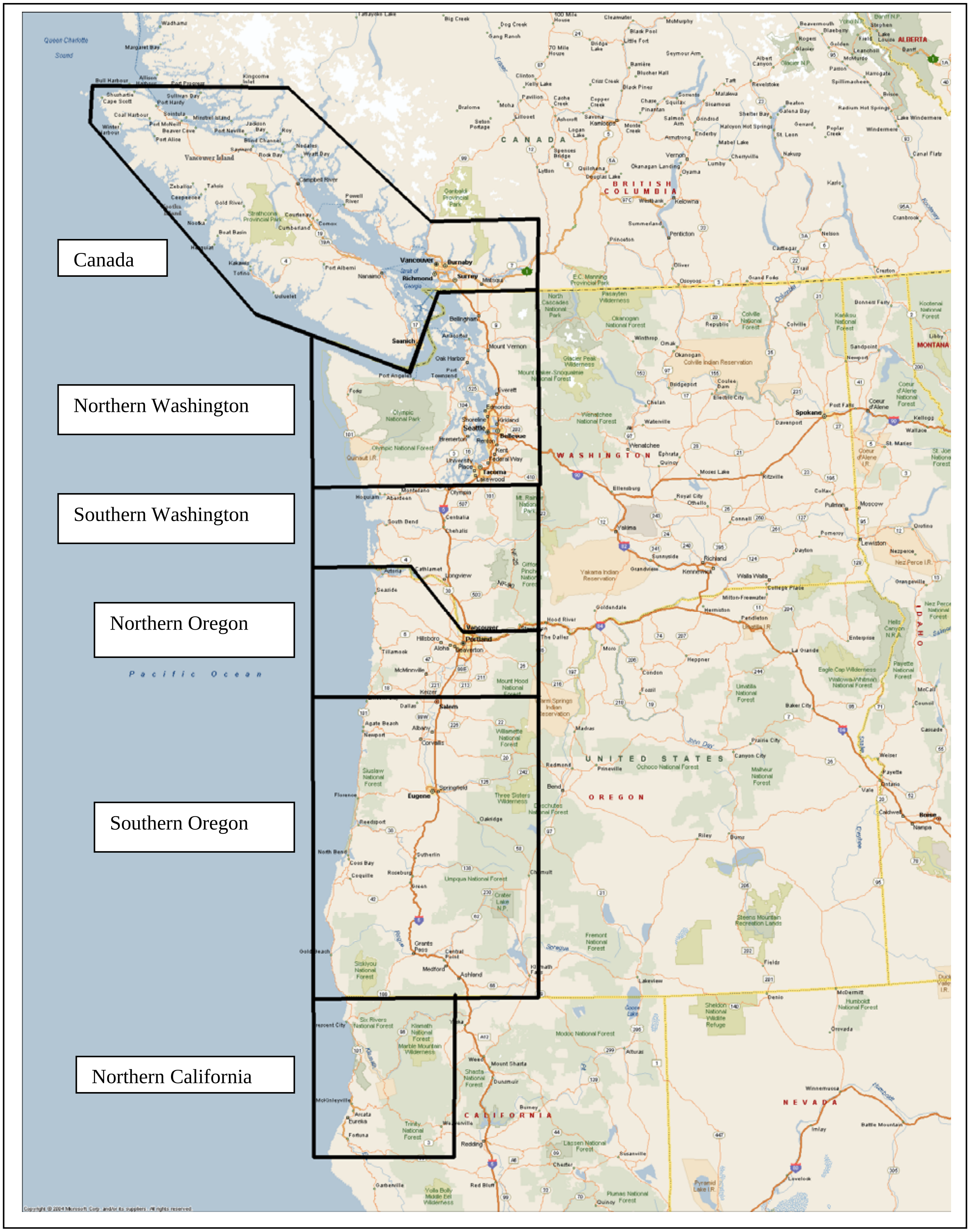

Figure B-15. Potential Quarry Locations (red dots) for MCR Rehab

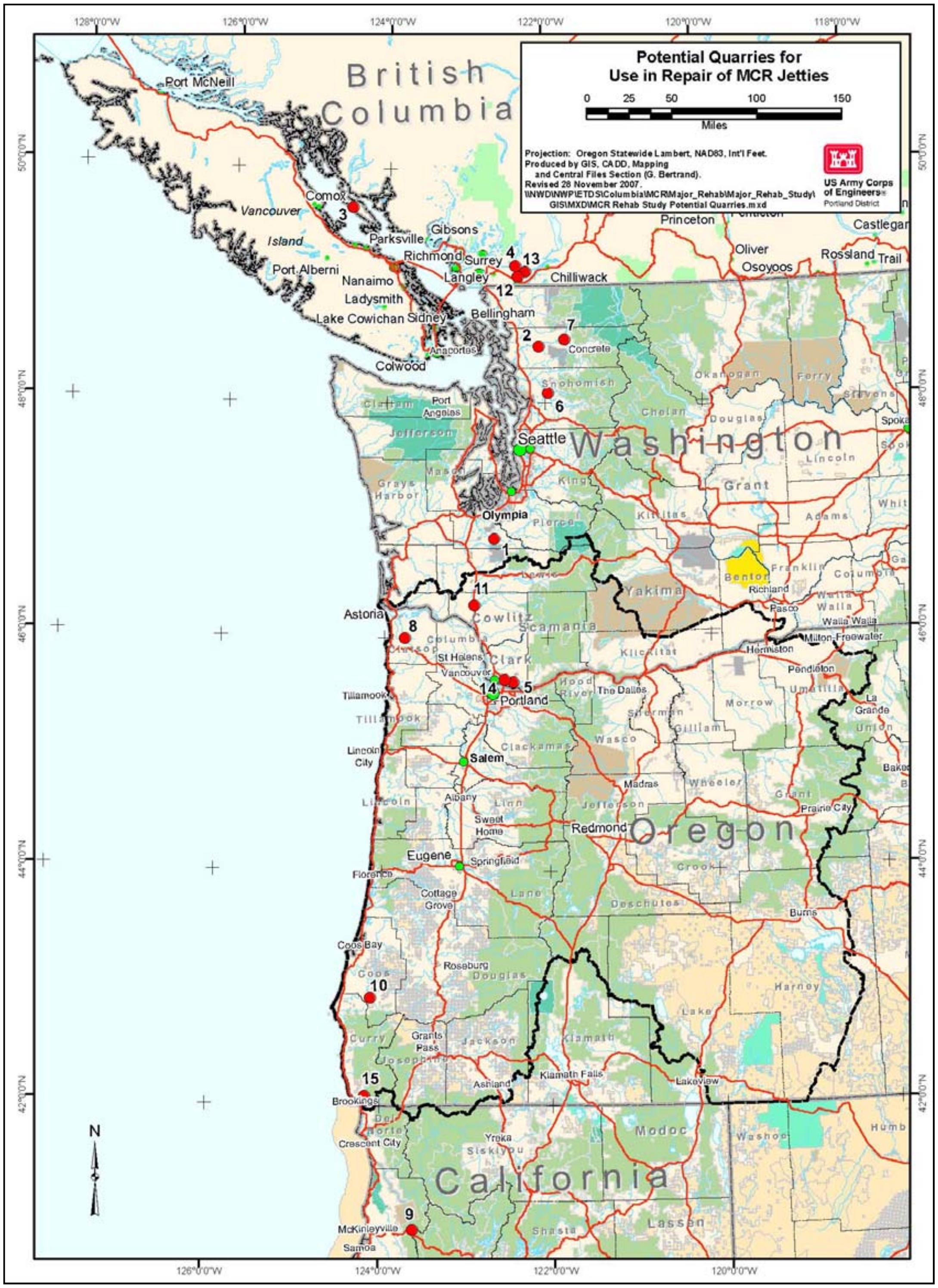

Table B-3. Potential Jetty Stone Quarries for MCR Rehab

Photo No.	Quarry	County, State	Nearest City	Road Miles from MCR	Unit Weight (pcf)	Reserves Available (tons)	Likely Transportation Method	Nearest Barge Facility
1	Columbia Granite Quarry	Thurston, WA	Vail, WA	129	168.5	28 M	Truck	N/A
2	Beaver Lake Quarry	Skagit, WA	Clear Lake, WA	251	181.1	1.86M	Truck, then Barge	Anacortes, WA
3	Texada Quarry	BC, CANADA	Texada Island, BC	363	173.5+	275M	Barge	Onsite
4	Stave Lake Quarry	BC, CANADA	Mission, BC	311	169.1	74M	Truck, then Barge	Mission, BC, Canada
5	192nd Street Quarry	Clark, WA	Camas, WA	109	168.5	0.5M	Truck/ Barge?	Camas, WA
6	Iron Mountain Quarry	Snohomish, WA	Granite Falls, WA	225	174	?	Truck	N/A
7	Marble Mount Quarry	Skagit, WA	Concrete, WA	276	189.7	2M	Truck, then Barge	Anacortes, WA
8	Youngs River Falls Quarry	Clatsop, OR	Astoria, OR	20	181.8	0.5M+	Truck	N/A
9	Liscomb Hill Quarry	Humboldt, CA	Willow Creek, CA	515	179.1	0.5M	Truck, then Barge	Eureka, CA
10	Baker Creek Quarry	Coos, OR	Powers, OR	275	200	?	Truck, then Barge	Coos Bay, OR
11	Phipps Quarry	Cowlitz, WA	Castle Rock, WA	69	167.4	0.5M	Truck	N/A
12	Cox Station Quarry	BC, CANADA	Abbotsford, BC	313	167.9	150M	Barge	Onsite
13	Ekset Quarry	BC, CANADA	Mission, BC	309	172.2	10M	Truck, then Barge	Mission, BC, Canada
14	Fisher Quarry	Clark, WA	Camas, WA	108	168.5	2M	Barge	Camas, WA
15	Bankus Quarry	Curry, OR	Brookings, OR	347	183 and 195	0.7M	Truck, then Barge	Crescent City, CA?

Northern Washington Stone Sources

Stone sources used for the project that are located west of the Cascade Mountains and north of Seattle would exist and be permitted quarries. It is also possible that permitted but undeveloped rock sources may be utilized for stone. This would come into play especially if a stone supply contract were awarded for multiple years to produce jetty stone. The Contractor may have an undeveloped stone source that he may develop especially for this work. Most of these quarries would likely be located within 50 miles of Puget Sound. Known quarries that have likely potential to supply stone for the repairs are listed below.

Beaver Lake Quarry. The Beaver Lake Quarry is located just east of Mt. Vernon in Skagit Co, WA. It is leased by Meridian Aggregate which primarily produces crushed aggregate for Forest Service access roads. This quarry was used by the USACE Contractor Kiewit in 2001 for the Yaquina North Jetty Repairs and produced approximately 33,700 tons of jetty stone for that Interim Repair Contract. Kiewit had approximately a 20% yield for usable material during these mining operations. The quarry is a rock monolith located in an outwash plain left from the last Ice Age, which ended around 10,000 years ago. Continental glaciers stripped off the overburden and any surrounding softer material, leaving only the more hard material in place. The rock was originally volcanic in origin, probably a pillow basalt, that was metamorphosed into a greenstone, or metabasalt. Rock conforms to all Portland District standards and has a unit weight of 180 lbs/ft^3. The rock monolith is quite massively jointed which tend to produce large sized material. There seems to be at least 3 main joint sets running through the rock body. These occur at intersecting angles, which tends to create stones with a blocky shape. Joint spacing appears to be quite variable, ranging from 3 feet to over 20 feet. Additional work, such as splitting, is required in many instances to obtain the sizes necessary.

As of 2006, the remaining intact rock body has approximate dimensions of 600 feet by 300 feet long through this base section and averages about 75 feet high above the ground surface. The waste rock from all mining operations has been pushed over the south and east faces of the rock body. Based on the dimensions of the remaining rock body, plus knowledge from the reclamation plan that mining will occur to one lift below the ground surface, estimated at 40 feet, total remaining in-place reserves are guesstimated to be 1.86 M tons. If the achieved 20% yield is applied, an estimated 370,000 tons of jettystones are still available for use from this quarry. Stones from this quarry that were utilized at Portland District jetties were hauled approximately 26 miles by truck to Anacortes where they were loaded on barges and shipped down the coastline.

Marblemount Quarry. The Marblemount Quarry is located approximately 5 miles west of the North Cascades National Park near Rockport, in Skagit County, WA. The existing quarry actually occurs in a talus slope at the base of a 400-foot high cliff. There is an estimated 800,000 cubic yards of material present at the base of the cliff. Many large sizes of rocks are present in the slope with occasional rocks to over 200 tons visible. Rocks tend to break big with many sizes greater than 10 tons present in the stockpile. Actual percentage of large sizes present in the talus slope is not known at this time, but it appears to be quite high. A small portion of the talus slope has been mined for the production of rip rap in years past. No estimate on how much material has been removed so far, but it has only made a small dent in the total amount. The rock cliff is near vertical and extends approximately 400 feet high from the base of the quarry floor. The cliff extends along the entire front of the 38 acre parcel which is calculated to be approximately 1300 feet long. The owner indicated a cat road has been built up to the top of the cliff from the west side, but little work has been done up there. No blasting has ever been conducted at the site, as more than enough material is present in the talus slope for current uses. Examination of the cliff face shows that the rock is massive and will tend to break into large sizes.

Petrographic analysis has not been performed on this material; however, the rock appears to be a metavolcanic breccia. The rock has a greenish color, due to alteration of feldspar minerals to the mineral chlorite. Some relict structure is still present. The rock is fresh and hard. Material from this quarry has been tested and passed all Portland District standards. Rocks have a unit weight of almost 190 lbs/ft^3. Stone from this quarry has never been used as jettystone, but was used at one time by local agencies for riprap along the Skagit River before it was classified as a Wild and Scenic River. Haul distance to the nearest barge on-loading site in Anacortes is about 67 miles one way.

Iron Mountain Quarry. The Iron Mountain Quarry is located just outside of Granite Falls, which is approximately 15 miles NE of Everett, WA. This is a large quarry that has been in operation since the1980s. The quarry owns part of the land and also has a lease with Weyerhaeuser for the remaining portion. The quarry is approximately 500 acres in size. The quarry is active and produces a variety of material sizes ranging from crushed aggregate through riprap. Larger stone sizes exceeding 15 tons are capable of being produced. The quarry is located on a large hill and contains multiple areas being mined. Jettystone sizes were observed in oversized stockpiles present on the top of the quarry. Rock consists of metamorphosed sedimentary rock with remnant bedding very visible in the quarry and mined stones. Variability of visible rock characteristics does exist within the quarry; however, stones appear to have similar engineering properties. The rock was tested to Portland District standards in 2005 and passed all tests. Stones weigh approximately 170 lbs/ft^3. This stone has been used by Seattle District for some of their projects and has performed satisfactorily. Minable reserves have been estimated to exceed 30 million tons. Stones would likely be trucked directly to the jetties, but may be on-loaded to a barge facility in the vicinity of Everett, WA, within 20 miles of the quarry.

Southern Washington Stone Sources

Rock sources in southern Washington would primarily be existing quarries with the possibility of permitted, but undeveloped rock sources being opened up to supply some of the large amount of stone necessary for construction. Stone sources would most likely be distributed east of I-5 closer to the Cascade Range, but selected deposits, especially intrusive bodies, may occur at any location within the region. Here again, most quarries will be west of the Cascade Range.

Columbia Granite Quarry. The Columbia Granite Quarry is located approximately 10 air miles southeast of Tenino, Washington. The quarry, located on Weyerhaeuser land, has a long history of use when it was known as the Skookumchuck Quarry, but had been inactive from the late 1940's until the late 1990's when it was purchased by private sources. Stones from this quarry have been used by Portland District on the Columbia River North Jetty, Jetty A, and Yaquina North Jetty, MCR North Jetty, and by Seattle District for rehabilitating the jetties at Westport, WA. This quarry has been developed in a large intrusive sill and consists of rock described as both a gabbro porphyry and a diorite. It is uniform medium-dark gray, medium crystalline, fresh, and hard. Little variation in composition or surface expression exists within the quarry. This quarry has massive jointing characteristics which give the capability to produce large stone sizes with a shape conducive to facilitate good interlocking. The stone tends to break in tabular shapes, due to the intersecting nature of the jointing. When specialized blasting techniques are applied, a very high yield can be achieved. This stone also has the characteristic of being able to resist abrasion, which creates a higher coefficient of friction on the surfaces, and also tends to hold the shape better in a marine environment through time. Rock from this quarry has been tested at approximately 168 lbs/ft^3 and meets all of the Portland District standards. Minable reserves have been estimated to be approximately 28 million tons, with adjacent properties containing even more amounts. Stones would be trucked directly to the jetties, or to a barge loading facility in Aberdeen, WA for transport down the coast.

Fisher Quarry. Fisher Quarry is located approximately 3 miles west of Camas, Washington, adjacent to the Columbia River. CEMEX USA owns the property. The quarry is presently active and produces a variety of crushed aggregate and riprap sizes. Stones from this large quarry have been used on many of Portland District's jetties, both during original construction and in subsequent repairs. Quarrying operations have continued continuously for over 100 years. The quarry is developed in a thick andesitic basalt lava flow and produces rock with a unit weight of around 168 lbs/ft^3. Stone quality is quite consistent in this quarry. Stone shape varies depending on where in the quarry the stone is mined. Some areas, especially near the volcanic vents present in the quarry are platier, which produces a more tabular shape, where other areas will produce stone with a more equidimensional shape.

Remaining reserves for this quarry have been estimated at 2 million tons. Quantities, however, are limited for large rock production, and this quarry is considered to only be able to produce a small portion of the overall quantity of stone necessary. Essentially, stone contained in the outer margins or the northern rim of the quarry comprise the remaining resources for most of the jettystone. Rock from this quarry meets all of the Portland District's quality standards. Fisher Quarry has a private barge loading facility located just across the highway from the quarry on the Columbia River, and is located approximately 116 river miles upstream from the MCR.

192nd Street Quarry. This quarry is located immediately east of the Fisher Quarry, approximately 3 miles west of Camas, WA. The property is now owned by Sierra Pacific Communities, which recently bought it from the State of Washington. It is currently the site of the new 192nd Street Interchange which has recently been built through the quarry. Prior to that, a lease agreement with the operators of the Fisher Quarry existed from the mid-1960's to 1986 during which time both quarries were operated collectively under the Fisher Quarry name. This quarry has produced jettystone for many of the jetties in the past while under the Fisher Quarry name. The quarry is developed in the same lava flow as the Fisher Quarry and the rock weighs approximately 168 lbs/ft^3. As with the Fisher Quarry, large jettystone production is limited to along the margins of the quarry. Stone shape is the same as for the Fisher Quarry, and varies depending on where in the quarry the stone is mined. The quarry is estimated to contain 5-7 million tons of reserves, however, only a portion of this is available for producing jettystones. Quarry Direct Stone Sales, Inc., the company hired to manage the mineral resources, has been directed to move a half million tons of material by the year 2011, and are interested in possibly supplying large stone for upcoming jetty jobs. No barge loading facilities are currently available to the operator. Either a deal would have to be made with Fisher Quarry to utilize their existing loading facility, or another facility would have to be found.

Phipps Quarry. The Phipps Quarry is located on Weyerhaeuser land in the Hollywood Gorge area east of Castle Rock, in Cowlitz County, WA. The quarry is leased by Tapani Underground, Inc., which acquired it for use on the MCR North Jetty repairs in 2005. The quarry appears to be founded in a large diabase sill on a logged off hillside. The sill is estimated to be at least 130 feet thick and has intruded pre-existing sedimentary rocks, some of which contain coal seams. The top contact of the rock body is exposed in some places. Very little overburden is present on much of the surface, but the thickness increases as you proceed into the hillside. The area encompasses several acres, and includes reserves estimated at 11 million tons. The stone is very hard in places, blocky and angular, except for the margins of the rock body where platy jointing is present. Variability in stone size exists within the quarry with some areas being able to produce stones larger than 20 tons. Some iron stained joints are present on mined stones, but this is primarily surficial and doesn't affect the overall quality of the stone. The stone has passed all Portland District standards and weighs approximately 167 lbs/ft^3. This stone has been used by Seattle District for the Ocean Shores jetties, and Portland District has used this source for repairs to the MCR North Jetty in 2005. Stone from this quarry would most likely be trucked the entire distance to the jetties, estimated to be approximately 75 miles.

Northern Oregon Sources

Northern Oregon stone sources would probably be existing active quarries. Few quarries with any substantial reserves located within 50 miles of the MCR jetties have the capability to produce large-sized stones that would be acceptable for use in jetty repairs. Many of these sources can produce a few large stones and these are usually incidental to their normal operations. Many times the quarries will temporarily set aside these stones to be broken up into more manageable sizes later. Due to the close proximity of the quarries to the repair sites, it may be economically feasible to transport these few existing stones from these quarries, as a way to supplement the total amount required. Some sources may also occur as far away as the Cascade Range. Stone sources at this distance may need to have a larger supply of existing large stone on hand to make it economical to move sorting and loading equipment on site. The following quarry is included as a potential source due to the close proximity to the MCR jetties.

Young's River Falls Quarry. The Young's River Falls or Drake Quarry is located adjacent to the upper end of Young's Bay, south of Astoria, OR. It is located on Weyerhaeuser property and is currently leased by Big River Excavating. The quarry is founded in a basaltic dike that is part of a ring dike structure found in the area. The quarry was originally opened in 1960 for repairs to the MCR South Jetty. It has also been used in 1976 for the Hammond Boat Basin breakwater and the interim repair contracts for the MCR North Jetty in 2005 and South Jetty in 2006 and 2007. The rock is a medium gray, medium to coarsely crystalline diabase. Jointing varies between 2 and 5 feet which tend to create stones that are long and slabby. Most stone surfaces are angular with the exception of those stones mined close to the weathered margins of the dike. Many stones have some iron stained surfaces that do not detract from the overall engineering properties of the rock. The rock has passed all Portland District lab tests for jettystone and weighs approximately 182 lbs/ft^3. This quarry is located about 20 miles from the MCR South Jetty.

Southern Oregon Sources

There is a smaller likelihood that stones may be utilized from this area for upcoming MCR jetty repairs. The reason for this is that most quarries in this area that can produce large stones are smaller quarries located at some distance away from jetty repair areas, as well as at larger distances from barge on-loading facilities. These stone sources are most likely to be active, permitted quarries with known capability of producing large stone. Many quarries that fall within this area are located near the coast; however, a few quarries are also present closer to the I-5 corridor. The quarries closer to I-5 are less attractive due to the large distance required to transport the stone to the MCR jetties. Quarries that have been visited by Portland District personnel that could potentially be included are identified below.

Baker Creek Quarry. The Baker Creek Quarry is located just west of the town of Powers, OR, about 70 miles southwest of Coos Bay. The quarry is owned and operated by the BLM, Coos Bay District. This quarry contains very dense and very hard metamorphic rock on the order of 200 lbs/ft^3. This quarry was utilized for the repair of the Coos Bay South Jetty in 1963-64. The quarry is currently permitted for utilizing stone for road base, but environmental assessments need to be completed and filed prior to any major mining. This quarry has the capability of providing large size stone. Jointing characteristics present in this quarry will produce stones of a more tabular shape. The stone is also very hard and durable, but is also hard on quarrying and handling equipment. Stone from this quarry would likely be hauled by truck to a potential barge loading facility in Coos Bay for further transport to the jetties. Reserve quantities are unknown at this time. Even though this quarry is small in nature and quite some distance from a barge on-loading facility, due to the high density of the stone, it could potentially be an important source of stone for the repairs.

Bankus Quarry. The Bankus Quarry is located approximately 7 miles east of Brookings, OR just north of the Chetco River. The quarry is owned by South Coast Lumber Co. and has been in operation since the late 1950s. The quarry has produced jettystone for the Chetco River Jetties in 1958, 1963, and 1995. Stones were also produced in 1981 or 1982 for use at the Crescent City, California jetties. The quarry operation is divided into 2 areas. The quarry is located in the remnant of an exposed knob of rock located on a hillside. Most of the knob exposed above ground has been excavated, with only the back portion of the present lift located within the hillside remaining. Overburden has been only partially removed along the back side of the remaining lift. The quarrying operation started on the east side of the rock body and has proceeded west. A stockpile area containing jettystones is located to the north of the quarry in an unprepared area just south of a creek. A large quarry floor is present to the east of the quarry face. The floor measures approximately 250 feet long and perhaps 200 feet wide. A fairly large stockpile area is associated with this quarry, located in an undeveloped area to the north of the quarry and extending to an east-flowing creek. Stones produced for various jobs have ranged in size from 10 to 25 tons. The quarry has the potential to produce additional stones within the range of 15 tons to over 25 tons, based on jointing observed in the quarry face.

The rock present in this quarry is a fine to medium crystalline metavolcanic rock that has been brecciated and subsequently healed with green mineral seams. The mineral seams do not control rock breakage. It is medium gray-green in color, primarily fine grained with coarser crystalline clasts visible. The rock is fresh, hard, dense, and pit quality. Abundant seams of quartz are present along joint seams. Also present are small amounts of calcite, pyrite, and muscovite. The rock mass is fairly uniform in composition but some variation does exist in color and grain size. Two distinct colors of rocks were mined from this quarry for the Chetco South Jetty repairs in 1995. Samples selected during this contract were found to be of two separate unit weights.

The quarry face has a somewhat blocky appearance due to the intersection of joint sets. Three primary joint sets are present in the quarry face; one parallel to the quarry face, one set vertical and perpendicular to the quarry face, and one set parallel to the quarry floor. Most of the joints are tight and fresh, but many have been opened as a result of blasting. Open joints exposed to water have a stained surface, primarily limited to less than 1/4 inch. Joint spacing is variable and ranges from 2 to 10 feet. The stones in the stockpile tend to be quite irregular to rhombic in shape. The axes of the stones are pretty much equidimensional as opposed to being elongated in one direction. Most stones have at least two sharp edges created by intersecting joints, with other edges being somewhat rounded.

Laboratory tests were run by the Northwestern Division Materials Laboratory in June of 1982. A lighter colored stone weighed out at approximately 183 lbs/cu ft. and a darker colored variety weighed out at 195 lbs/cu ft. Results of tests performed indicated specific gravity was 2.85 (177.6 pcf). The LA abrasion test resulted in a 9.2% loss at 500 revolutions. Absorption was 0.8%. Accelerated expansion by immersion in ethylene glycol gave no action.

An additional rock body was available for mining immediately adjacent to the Bankus Quarry. This rock body, indicated by a large, mostly vegetated hill approximately 200 feet in diameter and 100 feet high based on the present quarry floor elevation, is located just northwest of the existing quarry and just west of the stockpile area. A creek flows on the north side of the rock body. This additional source is not covered by the existing permit. The owners are going to go through the permitting process to have it included. A representative from DOGAMI has looked at this site and indicated that it should not be a problem to have it included. The rock body supposedly contains the same rock material as the Bankus Quarry. If all the above assumptions hold true, this would allow for additional reserves to be developed.

Reserve quantity estimates for this rock source are based on both the existing quarry exposures as well as the adjacent additional rock source. A conservative estimate of reserves in this quarry is 270,000 cubic yards of material. Material from this quarry would likely be trucked to a suitable barge loading facility, perhaps in Crescent City, for transport up the coastline to the MCR jetties. Even though this quarry is small in nature and quite some distance from a barge on-loading facility, due to the high density of the stone, it could potentially be an important source of stone for the repairs.

Northern California Sources

Stones produced from northern California quarries have been utilized for jetty repair on the northern Oregon coast in the past. Stones from these, as well as other quarries in the area are still being produced. The quarries to be utilized for this work are primarily permitted, existing quarries that have proven capability to produce large stone. Most of the known quarries that have produced large stone in this area are located near the coast within about 20 miles of Eureka. The only larger quarry visited by NWP personnel is listed below.

Liscom Hill Quarry. The Liscom Hill Quarry is located approximately 8 miles east of Arcata, California, north of Eureka. The quarry is near the top of a fairly steep grade and is owned by Simpson Timber Co. The quarry is presently leased by Mr. Art Tonkin of Tonkin Construction Co. Stones from this quarry were used in the 1991 repair of the Tillamook North Jetty. Haul distance from the quarry to the barge facility in Eureka, CA is about 18.5 miles. This quarry was last visited by Portland District personnel in 1993.

The quarry operation is divided into 2 areas. The quarry is located in the remnants of an exposed knob of rock located on a hillside near the top of a ridge. Most of the knob exposed above ground has been excavated, with only a small corner remaining. A stockpile area is located lower on the hillside, below and west of the quarry. A bench of tailings or waste rock is present between the quarry floor and the stockpile area. This bench is about 15 feet above the quarry floor and is approximately 300 feet long (from the stockpile East to the quarry floor) by 200 feet wide (parallel to the quarry face). The bench is presently used as a staging area for the quarrying operation. The quarry has been excavated in lifts with the back of the present quarry floor now below ground level. Overburden is still present on the back and side margins of the quarry. The hillside slopes bordering the quarry have been flattened to an approximate 1V on 1H slope. The boundary between the bench and the quarry floor is the approximate western boundary of the rock body. The quarry floor dimensions are approximately 300 feet long by 250 feet wide. Rock body dimensions at the quarry floor are approximately 300 feet in diameter.

The quarry face is located on the north side of the quarry floor in the remaining rock mass comprising the present lift. The quarry face is triangular in elevation view and is rectangular to somewhat convex-shaped in plan view, generally facing west and south. The quarry face dimensions are approximately 50 feet high by 50 feet long on a side. The intact rock body appears to extend only an additional 50 feet behind the quarry face. The quarry face has a blocky appearance due to the presence of 2 prominent joint sets. Overburden consists of residual soil from surrounding rocks which incorporates the pod. Overburden is present along the quarry margins adjacent to the hillside. Water is present on the quarry floor. This appears to be surface water collected into shallow ponds as no springs are evident in the quarry limits. Groundwater is probably present in the area, however, as a drainage ditch present on the north side of the quarry operations leading from the quarry floor area does contain a small amount of running water.

A large stockpile area is associated with this quarry, located lower on the hillside to the west of the quarry and is primarily built on waste rock from the quarrying operation. Stockpile dimensions are approximately 450 feet long by 200 feet wide. The western edge of the tailings bench forms the eastern side of the stockpile area.

The rock present in this quarry is a metavolcanic breccia. It is medium-dark gray-green in color, primarily fine grained with occasional medium grained clasts visible. The rock is fresh, hard, dense, and pit quality. A chlorite mineral is present on some joint surfaces. Open fractures are stained yellow-orange. Occasional quartz, feldspar, and blebs of pyrite are present. The rock mass is fairly uniform in composition but some variation does exist in color and grain size.

The quarry face has a somewhat blocky appearance due to the intersection of joint sets. Two prominent joint sets are present in the remaining lift. The surfaces of these joint sets range from fresh to stained, depending on tightness of the joints. Many of the tight joints opened by blasting or excavation have a coating of a chlorite mineral. Open joints exposed to water have a stained surface, generally limited to less than 1/4-inch. Joint spacing ranges from 1 foot to greater than 5 feet for each joint set. A few discontinuous, incipient joints are present, primarily opened by blasting and excavation.

The stones in the stockpile tend to be quite irregular to rhombic in shape. The axes of the stones are pretty much equidimensional as opposed to being elongated in one direction. At least one surface on

most stones has a stained weathered surface of an open joint or an opened joint containing a chlorite mineral.
Laboratory tests were run by the Northwestern Division Materials Laboratory in March 1991 for stone to be used on the Tillamook North Jetty repair. Tests indicated specific gravity was 2.87 (179 pcf). The LA abrasion test resulted in a 7.7% loss at 500 revolutions. Absorption was 0.4%. Accelerated expansion by immersion in ethylene glycol gave no action. The quarry has the capability to produce additional stones within the range of 15 tons to over 25 tons, based primarily on stones present in the stockpile. Recovery rate for large stones was estimated by Mr. Tonkin, who is presently leasing the quarry, to be 15%-20%.

Canadian Sources

Several sources have been identified in southwest British Columbia adjacent to Vancouver Island. Many quarries are present on smaller islands in the Straits of Georgia east of Vancouver Island and in the terrain east of Vancouver. These are all existing quarries that are currently operating and producing stone, primarily granitic in nature. These quarries predominantly have large reserves and have the potential to supply large stones. The following quarries were inspected by Portland District personnel in 2006. Other prospects have since been identified but as of yet, not been permitted or inspected.

Texada Island Quarry. The quarry is located approximately 2 miles north of Gillies Bay on the western side of Texada Island, BC, between the Canada mainland and Vancouver Island. The quarry is owned by Lafarge North America and is operated by Texada Quarrying Ltd. This quarry is one of the largest in Canada, supplying primarily limestone products to various markets. The property was originally developed as a limestone quarry with production beginning in 1945. The magnetite skarn mineralization was developed and mined starting in 1952 in the form of 4 mines. These started out as open pit mines but eventually went underground to go deeper. A headshaft was sunken 850 feet into granitics and the ore body has since been mined out. The limestone portion of the quarry is 325 acres and produces a variety of limestone grades, including a pure calcium form for cement production, chemical and agricultural grades, as well as crushed aggregate and riprap. There isn’t much market for the granitic rock at this time; however, the company is interested in developing the granite resource as well. The quarry property comprises a total of 2,500 acres. The granitic intrusion has an estimated 250 million tons of mineable reserves.

The granite portion of the quarry is located on the west side of Texada Island. The granite extends from the water level to the top of the hills adjacent to the shoreline in the vicinity of three of the four existing iron mine excavations in the area. To date there has been limited mining of the granite stone, primarily on the southern portion of the intrusion. Quarrying operations in the granite were mostly associated with the mining of the iron mines. In each instance, the iron mines have been excavated back in the hillside around the mine. The character of the rock in the excavated areas appears to be heavily fractured due to blasting of the ore body; however, some massive areas are present as well. Outcrops of rock both in the excavation as well as adjacent to the mining operations reveal a more massive appearance and are probably more characteristic of rock in the area. Based on observations of jointing in these outcrops, it appears that large stone sizes could be produced. It is known from mining operations that the granite body extends at least 850 feet below sea level. Adequate areas are present for stockpiling of stone as well as storage of waste rock. Overburden is very shallow in all areas.

The granitic rock present in this quarry is classified as either a granodiorite or quartz monzonite. The granite types tend to be a light gray to pinkish gray in color. All are predominantly fresh, hard, and dense. Diorite dikes found in the limestone quarry are light greenish- gray in color and are of medium crystallinity. It also is fresh, hard, and dense. All types of rock present seem to have similar engineering properties.

No stockpiles of granite stones were available to see what shapes were produced from quarrying operations. Intersecting joint sets observed in outcroppings indicates that blocky to tabular shapes would most likely be produced, but also irregular shaped stones would also be produced. Diorite dike stones present in the limestone quarry tended to have a blocky shape due to the intersecting joint sets, but there were also irregular shaped stones present as well.

The quarry has the capability to produce granitic stones within the gradation of 2 tons to over 40 tons in size, based primarily on jointing observed in outcrops and mine excavations. Jointing in the rock mass, as described above, indicates that the capability to produce stones greater than 30 tons exists. The quarry has never conducted blasting tests to determine what sizes or yield would be available if actually mining for large stones. True yield would be known only if blasting were carried out to create the larger sizes. The quarry is very large and has large resources available for production of granitic stone without impacting its current production levels. The quarry lacks equipment capable of efficiently handling large stones, but would be willing to acquire that equipment for stone production.

Specific laboratory tests have been run by the quarry reportedly to Portland District standards. The quarry’s laboratory is located onsite, and ran tests specifically on the granitic stones. The lab is not a USACE validated laboratory, so it is not known if actual modified ASTM tests used by Portland District were run. All required tests were run and the unit weight of the stone varied between 173.5 and 193 pcf. Samples will need to be taken of the various materials from this quarry and will be tested to Portland District standards to verify results.

The quarry is located immediately adjacent to water on the west side of Texada Island. Water is deep at this location and a deep draft barge loading facility is present on site. The quarry regularly loads and ships material on ocean-going barges. The granite body to be mined is located near shore as well, so minimal hauling of stone would be required to load onto a barge.

Stave Lakes Quarry. The quarry is located approximately 45 miles east of Vancouver, BC and about 6 miles north of the District of Mission. The quarry is owned by Barry Holmes, who permitted the quarry in 1992 and developed it shortly after. The quarry property is 72 acres in size, permitted for 67 million metric tons of material, and is all mineable except for 6 acres. The quarry is located on the north side of the Fraser River on the east flank of a series of north-south-trending hills. The quarry operation originally started at the base of the hill, immediately behind the existing scale shack. This had limited storage space, so mining operations were developed at the crest of the hill in a flatter bench area. Mining is currently taking place only in this area. The quarry occupies a space of approximately 5 acres where mining occurs on several faces and benches. Rock appears to be fairly massive in both locations and should have the capability to produce large jettystones with a decent yield. Development in the upper quarry area has proceeded to where the thin layer of overburden has been stripped and benches have been excavated starting at the top and working down, which will be developed back into the hillside. Rock in some of these areas is more massive in nature, but joints and fractures are present that tend to limit the sizes and amounts of large stones that can be produced. The quarry plan is to develop the upper portion back into the hillside as far as the permit boundary, then bench down to the level of the lower quarry floor. A berm must be left in place between the quarry and the road to the east, so residents will be less affected by quarrying operations. The only holes drilled in the quarry area were for water monitoring purposes. It is not known how deep those holes were drilled, or details of the rock properties, but granite was encountered to full depth.

The rock present in this quarry is variable in nature but is all granitic in character. Most types fall into a granite, granodiorite, quartz diorite or gabbro rock classification. Rock varies in color but most are predominantly light gray to pink. The quartz diorite and granite are coarsely crystalline while the gabbro and granodiorite are predominantly fine to medium crystalline. All are predominantly fresh, hard, and dense. All types of rock present seem to have similar engineering properties.

Jointing is variable within the quarry with some areas being more massive than others. Three main joint sets are present with the principle joints intersecting at near right angles to produce a blocky-shaped stone. There are also lesser joints of various angles with variable spacing that control the shape of stones and tend to limit sizes in many places. Sheeting joints, or areas of multiple close-spaced parallel jointing, are present in some places that are parallel to the ground surface and usually occur near the top of the rock body. Jointing varies in width but substantial areas exist with joint spacing exceeding 7 feet in width. Areas observed within the upper quarry that have this wider joint spacing occur in the western upper bench, as well as the lower eastern bench area. The lower quarry area at the bottom of the hill near the scale shack also appears to have a wider joint spacing. Exposed outcrops show that jointing can exceed an estimated 5 feet in width, which will help to produce larger stones. This indicates that there is the potential for wider joints through the entire mineable rock body. The joint surfaces appear to be primarily fresh and tight with no obvious signs of staining. The general exception occurs in those areas near the ground surface.

Two main stockpile areas are associated with this quarry. The lower quarry area near the scale shack is a temporary storage area where material produced from the upper quarry is transported and stored. The second, and larger stockpile area, is located at the top of the hill in the active portion of the quarry. These stockpile areas are used primarily for crushed aggregate. There is a temporary stockpile of riprap and larger sizes present in the southern portion of the quarry floor. Stones in the stockpile vary in size up to greater than 6 feet in diameter. No permanent stockpiles of large material, such as jettystone sizes are present in the quarry. Large jettystone sizes are produced incidental to the blasting operation that is designed for crushed aggregate. Approximately 20 or so stones in the 10 to 30 ton range were observed on the lower and upper benches in the upper quarry. The stones present in the temporary stockpile areas tend to have a blocky shape due to the intersecting joint sets. There are also irregular shaped stones as well. Most of the larger stones observed are massive and do not contain multiple joints that tend to control the breakage of stones into smaller sizes. Most stones break along the joints rather than through the fabric of the rock.

The quarry has the capability to produce some stones within the gradation of 2 tons to over 40 tons in size, based primarily on stones present in stockpiles. Jointing in the rock mass indicates that the majority of stones that can be produced will be in the smaller size range of 5 to 20 tons. The yield on large stones will be low, limited to those areas identified with wider joint spacing. Some stones larger than 40 tons would also be produced, but at a considerably lower yield. The quarry has never conducted blasting tests to determine what sizes or yield would be available if actually mining for large stones. True yield would be known only if blasting were carried out to create the larger sizes. The quarry has the potential to greatly expand its area of production and is considered capable of making large quantities of larger sized material. The quarry owner, Barry Holmes, indicated that the quarry could easily produce 200,000 tons of rock in an 8 month period, based on 1,000 tons a day working six, 12-hour days a week. The quarry currently has no equipment to efficiently handle very large stones.

Specific laboratory tests have been run to Portland District standards on samples taken from the quarry. Test results indicated specific gravity was 2.71 (169 pcf) and absorption was 0.2%. The LA abrasion test resulted in a 12.5% loss. The sodium sulfate soundness test had 1% loss. Accelerated expansion test also showed a 1% loss. Test results show that rock from this quarry meets all Portland District quality standards.

An existing 10-acre barge loading facility is located about 6 miles south of the quarry in the District of Mission. The facility is being improved for rock transport, including jettystone sizes, down the Fraser River. At this point in time, all stone is trucked to markets. When completed, 7,000 ton barges will be able to be light loaded to 4,000 tons then transported downstream to deeper water where they can be topped off. There are no work restrictions on the barging operations. They have the ability to work 24/7. A sandbar located downstream limits the draft of shipping traffic to 12 to 15 feet during normal water. The quarry is located approximately 45 miles from the mouth of the Fraser River.

Ekset Quarry. This quarry is located approximately 45 miles east of Vancouver, BC and 5 miles north of the District of Mission. It is located just a few miles east of the Stave Lake Quarry. The quarry property is approximately 36 acres in size with an estimated 30 acres still to be mined. A rough estimate of 10 million tons of material is present within the quarry, provided that mining extends only to the level of the current quarry floor. The quarry is located on the north side of the Fraser River on the west flank of a series of north-south-trending hills. The quarry operation started at the edge of the rock body a few hundred yards from the road. The quarry is confined by 2 creeks, one on each side of the quarry, so mining has taken place between the creeks straight back into the hillside. Rock appears to have some massive jointing in areas and should have the capability to produce large jettystones. The quarry has only a west-facing face and one intermediate bench. Above the intermediate bench at the top of the quarry face, the rock body seems to be fairly flat for some distance behind the face, with trees on top. The upper portion was not accessible at the time, so no evaluation was performed. Overburden appears to be very shallow. The quarry floor is currently used for stockpiling of crushed aggregate.

The rock present in this quarry is variable in nature but is all granitic in character. Most types fall into a granite, granodiorite, quartz diorite or gabbro rock classification. Rock varies in color but most are predominantly light gray to pink. The quartz diorite and granite are coarsely crystalline while the gabbro and granodiorite are predominantly fine to medium crystalline. All are predominantly fresh, hard, and dense. All types of rock present seem to have similar engineering properties.

The quarry face has limited exposures of in-place rock due to large talus piles on the lower slope. Talus is the result of pushing blasted material from the upper bench over the lower face for easy access to the crushing operation. The visible jointing on the lower face is variable with some areas being more massive than others. Three main joint sets are present with the principle joints intersecting at near right angles to produce a blocky-shaped stone. There are also lesser joints of various angles with variable spacing that control the shape of stones and tend to limit sizes in many places. Jointing varies in width but areas exist with joint spacing exceeding 5 feet. The upper bench was not observed due to time constraints. The joint surfaces appear to be primarily fresh and tight with no obvious signs of staining. The general exception comes from those areas near the ground surface.

No stockpiles of large material, such as riprap or jettystone sizes were present in the quarry. Larger stone sizes produced incidental to the blasting operation are supposedly crushed on a regular basis. Very few larger sizes were observed in the quarry.

The quarry has the capability to produce some stones within the gradation of 2 tons to over 20 tons in size with some larger sizes also available. This is based primarily on jointing observed in the quarry face, as well as eyewitness accounts by people familiar with the quarry operations. Jointing in the rock mass, as described above, indicates that the majority of stones that can be produced will be in the smaller size range of 5 to 20 tons. The yield on large stones will be low, limited to those areas identified with wider joint spacing. Some stones up to 40 tons may also be produced, but at a considerably lower yield. The quarry has never conducted blasting tests to determine what sizes or yield would be available if actually mining for large stones. True yield would be known only if blasting were carried out to create the larger sizes. The quarry has limited potential to expand its area of production except for back into the hillside. The quarry currently has no equipment to efficiently handle very large stones.

Specific laboratory tests have been run to Portland District standards on samples taken from the quarry. Test results indicated specific gravity was 2.76 (172.2 pcf) and absorption was 0.3%. The LA abrasion test resulted in a 13% loss. The sodium sulfate soundness test had 1% loss. Accelerated expansion test also showed a 1% loss. Test results show that rock from this quarry meets all Portland District quality standards.

An existing 10-acre barge loading facility is located about 5 miles south of the quarry in the District of Mission. The facility is being improved for rock transport, including jettystone sizes, down the Fraser River. At this point in time, all stone is trucked to markets. When completed, 7,000 ton barges will be able to be light loaded to 4,000 tons then transported downstream to deeper water where they can be topped off. There are no work restrictions on the barging operations. They have the ability to work 24/7. A sandbar located downstream limits the draft of shipping traffic to 12 to 15 feet during normal water. The quarry is located approximately 45 miles from the mouth of the Fraser River.

Cox Station Quarry. The quarry is located approximately 8 miles Northeast of Abbotsford, which is about 30 miles east of Vancouver, BC. The property was originally bought in 1979 and developed in 1986 as a sand and gravel operation. The mining operation hit bedrock in 1989 and the quarry has been developed as a hard rock quarry since. The quarry originally was 450 acres in size but MS&G recently purchased an additional 150 acres adjacent to the east side of the property in Government (Crown) land. The quarry is located on the north side of Sumas Mountain. The quarry operation appears to be divided into 2 areas. The older portion of the quarry is located on the western portion of the property with the lowest bench at an elevation close to river level. Rock in this area is highly fractured and appears to have a more weathered texture, and is probably not conducive to the production of jettystones. The newer portion of the quarry, that portion developed in the newly added 150 acres, is located in the eastern portion of the property near the top of the ridge. Development is going on to strip remaining overburden and produce benches starting at the top and working down, which will be developed back into the hillside. Rock in some of these areas is more massive in nature, however is still well jointed and fractured, which limits the sizes and amounts of large stones that can be produced.

Two separate quarry faces are present within this quarry. The older quarry face is located on the western portion of the property on the north side of the hill. It has multiple benches plus a haul road located on the outer portion of the benches. This area was the first portion developed in the original

450 acres. The height of this quarry face is on the order of around 200 feet and extends to the top of the hill, which appears to be a bench, lower than much of the surrounding area,

The second quarry face is located on the far eastern portion of the property on the more newly purchased 150 acres. The quarry face is substantially higher than the other and extends to the top of a west facing ridge. Multiple high working faces are established in benches along with steep grade access roads to the top of the quarry face. Development is presently underway to create access roads with less steep slopes. Presently material is mined at the top of the hill and pushed over the edge to the bench below. Successive shifts take that material and push it to lower benches yet. Overburden is very shallow and only exceeds a few feet along the tip of the hill. This is stripped and stored for later reclamation purposes and benches are being developed back into the hill for production down into the hill.

A very large stockpile area is associated with this quarry, located at the base of both quarry faces as well as a large area between the two faces. A large crushing operation is in place in this area and large stockpiles of varying sizes of crushed aggregate are in place. Much smaller stockpiles of riprap and smaller sized material are also present. Most of this stone is 2-feet in diameter or smaller and is used for specialty work. No permanent stockpiles of large material, such as jettystone sizes are present in the quarry. Large jettystone sizes are produced incidental to the blasting operation which is designed for crushed aggregate. Most of these stones are present on the production benches and are usually broken down into more manageable sizes for the crushing operation. Approximately 20 or so stones in the 10 to 20 ton range were observed on a production bench near the top of the east side quarry face.

The rock present in this quarry is variable in nature but is all granitic in character. Most types fall into a granite, granodiorite, or diorite. Rock varies in color but much of it takes on a pinkish color due to the presence of the feldspar orthoclase. Quartz, biotite and hornblende are also present. The rock is coarsely crystalline and is predominantly fresh, hard, and dense. All types of rock present seem to have similar engineering properties.

Jointing varies greatly within the two quarry faces. The western quarry face has multiple, close-spaced jointing. Joint spacing varies and is hard to distinguish in places due to heavy blasting that takes place to produce the small sizes for the crusher. The east quarry face has an overall wider joint spacing, but has more variability. There are specific areas that have been identified in the east quarry face that lend themselves to producing larger sizes. Major joint spacing in these areas can exceed 5 feet, but smaller, less prominent and somewhat incipient jointing occurs in many places between these larger joint sets. Joint sets are generally at near right angles to each other which tend to produce tabular and blocky shapes. Irregular shapes are produced as well. The joint surfaces appear to be primarily fresh and tight with no obvious signs of staining. The general exception comes from those areas near the ground surface. The stones present in the smaller riprap stockpiles tend to be blocky and tabular. This is due to the intersecting joint sets. There are also irregular shaped stones as well. Some of the larger stones contain multiple joints within the stone. These are mostly tight and hold together well. Most stones break along the joints rather than through the fabric of the rock.

Specific laboratory tests have been run by Portland District to current jettystone standards. Tests indicated specific gravity was 2.69 (167.9 pcf). The LA abrasion test resulted in a 9.4% loss at 500 revolutions. Absorption averaged around 0.5%. The sodium sulfate soundness test had 1.0% loss after 5 cycles. The accelerated expansion test had a 1% loss after 15 days. This stone passed all Portland District jettystone standards.

The quarry has the capability to produce some stones within the gradation of 2 tons to over 20 tons in size, based primarily on stones present in stockpiles. Jointing in the rock mass, as described above, indicates that the majority of stones that can be produced will be in the smaller size range of 5 to 20 tons. The yield on large stones will be low, limited to those areas identified with wider joint spacing. Some stones larger than 25 tons would also be produced, but at a considerably lower yield. The quarry has never conducted blasting tests to determine what sizes or yield would be available if actually mining for large stones. True yield would be known only if blasting were carried out to create the larger sizes. The quarry is very large, considered advantageous; however, mining for larger sizes should only be conducted in areas with wider joint spacing.

Reserves are estimated at between 100 and 200 million tons within the 600 acres currently permitted for the quarry. Mining is planned down to river level, providing for many years of quarry work. Additional Crown land is also available for future quarry expansion.

A barge loading facility is present on site, and is currently scheduled for improvements to lengthen and widen the ramp to allow heavier material, such as jettystones, to be delivered onto barges. The largest barge currently loaded there is 4,000 tons. Water is consistently 35 feet deep adjacent to the quarry, and can exceed 45 feet during spring freshets, but there is a sandbar downstream that limits the draft of shipping traffic to 12 to 15 feet during normal water. The river shallows dramatically upstream of the quarry and no barge traffic goes above that point. The quarry is located 47 miles from the mouth of the Fraser River. The Canadian National (CN) railroad also runs adjacent to the river and the quarry. MS&G loads their product into railway cars (65 at a time) but at this time, CN will only allow railroad use for their own purposes.

6. STONE TRANSPORTATION ROUTES

Stone sources located within 150 miles of the MCR jetties are likely to be transported by truck directly to the jetty. Sources located at further distances, especially if they are located near waterways, are likely to transport stones by truck to a barge on-loading facility, then transport them by tug and barge to either a Government-provided or commercial barge offloading site located nearby. With the rising cost of transportation, railway may also be an option for transporting stone, provided an on-loading site is convenient to the quarry. Most railroads follow main highway arterials, such as I-5. The closest railroad terminal to the South Jetty is at Tongue Point, east of Astoria, which is about 15 miles from the jetty. The nearest railroad terminal to MCR on the north side of the Columbia River is Longview, WA. Potential stone transportation routes are identified in Figures B-16 through B-20.

Quarry Development and Production Time

No stockpiles of any appreciable size for stone of the sizes required for this Project are available at any of the quarries listed above. The larger stone sizes required translate to lower yields at the quarry than for previous jetty contracts. This means that more material needs to be quarried to supply the stone quantities required. The percent yield for these size stones varies by quarry based on jointing characteristics and quarrying techniques. Utilizing more than one quarry could reduce production time, but that is entirely the Contractor’s option. The ideal situation for construction would be to award a separate stone procurement contract prior to construction, or to award the repair contract early, allowing sufficient time for stone production prior to the summer months’ when placement would take place.

Figure B-16. Potential Canadian Rock Source Transportation Routes

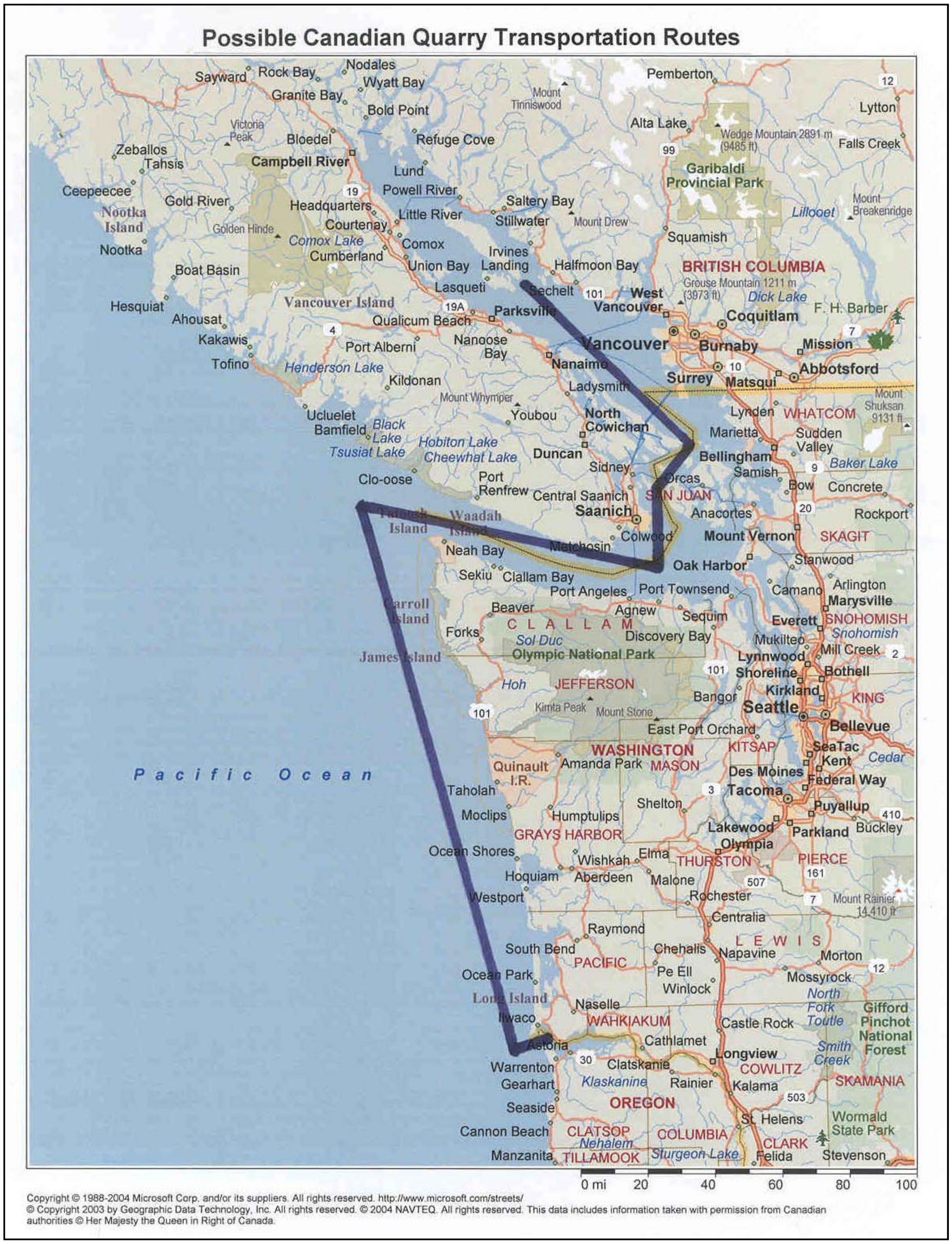

Figure B-17. Potential Washington Rock Source Transportation Routes

Figure B-18. Potential Oregon Rock Source Transportation Routes

Figure B-19. Potential Northern California Rock Source Transportation Routes

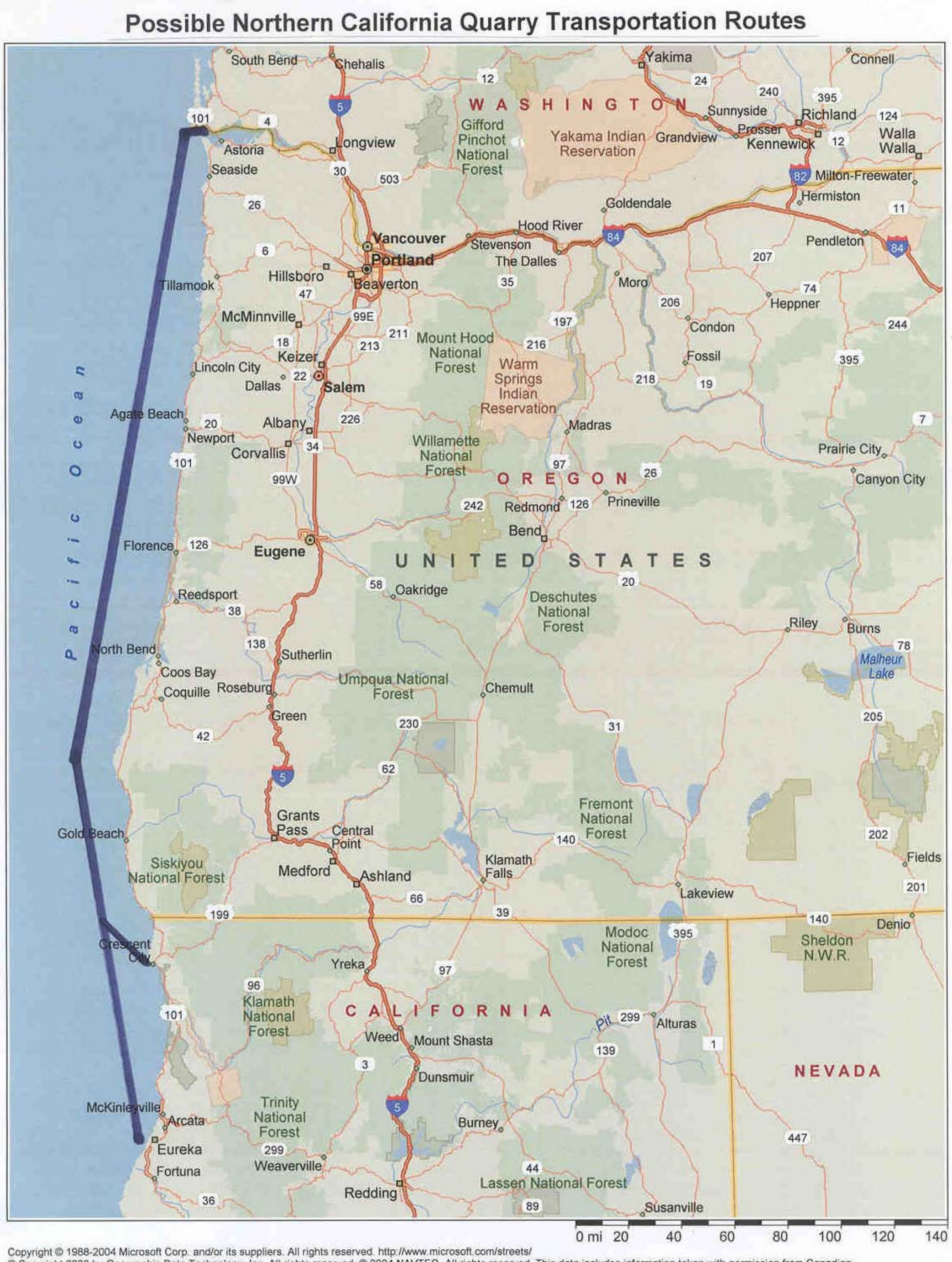

Figure B-20. Potential Railway Transportation Routes

7. CONCLUSIONS

The following items highlight the key elements necessary to consider for repair of the MCR jetties with jetty stone:

a. Jetty stone of the sizes and quantities identified as necessary for repairs to the MCR jetties are available within the combined known sources in Washington, Oregon, California, and Canada. Not all of the quarries or prospects are capable of producing the quantity of stones necessary for repairs; however, some sites or a combination of sites would be able to produce sufficient quantities for contracts over a number of years.

b. Stockpiles of existing stones in the necessary large sizes are very limited. The combined stockpiles of all quarries investigated do not have the quantities necessary for repairs at this time.

c. A greater lead-time for jettystone production than normal is evident based on these investigations. The lead-time after Contract award and notice to proceed to actual delivery of the stones at the Project should be greater than 6 months. The primary reasons for this are insufficient existing stockpiles, the need for quarry development, and the difficulty of producing large stones. A possible alternate solution may be to let separated stone procurement and delivery contracts to provide a sufficient stockpile of stones onsite prior to construction.

d. Repairs will primarily be accomplished on relict stone within the original footprint of the jetty. This will provide a sound base for repairing the jetty, with no settlement or foundation disturbance taking place. There may be areas outside the footprint, primarily if spur groins, flatter side slopes, or toe berms are used, that may be founded on sand deposits. These areas need to have a bedding layer of stone place prior to placement of the jettystones to help reduce the risk of settlement or scour.

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MCR Jetty System Major Rehabilitation Evaluation Report

Appendix C

Economic Analysis

Appendix C
MCR JETTIES MAJOR REHAB ECONOMIC ANALYSIS

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MCR JETTIES MAJOR REHAB ECONOMIC ANALYSIS

1. INTRODUCTION

This appendix describes the Federal interest in the rehabilitation of the MCR Jetties, as well as the procedures used and the results of the economic analysis. The economics are one of the key considerations in the selection of the recommended plan. The Columbia River comprises the M-84 Corridor for the Marine Highway Program. It is noted by the US Department of Transportation as a truck bottleneck resulting in up to 750,000 truck delay hours and an area of major rail congestion. The marine highway serves to reduce the congestion

The procedures adopted for use in economic[1] cost analysis stem from national policy and the NED efficiency objective. Life-cycle cost analysis presents a method by which economic benefits can be compared against economic costs to derive a cost-benefit ratio and to compute net economic benefits. Benefits and costs are converted to average annual cost equivalent values that represent the stream of investments and benefits accrued from those investments over the period of analysis.

The method follows standard life-cycle cost accounting principles in that investments occurring intermittently over a fixed period of analysis are adjusted to account for the time value of money to create equivalent values at a common point in time. The common point in time for USACE planning purposes is designated as the base year, which is defined as the first year during which benefits of the project accrue. Investments and benefits that occur prior to the base year are escalated to the base and investments and benefits that occur after the base year are discounted to the base. The present worth equivalent values are then summed and amortized over the period of analysis to derive an average annual equivalent value. The rate that is used for discounting and amortizing is published annually and is provided by the U.S. Treasury for USACE investment and benefit calculations.

In order for various alternatives with differing investment strategies to be equitably compared, guidance requires that the same period of analysis be used for all alternative plans. The period of analysis is defined as the time horizon for project benefits, deferred installation costs, and operation, maintenance, repair, rehabilitation, and replacement (OMRR&R) costs. OMRR&R costs are the expected costs over the period of analysis for operation, maintenance, repair, rehabilitation, and replacement necessary to maintain the benefit stream and agreed-upon levels of mitigation of losses to fish and wildlife habitats. For USACE navigation projects, the period of analysis is typically 50 years.

Also an equitable comparison of alternatives requires that a common price level for costs be applied. Usually, comparative economic cost values are developed for planning level estimates of alternatives. Historical bid cost data, experience, and/or unit prices adjusted to expected project conditions are acceptable methods of developing project costs for these alternatives. The selected plan is then refined to create a Total Project Cost using the USACE-certified MCASES (MII) cost model in accordance with

[1] COE planners use economic cost information to make the basic efficiency decisions about alternative plans. NED costs are used to make these decisions. Once the efficiency decision has been reached, the COE uses financial costs for project implementation, also referenced as fully-funded costs. A fully-funded cost is a financial cost, not an economic cost.

guidance.[2] While economic costs are used for efficiency decisions, fully funded total project costs are used for budgeting and implementation.

2. Federal Interest

The guidance for major rehabilitation projects is cited in ER 1105-2-100 and in ER/EP 1130-2-500. During initial discussions, the PDT worked with the MSC to determine the appropriate approach for the evaluation. Given the expected nature of projected failures and the usual Portland District repair response, service disruption and economic consequences would be significantly limited. The PDT and MSC determined that there was an obvious Federal interest in this project, and it would be appropriate to use a basic comparison of least cost alternatives to construct and repair. ER 1105-2-100, Section X, Major Rehabilitation Studies, notes that for the majority of cases, the Federal interest in an existing project will be obvious, and that a reasonable argument showing that Federal interest should be provided in the report.

The MCR jetty serves as the gateway to the larger Columbia/Snake River navigation system, carrying about 42 million tons of cargo on an annual basis, with an estimated cargo value of $20 billion in 2009 (source: Pacific Northwest Waterways Association [PNWA] fact sheet). The Columbia/Snake River navigation system from the Pacific Ocean to Lewiston, Idaho is a vital transportation link for the states of Oregon, Washington, Idaho, and Montana, as well as for the Nation as a whole. Failure to maintain navigation through the MCR project would lead to inefficiencies in the navigation system. It could potentially shut down a main artery of commerce in the region and the nation.

The Columbia/Snake navigation system flows through Idaho and Washington and forms the southern border of Washington and the northern border of Oregon, serving multiple ports along the way. The system was developed in two segments. The first is the authorized 43-foot deep-draft channel for ocean-going vessels, which extends about 106 miles from the Pacific Ocean to Portland, Oregon, and Vancouver, Washington. The second is the 14-foot deep inland navigation channel with eight locks that extends from Vancouver to Lewiston, about 365 miles. Table C- 1 displays the cargo volume, vessel trips, and drafts of vessels traversing the entrance to the Columbia River over the period 2005-2009.

[2] U.S. Army Corps of Engineers, ER 1110-2-1302, Engineering and Design, Civil Works Cost Engineering, 15 September 2008.

Table C- 1. Volume of Cargo, Vessel Trips, and Vessel Drafts, 2005-2009

Columbia River Entrance, OR and WA					
	All Traffic Types (Domestic & Foreign)				
	All Traffic Directions				
	CY2009	CY2008	CY2007	CY2006	CY2005
All Commodities (short tons)	36,171,434	44,735,799	44,775,751	39,651,806	39,166,863
All Vessel Trips (number)	3,844	4,967	5,349	5,165	5,364
Drafts (feet)					
0-5	237	370	413	459	543
6-9	80	126	165	136	147
10-12	132	226	374	323	458
13-14	331	404	348	390	513
15-17	352	338	377	471	411
18-20	306	406	350	372	515
21-23	515	567	602	540	559
24-26	337	452	569	568	500
27-29	306	521	549	549	440
30-32	440	422	444	428	418
33-35	336	448	451	420	407
36-38	212	335	333	277	245
39-40	254	343	368	221	205
41	6	9	0	10	3
42	0	0	3	1	0
43	0	0	3	0	0
44	0	0	0	0	0
45	0	0	0	0	0

source: U.S. Army Corps of Engineers, Navigation Data Center, Waterborne Commerce of the United States, Part 4, Cargo and Trips by Waterways, CY 2009-2005

The U.S. Army Corps of Engineers, Portland and Walla Walla Districts, maintains the navigation channels and operates navigation locks at eight federal hydropower projects on the Columbia/Snake River system. The navigation channels and locks provide access to markets for producers throughout the United States, and are part of a just-in-time delivery system for this major international trade gateway. The elements of the Columbia/Snake navigation system include the deep-draft navigation channel, the inland navigation channel, and the jetties, anchorages, turning basins, and upriver locks necessary to accommodate increasingly larger ships and growing inland barge movements.

The inland navigation channel runs about 365 miles upstream from Portland/Vancouver to Lewiston, Idaho. The channel is 14-feet deep. PNWA indicates that about 10 million tons of cargo is barged annually, with an estimated value of $1.5 to $2 billion. The deep-draft navigation channel runs 110 miles downstream of Portland/Vancouver to the mouth of the Columbia River, the gateway to the Pacific Ocean. This channel is currently being deepened to 43 feet. PNWA indicates that the deep-draft channel carries about 40 million tons of cargo annually, with an estimated value of $17 billion in 2009.

The Columbia/Snake River navigation system is a critical regional and national gateway linking agricultural, mineral and goods production across the Northwest, Mountain, Midwest, and East Coast states to growing markets in the Pacific Rim (see Figure C- 1). The economies of many states rely on the trade and commerce that flows up and down this important navigation system. According to the Center for Economic Development and Research[3] (CEDER), the Columbia/Snake River navigation system is the leading gateway for the Nation's wheat and barley exports. It is also a primary paper/paper products export gateway, bulk minerals export gateway, and automobile import gateway for the West Coast.

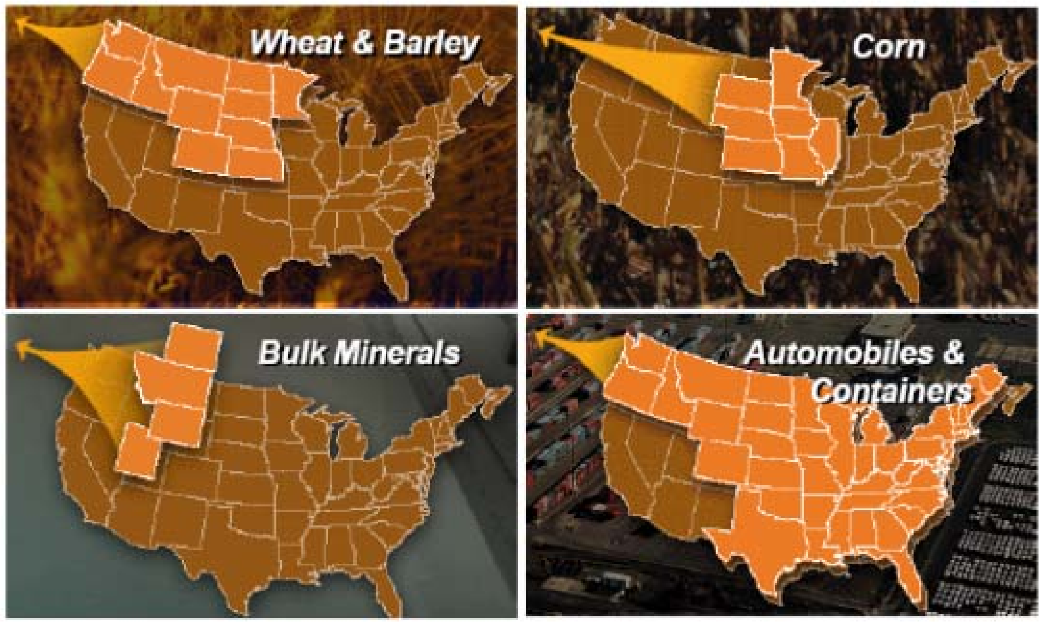

Figure C- 1. Regional and National Markets Served by the Columbia/Snake System

Each of the navigation components in the Columbia/Snake system contributes in valuable ways to the trade moving to, from, and through the region. The Columbia/Snake system provides a low-cost and energy-efficient means of transporting goods. The Columbia River Towboaters Association indicates that one 60,000-ton Panamax vessel is equivalent to a 4- to 5-barge tow, which is also equivalent to 600 rail cars, or to 2,400 semi-trucks.

The Texas Transportation Institute prepared a study[4] for the U.S. Department of Transportation Maritime Administration and the National Waterways Foundation, dated November 2007, showing the relative energy efficiency of barges over rail or truck. It showed the miles per gallon (mpg) carrying one ton of cargo for each of the modes: 155 mpg for trucks, 413 mpg for railroads, and 576 mpg for inland towing. It also provided a summary of emissions that showed that inland towing had the least emissions of the three modes.

[3] Center for Economic Development and Research (CEDER). June 2005. Columbia/Snake River System and Oregon Coastal Cargo Ports Marine Transportation System Study. Prepared by PB Ports and Marine, Portland OR; BST Associates, Bothell WA; and Pacific Northwest Waterways Association, Portland OR.

[4] The following link is to the executive summary of the study: http://waterwayscouncil.org/study/Executive%20Summary.pdf

a. Columbia River Entrance Fast Facts

- The mouth of the Columbia River is the opening point to the Columbia/Snake River navigation system.
- $20 billion in value each year moves on the Columbia-Snake system (PNWA).
- Nation's number one wheat gateway and number one barley export gateway (PNWA).
- 42 million tons of traffic (products) moves annually through the entrance, 90 percent of which is to or from foreign markets. (See Figure C- 2, WCUS data).
- About 1400 vessels with drafts 30 feet or greater use the entrance. (See Figure C- 3, WCUS data).

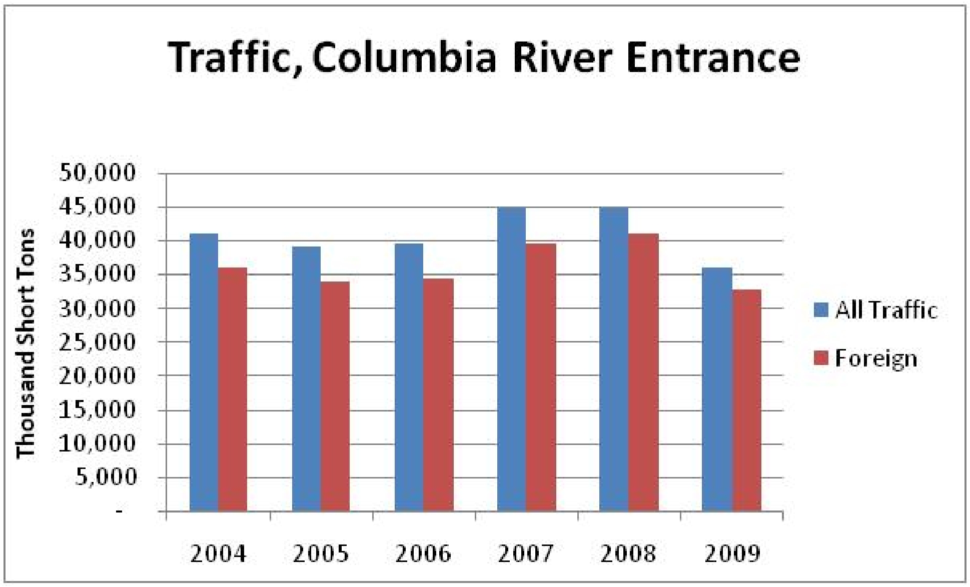

Figure C- 2. Annual Traffic at the Columbia River Entrance

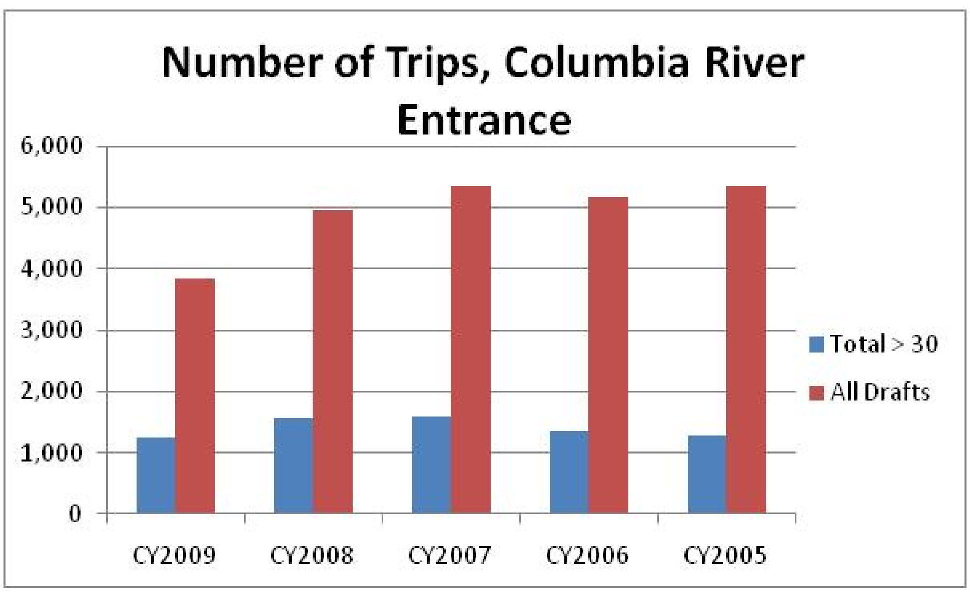

Figure C- 3. Annual Number of Traips at the Columbia River Entrance

In addition, the volume of passengers carried on cruise ships on the Columbia/Snake system has been growing dramatically. These vessels benefit from the same infrastructure maintenance and improvements as maritime cargo, and contribute economic benefits to the local communities located along the Columbia/Snake system. The Pacific Northwest Waterways Association (PNWA) indicates that 5/7 day cruise ship tours carry 6,000 passengers annually, and thousands of tour boat passengers take day trips and dinner cruises. These activities generate about $15 to $20 million in revenue annually for local economies. Additionally, the CEDER report, Appendix A, provides an indicator of Regional Economic Development impacts[5].

> *Direct impacts are the economic activities directly caused by the movement of cargo flows through the port, or the operations of port tenants and users. These activities represent the first round of spending, employment, and wages. Rounds of inter-industry purchases generate indirect and induced impacts. Indirect impacts represent purchases by the industry of goods and services, such as the payment for outside contractors or for accounting or legal services. Induced impacts refer to the household purchases based on the employment earnings from direct and indirect economic activities. As wages are paid out, workers' families spend their income on a wide array of goods and services, much of which are supplied by the local economy. Total impacts incorporate the sum of direct, indirect, and induced impacts. The Lower Columbia River region had over 15,000 direct and 40,000 total jobs in 2000 due to marine cargo activity. The direct payroll of port activity was estimated at $576 million. This generated an income of $1.8 billion, including direct, indirect and induced effects.*

3. Most Likely Future "Without Project" Base Condition

The Base Condition is the plan/scenario against which all other plans are measured. Several considerations need to be determined when developing the Base Condition: determining operating trends, current and projected reliability of all critical components, and planned maintenance on the project. These must all be provided throughout the entire study period.[6]

4. Future "With Project" Alternatives

The goal of implementing with-project alternatives is to maintain navigation within the Federal navigation channel and to avoid any negative impact to mission over the period of analysis. All with-project alternatives include monitoring and advance repairs (i.e., repairs that are intended to occur before potential breaches impact navigation). Detailed descriptions of the alternatives and the different repair strategies are shown in Main Report 3.8.2 and further detailed in Appendix A2.

These alternatives are listed in Table C- 4.

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[5] http://pnwa.net/ceder/Appendix%20A%20CEDER%20MTS%20Economic%20Impacts%20050422.pdf

[6] U.S.Army Corps of Engineers, EC1110-2-6062, Engineering and Design, Risk and Reliability Engineering for Major Rehabilitation Studies, 5-5. Establishing the Base Condition and Alternative Without-Project Scenarios, 1 Feb 2011

5. Assumptions for the Life-Cycle Costing of MCR Jetties Alternatives

a. Benefits

The fundamental economic assumption of the MCR Jetties Major Rehabilitation Report is that the navigational or functional performance of the jetty system will be maintained throughout the period of analysis. In fact, in only in one instance during the history of the jetty system has navigational service been disrupted. This assumption implies that transportation service benefits from the jetty system are constant across any scenario or alternative considered. The "most likely" future without project condition maintains the functional integrity of the jetty system as do all alternatives considered throughout the period of analysis. Increasing structural resiliency is a goal of the alternative actions; however, this concept is not monetized as an economic benefit.

Therefore, with no expected variation in transportation service benefits and a lack of monetization of structural resiliency, the remaining economic consideration is the cost effectiveness of the alternatives considered with costs avoided being the remaining monetized benefit to the project.

Price Level, Period of Analysis, and Federal Interest Rate[7]

The costs applied in the life-cycle cost analysis are USACE-provided 2012 values. The period of analysis is 50 years, from beginning of year 2015 to end of year 2064. The project economic evaluation rate applied is the FY12 Federal interest rate of 4.0 percent. Prices used do not include inflation. End of year values were calculated for the life cycle cost analysis.

Base Year and Interest during Construction

Alternative plans can differ in their implementation timing, that is, not all plans or features have to be in place at the beginning of the period of analysis. As project on-line dates are varied, annual benefits and costs will often vary. In general, the more the benefits vary through time and the longer the time to implementation from the base year (first year of period of analysis), the stronger this effect will be. The best schedule for implementing project features shall be considered as an element in the formulation and evaluation of alternative plans.[8]

Table C- 4 lists the alternatives evaluated and the construction schedules of the alternatives that have rehab components for the three jetties in the Mouth of the Columbia River Jetty system: North Jetty, South Jetty, and Jetty A. All alternatives have an annual dredging component cost estimated which is not reflected in Table C- 4 but is incorporated into the life cycle cost analysis. Other repair costs occur intermittently over the period of analysis and are incorporated into the life cycle cost analysis also.

The base year was set at the beginning of implementation period in the year 2015 based on two factors:

1) The implementation periods are lengthy due to the large quantity of rock required to complete the work, seasonality of construction, the rock supply and storage activities; and,
2) Benefits will begin accruing with each implementation stage.

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[7] U.S. Army Corps of Engineers ER 1105-2-100, Planning Guidance Notebook, Appendix D, Amendment #1, paragraph D-6, 30 June 2004.
[8] U.S. Army Corps of Engineers, ER 1105-2-100, Planning Guidance Notebook, paragraph 2-4 (o), 22April 2000.

This method is intended to produce a straight-forward and consistent comparison of alternatives. All alternative costs are discounted at the end of the year to the beginning of the base year 2015 using the stated Federal interest rate and amortized over the period of anlaysis to produce average annual equivalent values. This method will allow for the simple combination of alternatives among the three jetties to identify a combination least cost plan because all economic costs for all three jetties will be represented as equivalent costs.

Also due to the expectation of an immediate accrual of benefits, interest during construction (IDC) was not calculated. IDC is calculated typically when completion of construction is required before benefits are realized. For the MCR jetties rehabilitation alternatives, benefits are assumed to be realized immediately beginning with each activity for which costs are generated.

Also because the first year of construction is also the designated base year due to the expectation of an immediate accrual of benefits, no escalation of costs prior to the base year was necessary. Costs incurred over the period of analysis were discounted to the base year.

6. Life-Cycle Costing of MCR Jetties Alternatives

This life cycle cost analysis should not be confused with the derivation of total project costs which are financial in nature and take into consideration factors of implementation. The life cycle cost analysis presented represents a method by which alternatives can be compared equitably and decisions regarding economic efficiency can be made.

A life cycle cost analysis was performed over the 50-year project life for the alternatives listed in Table C- 17 with consideration, as appropriate, of project construction costs and associated operations and maintenance (O&M) and other costs over the period. Each alternative, with the exception of the “fix-as-fails” alternatives, was modeled allowing the jetty trunks to recede over the period of analysis and then again with holding the current jetty length constant.

a. Unit Cost Components of Alternatives

Repairs, rehabilitation, and dredging are projected throughout the period of analysis in response to scenarios developed with the SRB Model. USACE-provided 2012 cost variables contribute to the jetty alternatives cost estimates over the period of analysis and are assembled to reflect the activities that define each alternative’s repair strategy:

1. Repair activities: unit costs/ton of rock for expedited, base, and scheduled repairs, specific to jetty structure;
2. Rehabilitation activities: unit costs/ton of rock for a variety of scaled activities ranging from minimal to large;
3. Additional fixed costs of activities associated with rehabilitation for every year that rehabilitation occurs: mob/demob; jetty crest haul road construction; barge off-loading facility; mitigation costs; dredging costs; and offloating costs;
4. Jetty head capping: unit cost/ton of rock specific to each jetty;
5. Spur construction: fixed cost specific to each jetty; and
6. Normal dredging: unit cost/cy of sediment dredged specific for North Jetty, same unit cost for South Jetty and Jetty A.

All alternatives contain expedited repair activities and normal dredging activities. All alternatives contain O&M activities that are base repair, interim repair, or scheduled repair.

Table C- 4 presents the array of unit and fixed costs applied in the life cycle cost analysis. The derivation of these costs and their application is discussed in detail in Appendix E, MCASES Cost Estimates. Table C- 6 through Table C- 16 display the cost components specific to each of the alternatives considered for the three jetties in the Mouth of the Columbia River system. Alternatives that share the same unit and fixed costs are listed together in the displays.

b. Interface between the SRB Model and the Life Cycle Cost Analysis

The life cycle cost analysis is performed separately and subsequently to the SRB Model calculations. The execution of the SRB model results in calculations of jetty degradation and required repair (e.g. material quantities required to create a defined condition based on the alternative considered, described in Appendix A1). The output files containing quantities from this model analysis are then used as inputs to the cost analysis to estimate life-cycle costs and other parameters for each alternative. The cost analysis is performed via a set of Microsoft Excel spreadsheets. This section discusses the life cycle cost component of the analysis and the outputs of the SRB model which feed the life cycle cost analysis.

As shown in Table C- 2, the SRB model creates outputs that contain a set of mean values for seven types of activities—rehabilitation; expedited repair, emergency repair; interim repair, base repair, scheduled repair, and normal dredging. These output parameters are listed in the life cycle cost spreadsheets which have a consistent nomenclature, generally titled "MCR_LifeCycleCosts_{name of jetty}_{name of alternative}". These files are built automatically from a single template file “cost_template.xlsx” by calling MCR_COST script in Matlab. The script takes SRB Model CSV files from “output” folder for each alternative and converts them into Microsoft Excel files. The main CSV files are listed in Table C- 2 below.

Table C- 2. Output CSV Files Used to Populate Life Cycle Cost Analysis Spreadsheets

Output File	Description
OUTPUT_Repair_for_COST_MEAN_INNER.csv	Stone volumes for inner range of the jetty for emergency, expedited, fix-as-fail, interim and scheduled repairs.
OUTPUT_Repair_for_COST_MEAN_MIDDLE.csv	Stone volumes for middle range of the jetty for emergency, expedited, fix-as-fail, interim and scheduled repairs.
OUTPUT_Repair_for_COST_MEAN_OUTER.csv	Stone volumes for outer range of the jetty for emergency, expedited, fix-as-fail, interim and scheduled repairs.
OUTPUT_Rehab_for_COST_MEAN.csv	Stone volumes for minimum, small, moderate and large rehab templates and head capping.
OUTPUT_Dredging_for_COST_MEAN.csv	Maintenance dredging volumes.
OUTPUT_Head_Recession_Repair_COST_MEAN.csv	Repairs on North Jetty due to scour associated with Jetty “A” head recession.

Note: Emergency repairs were not used in the SRB Model for the MCR Jetties.
The cost for each activity is calculated in the MCR_LifeCycleCosts spreadsheets, based on actions and volumes projected by the SRB Model to which unit and fixed prices are applied. The unit prices are initially specified in “cost template” spreadsheet on the “Setup” sheet for all jetties and activities. The referencing of the unit costs within the spreadsheets allows for updating, modification, and adjustment, if necessary.

Only the values that occur during the period of analysis, 2015-2064, are considered in the life cycle cost analysis even though the SRB Model outputs a stream of volumes.

Project Life (Years)	Inner Cost/ton	Middle Cost/ton	Outer Cost/ton	Federal Discount Rate	Monthly Compound Interest Factor	Amortization factor, 50 yrs	Activity Index
50	$ 216.00	$ -	$ 241.50	4.00%	1.003274	0.046550	2

Alternative: NJ_fut1_base
Activity: Expedite Repair

Totals over Project Life 2015-2064

Year	2015	Inner Annual Repair Volume (ton)	Middle Annual Repair Volume (ton)	Outer Annual Repair Volume (ton)	Total Annual Repair Cost ($)	Present Work Equivalent ($)
Totals		103,653	-	74,698	$ 40,428,615	$ 18,294,141
2007	-7	-	-	-	$ -	$ -
2008	-6	352	-	-	$ 76,032.00	$ 76,032.00
2009	-5	1,444	-	200	$ 360,204.00	$ 360,204.00
2010	-4	1,932	-	976	$ 653,016.00	$ 653,016.00
2011	-3	2,424	-	2,985	$ 1,244,461.50	$ 1,244,461.50
2012	-2	2,009	-	4,548	$ 1,532,286.00	$ 1,532,286.00
2013	-1	1,988	-	5,161	$ 1,675,789.50	$ 1,675,789.50
2014	0	1,332	-	4,558	$ 1,388,469.00	$ 1,388,469.00
2015	1	1,570	-	397	$ 434,995.50	$ 418,264.90
2016	2	1,341	-	730	$ 465,951.00	$ 430,797.89
2017	3	1,905	-	933	$ 636,799.50	$ 566,112.44
2018	4	2,300	-	1,408	$ 836,832.00	$ 715,327.50
2019	5	3,127	-	1,934	$ 1,142,493.00	$ 939,045.97
2020	6	5,008	-	1,418	$ 1,424,175.00	$ 1,125,546.19
2021	7	6,123	-	1,308	$ 1,638,450.00	$ 1,245,087.34
2022	8	6,712	-	1,161	$ 1,730,173.50	$ 1,264,220.83
2023	9	6,632	-	559	$ 1,567,510.50	$ 1,101,312.09
2024	10	6,047	-	93	$ 1,328,611.50	$ 897,562.32
2025	11	5,243	-	160	$ 1,171,128.00	$ 760,742.42
2026	12	5,506	-	111	$ 1,216,102.50	$ 759,574.03
2027	13	3,634	-	158	$ 823,101.00	$ 494,333.13
2028	14	2,765	-	221	$ 650,611.50	$ 375,711.93
2029	15	2,834	-	380	$ 703,914.00	$ 390,858.46

Figure C- 4. Example of Life Cycle Cost Spreadsheet with Reference Unit Costs and Input Volumes from the SRB Model

In the above example, the cost for repair options is calculated in each "Repair" worksheet (Expedited Repair is shown), and unit costs are linked to the "Setup" sheet for named jetty. The present worth equivalent values for all activities associated with each alternative response scenario are totaled and accumulated into a summary spreadsheet, "Cost_Summary.xlsx," and then the present worth equivalent values are amortized over the period of anlaysis to create average annual equivalent values. Table C- 5 displays the results of the life cycle cost analyses for all the alternatives evaluated. Comparisons are made among the alternatives and the alternatives are ranked by net excess benefits.

7. Summary of Costs and Benefits

The most cost effective NED plans among the 71 alternatives are displayed in Table C- 3 below. The most cost effective alternatives are those that produce the greatest net excess benefits over costs. The full array of the alternatives are displayed in Table C- 6 through Table C- 16 and present the results of the life-cycle cost analysis, least cost ranking, benefit-cost ratio, and net excess benefits.

Table C- 3. Most Cost Effective NED Plans

Jetty	Most Cost Effective Alternative	Net Excess Average Annual Benefits	Average Annual Costs	Benefit to Cost Ratio
North Jetty	NJ fut=1 Scheduled Repair Hold	$251,729	$2,984,682	1.09
South Jetty	SJ fut=1_Base	$0	$9,566,691	1.0
Jetty A	JA fut=1 Scheduled Repair Hold	$383,847	$913,260	1.42

Table C- 4. MCR Jetty Alternatives and Implementation Periods for Construction

Alternatives	Location	Implementation Period for Rehab Construction Only																
		2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	~	2064
NJ_fut1_base	North Jetty																	
NJ_fut1_fixasfail_repair	North Jetty																	
NJ_fut1_sched_repair	North Jetty																	
NJ_fut10_sched_repair	North Jetty																	
NJ_fut10_sched_repair_no_headcap	North Jetty																	
NJ_fut21_immed_rehab_minimum	North Jetty																	
NJ_fut21_sched_rehab_minimum	North Jetty																	
NJ_fut23_immed_rehab_moderate	North Jetty																	
NJ_fut23_sched_rehab_moderate	North Jetty																	
NJ_fut24_immed_rehab_large	North Jetty																	
NJ_fut24_sched_rehab_large	North Jetty																	
NJ_fut30_immed_rehab_comp4_small	North Jetty																	
NJ_fut30_sched_rehab_comp1_large	North Jetty																	
NJ_fut30_sched_rehab_comp2_medium	North Jetty																	
NJ_fut30_sched_rehab_comp3_small	North Jetty																	
NJ_fut30_sched_rehab_comp4_small_modi	North Jetty																	
NJ_fut1_base_hold	North Jetty																	
NJ_fut1_sched_repair_hold	North Jetty																	
NJ_fut10_sched_repair_hold	North Jetty																	
NJ_fut10_sched_repair_no_headcap_hold	North Jetty																	
NJ_fut21_immed_rehab_minimum_hold	North Jetty																	
NJ_fut21_sched_rehab_minimum_hold	North Jetty																	
NJ_fut23_immed_rehab_moderate_hold	North Jetty																	
NJ_fut23_sched_rehab_moderate_hold	North Jetty																	
NJ_fut24_immed_rehab_large_hold	North Jetty																	
NJ_fut24_sched_rehab_large_hold	North Jetty																	
NJ_fut30_immed_rehab_comp4_small_hold	North Jetty																	
NJ_fut30_sched_rehab_comp1_large_hold	North Jetty																	
NJ_fut30_sched_rehab_comp2_medium_hold	North Jetty																	
NJ_fut30_sched_rehab_comp3_small_hold	North Jetty																	
NJ_fut30_sched_rehab_comp4_small_modi_hol	North Jetty																	
SJ_fut1_base	South Jetty																	
SJ_fut1_fixasfail_repair	South Jetty																	
SJ_fut1_sched_repair	South Jetty																	
SJ_fut10_sched_repair_head	South Jetty																	
SJ_fut10_sched_repair_head_spur	South Jetty																	
SJ_fut21_immed_rehab_minimum	South Jetty																	
SJ_fut21_sched_rehab_minimum	South Jetty																	
SJ_fut22_immed_rehab_small	South Jetty																	
SJ_fut23_immed_rehab_moderate	South Jetty																	
SJ_fut24_immed_rehab_large	South Jetty																	
SJ_fut30_immed_rehab_comp1_large	South Jetty																	
SJ_fut30_immed_rehab_comp2_modi1	South Jetty																	
SJ_fut30_immed_rehab_comp3_small	South Jetty																	
SJ_fut30_immed_rehab_comp4_medium	South Jetty																	
SJ_fut30_immed_rehab_comp5_modi2	South Jetty																	
SJ_fut30_sched_rehab_comp5_modi2	South Jetty																	
SJ_fut1_base_hold	South Jetty																	
SJ_fut1_sched_repair_hold	South Jetty																	
SJ_fut10_sched_repair_head_hold	South Jetty																	
SJ_fut10_sched_repair_head_spur_hold	South Jetty																	
SJ_fut21_immed_rehab_minimum_hold	South Jetty																	
SJ_fut21_sched_rehab_minimum_hold	South Jetty																	
SJ_fut22_immed_rehab_small_hold	South Jetty																	
SJ_fut23_immed_rehab_moderate_hold	South Jetty																	
SJ_fut24_immed_rehab_large_hold	South Jetty																	
SJ_fut30_immed_rehab_comp1_large_hold	South Jetty																	
SJ_fut30_immed_rehab_comp2_modi1_hold	South Jetty																	
SJ_fut30_immed_rehab_comp3_small_hold	South Jetty																	
SJ_fut30_immed_rehab_comp4_medium_hold	South Jetty																	
SJ_fut30_immed_rehab_comp5_modi2_hold	South Jetty																	
SJ_fut30_sched_rehab_comp5_modi2_hold	South Jetty																	
JA_fut1_base	Jetty A																	
JA_fut1_fixasfail_repair	Jetty A																	
JA_fut1_sched_repair	Jetty A																	
JA_fut22_immed_rehab_small	Jetty A																	
JA_fut23_immed_rehab_small	Jetty A																	
JA_fut1_base_hold	Jetty A																	
JA_fut1_sched_repair_hold	Jetty A																	
JA_fut22_immed_rehab_small_hold	Jetty A																	
JA_fut23_immed_rehab_small_hold	Jetty A																	

Table C- 5. Array of Unit and Fixed 2012 Costs for the MCR Life Cycle Analysis

Unit Cost for Repairs

Jetty	Expedite Repair			FixAsFail Repair			Base Repair			Scheduled Repair		
	Inner Cost/ton	Middle Cost/Ton	Outer Cost/ton	Inner Cost/ton	Middle Cost/Ton	Outer Cost/ton	Inner Cost/ton	Middle Cost/Ton	Outer Cost/ton	Inner Cost/ton	Middle Cost/Ton	Outer Cost/ton
North	$ 216.00	$ -	$ 241.50	$ 194.80	$ -	$ 214.60	$ 194.50	$ -	$ 217.40	$ 202.80	$ -	$ 228.80
South	$ 216.60	$ 236.60	$ 256.20	$ 200.50	$ 217.90	$ 234.90	$ 199.20	$ 214.40	$ 243.10	$ 205.40	$ 218.60	$ 258.90
A	$ 287.20	$ -	$ 311.90	$ 266.60	$ -	$ 288.00	$ 263.50	$ -	$ 291.70	$ 270.10	$ -	$ 305.20

Unit and Fixed Costs for Rehab

Jetty	Minimum Rehab Cost/ton	Small Rehab Cost/ton	Moderate Rehab Cost/ton	Large Rehab Cost/ton	Head Capping Cost/ton	Avg. Barge Offloading Costs	Avg. Dredging Cost	Avg. Jetty Haul Road Costs	Avg. Mob/demob Costs	Avg. Mitigation Costs	Avg. Offloading Factor Costs	Avg. Added Fixed Rehab Total Costs	Fixed Cost, Spur
North	$ 157.20	$ -	$ 173.80	$ 193.50	$ 254.80	$ 912,920.00	$ 238,570.00	$ 431,607.00	$ 1,292,097.00	$ 356,956.00	$ 89,994.00	$ 3,322,144.00	$ 7,267,729.00
South	$ 149.70	$ 156.90	$ 159.50	$ 153.50	$ 239.50	$ 158,961.00	$ 108,845.00	$ 1,093,097.00	$ 744,552.00	$ 586,649.00	$ 384,959.00	$ 3,077,063.00	$ 4,194,970.00
A	$ -	$ 154.70	$ 154.70	$ -	$ 251.20	$ 666,349.00	$ 464,986.00	$ 440,973.00	$ 1,922,761.00	$ 1,104,822.00	$ 402,197.00	$ 5,002,088.00	$ 3,008,949.00

Unit Cost for Dredging

Jetty	Normal Cost/CY	ILW Cost/CY	Annual Normal Dredge Mob/Demob
NJ	$ 2.50	$ -	$ -
SJ	$ 3.12	$ -	$ -
JA	$ 3.12	$ 9.46	$ -

Unit Cost for NJ Repairs due to JA Head Recession

Jetty	Cost/ton	Annual Mob/Demob
NJ	$ -	$ -
SJ	$ -	$ -
JA	$ 217.40	$ -

Table C- 6. Component Costs Applied to North Jetty Alternatives (1 of 4)

MCR_LifeCycleCosts_NJ_fut1_**base**.xlsx		
MCR_LifeCycleCosts_NJ_fut1_**base_hold**.xlsx		
Expedited Repair	Inner Cost/ton	$ 216.00
Expedited Repair	Outer Cost/ton	$ 241.50
O&M Component		
Base	Inner Cost/ton	$ 194.50
Base	Outer Cost/ton	$ 217.40
Normal Dredging	Cost/CY	$ 2.50

MCR_LifeCycleCosts_NJ_fut1_**Fix-as-fails**.xlsx		
Expedited Repair	Inner Cost/ton	$ 216.00
Expedited Repair	Outer Cost/ton	$ 241.50
O&M Component		
Fix-as-fails Repair	Inner Cost/ton	$194.80
Fix-as-fails Repair	Outer Cost/ton	$214.60
Normal Dredging	Cost/CY	$ 2.50

MCR_LifeCycleCosts_NJ_fut1_**sched_repair**.xlsx		
MCR_LifeCycleCosts_NJ_fut1_**sched_repair_hold**.xlsx		
Expedited Repair	Inner Cost/ton	$ 216.00
Expedited Repair	Outer Cost/ton	$ 241.50
O&M Component		
Scheduled Repair	Inner Cost/ton	$202.80
Scheduled Repair	Outer Cost/ton	$228.80
Normal Dredging	Cost/CY	$ 2.50

MCR_LifeCycleCosts_NJ_fut10_**sched_repair**.xlsx		
Expedited Repair	Inner Cost/ton	$ 216.00
Expedited Repair	Outer Cost/ton	$ 241.50
Rehab	Head Capping Cost/ton	$ 254.80
Rehab	Avg. Barge Offloading Costs	$ 912,920.00
Rehab	Avg. Dredging Cost	$ 238,570.00
Rehab	Avg. Jetty Haul Road Costs	$ 431,607.00
Rehab	Avg. Mob/demob Costs	$ 1,292,097.00
Rehab	Avg. Mitigation Costs	$ 356,956.00
Rehab	Avg. Offloating Factor Costs	$ 89,994.00
Rehab	Avg. Added Direct Rehab Costs(sum of shaded)	$ 3,322,144.00
Rehab	Spur Cost	$ 7,267,729.00
O&M Component		
Scheduled Repair	Inner Cost/ton	$ 202.80
Scheduled Repair	Outer Cost/ton	$ 228.80
Normal Dredging	Cost/CY	$ 2.50

Table C- 7. Component Costs Applied to North Jetty Alternatives (2 of 4)

MCR_LifeCycleCosts_NJ_fut10_**sched_repair_hold**.xls		
Expedited Repair	Inner Cost/ton	$ 216.00
Expedited Repair	Outer Cost/ton	$ 241.50
Rehab	Head Capping Cost/ton	$ 254.80
Rehab	Avg. Barge Offloading Costs	$ 912,920.00
Rehab	Avg. Dredging Cost	$ 238,570.00
Rehab	Avg. Jetty Haul Road Costs	$ 431,607.00
Rehab	Avg. Mob/demob Costs	$ 1,292,097.00
Rehab	Avg. Mitigation Costs	$ 356,956.00
Rehab	Avg. Offloating Factor Costs	$ 89,994.00
Rehab	Avg. Added Direct Rehab Costs(sum of shaded)	$ 3,322,144.00
Rehab	Spur Cost	$ 7,267,729.00
O&M Component		
Scheduled Repair	Inner Cost/ton	$ 202.80
Scheduled Repair	Outer Cost/ton	$ 228.80
Normal Dredging	Cost/CY	$ 2.50

CR_LifeCycleCosts_NJ_fut10_**sched_repair, no head cap_hold**.x		
MCR_LifeCycleCosts_NJ_fut10_**sched_repair, no head cap**.xlsx		
Expedited Repair	Inner Cost/ton	$ 216.00
Expedited Repair	Outer Cost/ton	$ 241.50
Rehab	Spur Cost	$ 7,267,729.00
O&M Component		
Scheduled Repair	Inner Cost/ton	$ 202.80
Scheduled Repair	Outer Cost/ton	$ 228.80
Normal Dredging	Cost/CY	$ 2.50

MCR_LifeCycleCosts_NJ_fut21_**sched**_rehab_minimum.xlsx		
MCR_LifeCycleCosts_NJ_fut21_**immed**_rehab_minimum.xlsx		
Expedited Repair	Inner Cost/ton	$ 216.00
Expedited Repair	Outer Cost/ton	$ 241.50
Rehab	Minimum Rehab Cost/ton	$ 157.20
Rehab	Head Capping Cost/ton	$ 254.80
Rehab	Avg. Barge Offloading Costs	$ 912,920.00
Rehab	Avg. Dredging Cost	$ 238,570.00
Rehab	Avg. Jetty Haul Road Costs	$ 431,607.00
Rehab	Avg. Mob/demob Costs	$ 1,292,097.00
Rehab	Avg. Mitigation Costs	$ 356,956.00
Rehab	Avg. Offloating Factor Costs	$ 89,994.00
Rehab	Avg. Added Fixed Rehab Costs(sum of shaded)	$ 3,322,144.00
Rehab	Spur Cost	$ 7,267,729.00
O&M Component		
Base Repair	Inner Cost/ton	$ 194.50
Base Repair	Outer Cost/ton	$ 217.40
Normal Dredging	Cost/CY	$ 2.50

CR_LifeCycleCosts_NJ_fut21_**sched**_rehab_minimum_hold.xl		
CR_LifeCycleCosts_NJ_fut21_**immed**_rehab_minimum_hold.x		
Expedited Repair	Inner Cost/ton	$ 216.00
Expedited Repair	Outer Cost/ton	$ 241.50
Rehab	Minimum Rehab Cost/ton	$ 157.20
Rehab	Avg. Barge Offloading Costs	$ 912,920.00
Rehab	Avg. Dredging Cost	$ 238,570.00
Rehab	Avg. Jetty Haul Road Costs	$ 431,607.00
Rehab	Avg. Mob/demob Costs	$ 1,292,097.00
Rehab	Avg. Mitigation Costs	$ 356,956.00
Rehab	Avg. Offloating Factor Costs	$ 89,994.00
Rehab	Avg. Added Fixed Rehab Costs(sum of shaded)	$ 3,322,144.00
Rehab	Spur Cost	$ 7,267,729.00
O&M Component		
Base Repair	Inner Cost/ton	$ 194.50
Base Repair	Outer Cost/ton	$ 217.40
Normal Dredging	Cost/CY	$ 2.50

Table C- 8. Component Costs Applied to North Jetty Alternatives (3 of 4)

MCR_LifeCycleCosts_NJ_fut23_**sched**_rehab_moderate.xlsx		
MCR_LifeCycleCosts_NJ_fut23_**immed**_rehab_moderate.xlsx		
Expedited Repair	Inner Cost/ton	$ 216.00
Expedited Repair	Outer Cost/ton	$ 241.50
Rehab	Moderate Rehab Cost/ton	$173.80
Rehab	Head Capping Cost/ton	$ 254.80
Rehab	Avg. Barge Offloading Costs	$ 912,920.00
Rehab	Avg. Dredging Cost	$ 238,570.00
Rehab	Avg. Jetty Haul Road Costs	$ 431,607.00
Rehab	Avg. Mob/demob Costs	$ 1,292,097.00
Rehab	Avg. Mitigation Costs	$ 356,956.00
Rehab	Avg. Offloating Factor Costs	$ 89,994.00
Rehab	Avg. Added Fixed Rehab Costs(sum of shaded)	$ 3,322,144.00
Rehab	Spur Cost	$ 7,267,729.00
O&M Component		
Base Repair	Inner Cost/ton	$ 194.50
Base Repair	Outer Cost/ton	$ 217.40
Normal Dredging	Cost/CY	$ 2.50

MCR_LifeCycleCosts_NJ_fut23_**sched**_rehab_moderate_hold.xls		
MCR_LifeCycleCosts_NJ_fut23_**immed**_rehab_moderate_hold/xl		
Expedited Repair	Inner Cost/ton	$ 216.00
Expedited Repair	Outer Cost/ton	$ 241.50
Rehab	Moderate Rehab Cost/ton	$173.80
Rehab	Avg. Barge Offloading Costs	$ 912,920.00
Rehab	Avg. Dredging Cost	$ 238,570.00
Rehab	Avg. Jetty Haul Road Costs	$ 431,607.00
Rehab	Avg. Mob/demob Costs	$ 1,292,097.00
Rehab	Avg. Mitigation Costs	$ 356,956.00
Rehab	Avg. Offloating Factor Costs	$ 89,994.00
Rehab	Avg. Added Fixed Rehab Costs(sum of shaded)	$ 3,322,144.00
Rehab	Spur Cost	$ 7,267,729.00
O&M Component		
Base Repair	Inner Cost/ton	$ 194.50
Base Repair	Outer Cost/ton	$ 217.40
Normal Dredging	Cost/CY	$ 2.50

MCR_LifeCycleCosts_NJ_fut24_**sched**_rehab_large.xlsx		
MCR_LifeCycleCosts_NJ_fut24_**immed**_rehab_large.xlsx		
Expedited Repair	Inner Cost/ton	$ 216.00
Expedited Repair	Outer Cost/ton	$ 241.50
Rehab	Large Rehab Cost/ton	$193.50
Rehab	Head Capping Cost/ton	$ 254.80
Rehab	Avg. Barge Offloading Costs	$ 912,920.00
Rehab	Avg. Dredging Cost	$ 238,570.00
Rehab	Avg. Jetty Haul Road Costs	$ 431,607.00
Rehab	Avg. Mob/demob Costs	$ 1,292,097.00
Rehab	Avg. Mitigation Costs	$ 356,956.00
Rehab	Avg. Offloating Factor Costs	$ 89,994.00
Rehab	Avg. Added Fixed Rehab Costs(sum of shaded)	$ 3,322,144.00
Rehab	Spur Cost	$ 7,267,729.00
O&M Component		
Base Repair	Inner Cost/ton	$ 194.50
Base Repair	Outer Cost/ton	$ 217.40
Normal Dredging	Cost/CY	$ 2.50

Table C- 9. Component Costs Applied to North Jetty Alternatives (4 of 4)

CR_LifeCycleCosts_NJ_fut24_**sched**_rehab_large_hold.xl		
CR_LifeCycleCosts_NJ_fut24_**immed**_rehab_large_hold.xl		
Expedited Repair	Inner Cost/ton	$ 216.00
Expedited Repair	Outer Cost/ton	$ 241.50
Rehab	Large Rehab Cost/ton	$193.50
Rehab	Avg. Barge Offloading Costs	$ 912,920.00
Rehab	Avg. Dredging Cost	$ 238,570.00
Rehab	Avg. Jetty Haul Road Costs	$ 431,607.00
Rehab	Avg. Mob/demob Costs	$ 1,292,097.00
Rehab	Avg. Mitigation Costs	$ 356,956.00
Rehab	Avg. Offloating Factor Costs	$ 89,994.00
Rehab	Avg. Added Fixed Rehab Costs(sum of shaded)	$ 3,322,144.00
Rehab	Spur Cost	$ 7,267,729.00
O&M Component		
Base Repair	Inner Cost/ton	$ 194.50
Base Repair	Outer Cost/ton	$ 217.40
Normal Dredging	Cost/CY	$ 2.50

MCR_LifeCycleCosts_NJ_fut30_immed_rehab_comp4_small.xlsx		
MCR_LifeCycleCosts_NJ_fut30_sched_rehab_comp1_large.xlsx		
MCR_LifeCycleCosts_NJ_fut30_sched_rehab_comp2_medium.xlsx		
MCR_LifeCycleCosts_NJ_fut30_sched_rehab_comp3_small.xlsx		
MCR_LifeCycleCosts_NJ_fut30_sched_rehab_comp4_small_modi.xlsx		
Expedited Repair	Inner Cost/ton	$ 216.00
Expedited Repair	Outer Cost/ton	$ 241.50
Rehab	Minimum Rehab Cost/ton	$ 157.20
Rehab	Moderate Rehab Cost/ton	$ 173.80
Rehab	Large Rehab Cost/ton	$ 193.50
Rehab	Head Capping Cost/ton	$ 254.80
Rehab	Avg. Barge Offloading Costs	$ 912,920.00
Rehab	Avg. Dredging Cost	$ 238,570.00
Rehab	Avg. Jetty Haul Road Costs	$ 431,607.00
Rehab	Avg. Mob/demob Costs	$ 1,292,097.00
Rehab	Avg. Mitigation Costs	$ 356,956.00
Rehab	Avg. Offloating Factor Costs	$ 89,994.00
Rehab	Avg. Added Fixed Rehab Costs(sum of shaded)	$ 3,322,144.00
Rehab	Spur Cost	$ 7,267,729.00
O&M Component		
Base Repair	Inner Cost/ton	$ 194.50
Base Repair	Outer Cost/ton	$ 217.40
Normal Dredging	Cost/CY	$ 2.50

MCR_LifeCycleCosts_NJ_fut30_immed_rehab_comp4_small_hold.xlsx		
MCR_LifeCycleCosts_NJ_fut30_sched_rehab_comp1_large_hold.xlsx		
MCR_LifeCycleCosts_NJ_fut30_sched_rehab_comp2_medium_hold.xlsx		
MCR_LifeCycleCosts_NJ_fut30_sched_rehab_comp3_small_hold.xlsx		
MCR_LifeCycleCosts_NJ_fut30_sched_rehab_comp4_small_modi_hold.xlsx		
Expedited Repair	Inner Cost/ton	$ 216.00
Expedited Repair	Outer Cost/ton	$ 241.50
Rehab	Minimum Rehab Cost/ton	$ 157.20
Rehab	Moderate Rehab Cost/ton	$ 173.80
Rehab	Large Rehab Cost/ton	$ 193.50
Rehab	Avg. Barge Offloading Costs	$ 912,920.00
Rehab	Avg. Dredging Cost	$ 238,570.00
Rehab	Avg. Jetty Haul Road Costs	$ 431,607.00
Rehab	Avg. Mob/demob Costs	$ 1,292,097.00
Rehab	Avg. Mitigation Costs	$ 356,956.00
Rehab	Avg. Offloating Factor Costs	$ 89,994.00
Rehab	Avg. Added Fixed Rehab Costs(sum of shaded)	$ 3,322,144.00
Rehab	Spur Cost	$ 7,267,729.00
O&M Component		
Base Repair	Inner Cost/ton	$ 194.50
Base Repair	Outer Cost/ton	$ 217.40
Normal Dredging	Cost/CY	$ 2.50

Table C- 10. Unit Cost Components of South Jetty Alternatives (1 of 5)

MCR_LifeCycleCosts_SJ_fut1_**base**.xlsx MCR_LifeCycleCosts_SJ_fut1_**base_hold**.xlsx		
Expedited Repair	Inner Cost/ton	$ 216.60
Expedited Repair	Middle Cost/ton	$ 236.60
Expedited Repair	Outer Cost/ton	$ 256.20
O&M Component		
Base Repair	Inner Cost/ton	$ 199.20
Base Repair	Middle Cost/ton	$ 214.40
Base Repair	Outer Cost/ton	$ 243.10
Normal Dredging	Cost/CY	$ 3.12

MCR_LifeCycleCosts_SJ_fut1_**fixasfails**_repair.xlsx		
Expedited Repair	Inner Cost/ton	$ 216.60
Expedited Repair	Middle Cost/ton	$ 236.60
Expedited Repair	Outer Cost/ton	$ 256.20
O&M Component		
Fix as Fails Repair	Inner Cost/ton	$ 200.50
Fix as Fails Repair	Middle Cost/ton	$ 217.90
Fix as Fails Repair	Outer Cost/ton	$ 234.90
Normal Dredging	Cost/CY	$ 3.12

MCR_LifeCycleCosts_SJ_fut10_sched_repair_**head_hold**.xlsx MCR_LifeCycleCosts_SJ_fut1_**sched_repair**.xlsx MCR_LifeCycleCosts_SJ_fut1_**sched_repair_hold**.xlsx		
Expedited Repair	Inner Cost/ton	$ 216.60
Expedited Repair	Middle Cost/ton	$ 236.60
Expedited Repair	Outer Cost/ton	$ 256.20
O&M Component		
Scheduled Repair	Inner Cost/ton	$ 205.40
Scheduled Repair	Middle Cost/ton	$ 218.60
Scheduled Repair	Outer Cost/ton	$ 258.90
Normal Dredging	Cost/CY	$ 3.12

MCR_LifeCycleCosts_SJ_fut10_sched_repair_**head cap**.xls		
Expedited Repair	Inner Cost/ton	$ 216.60
Expedited Repair	Middle Cost/ton	$ 236.60
Expedited Repair	Outer Cost/ton	$ 256.20
Rehab	Head Capping Cost/ton	$ 239.50
Rehab	Avg. Barge Offloading Costs	$ 158,961.00
Rehab	Avg. Dredging Cost	$ 108,845.00
Rehab	Avg. Jetty Haul Road Costs	$ 1,093,097.00
Rehab	Avg. Mob/demob Costs	$ 744,552.00
Rehab	Avg. Mitigation Costs	$ 586,649.00
Rehab	Avg. Offloating Factor Costs	$ 384,959.00
Rehab	Avg. Added Fixed Rehab Costs (sum of shaded)	$ 3,077,063.00
O&M Component		
Scheduled Repair	Inner Cost/ton	$ 205.40
Scheduled Repair	Middle Cost/ton	$ 218.60
Scheduled Repair	Outer Cost/ton	$ 258.90
Normal Dredging	Cost/CY	$ 3.12

Table C- 11. Unit Cost Components of South Jetty Alternatives (2 of 5)

MCR_LifeCycleCosts_SJ_fut10_sched_repair_**head_spur**.xlsx		
Expedited Repair	Inner Cost/ton	$ 216.60
Expedited Repair	Middle Cost/ton	$ 236.60
Expedited Repair	Outer Cost/ton	$ 256.20
Rehab	Head Capping Cost/ton	$ 239.50
Rehab	Avg. Barge Offloading Costs	$ 158,961.00
Rehab	Avg. Dredging Cost	$ 108,845.00
Rehab	Avg. Jetty Haul Road Costs	$ 1,093,097.00
Rehab	Avg. Mob/demob Costs	$ 744,552.00
Rehab	Avg. Mitigation Costs	$ 586,649.00
Rehab	Avg. Offloating Factor Costs	$ 384,959.00
Rehab	Avg. Added Fixed Rehab Costs (sum of shaded)	$ 3,077,063.00
Rehab	Spur Cost	$ 4,194,971.00
O&M Component		
Scheduled Repair	Inner Cost/ton	$ 205.40
Scheduled Repair	Middle Cost/ton	$ 218.60
Scheduled Repair	Outer Cost/ton	$ 258.90
Normal Dredging	Cost/CY	$ 3.12

MCR_LifeCycleCosts_SJ_fut10_sched_repair_**head_spur_hold**.xlsx		
Expedited Repair	Inner Cost/ton	$ 216.60
Expedited Repair	Middle Cost/ton	$ 236.60
Expedited Repair	Outer Cost/ton	$ 256.20
Rehab	Spur Cost	$ 4,194,971.00
O&M Component		
Scheduled Repair	Inner Cost/ton	$ 205.40
Scheduled Repair	Middle Cost/ton	$ 218.60
Scheduled Repair	Outer Cost/ton	$ 258.90
Normal Dredging	Cost/CY	$ 3.12

MCR_LifeCycleCosts_SJ_fut21_**sched**_rehab_**minimum**.xlsx MCR_LifeCycleCosts_SJ_fut21_**immed**_rehab_**minimum**.xlsx		
Expedited Repair	Inner Cost/ton	$ 216.60
Expedited Repair	Middle Cost/ton	$ 236.60
Expedited Repair	Outer Cost/ton	$ 256.20
Rehab	Minimum Rehab Cost/ton	$ 149.70
Rehab	Head Capping Cost/ton	$ 239.50
Rehab	Avg. Barge Offloading Costs	$ 158,961.00
Rehab	Avg. Dredging Cost	$ 108,845.00
Rehab	Avg. Jetty Haul Road Costs	$ 1,093,097.00
Rehab	Avg. Mob/demob Costs	$ 744,552.00
Rehab	Avg. Mitigation Costs	$ 586,649.00
Rehab	Avg. Offloating Factor Costs	$ 384,959.00
Rehab	Avg. Added Fixed Rehab Costs (sum of shaded)	$ 3,077,063.00
Rehab	Spur Cost	$ 4,194,971.00
O&M Component		
Base Repair	Inner Cost/ton	$ 199.20
Base Repair	Middle Cost/ton	$ 214.40
Base Repair	Outer Cost/ton	$ 243.10
Normal Dredging	Cost/CY	$ 3.12

MCR_LifeCycleCosts_SJ_fut21_**sched**_rehab_**minimum_hold**.xlsx MCR_LifeCycleCosts_SJ_fut21_**immed**_rehab_**minimum_hold**.xlsx		
Expedited Repair	Inner Cost/ton	$ 216.60
Expedited Repair	Middle Cost/ton	$ 236.60
Expedited Repair	Outer Cost/ton	$ 256.20
Rehab	Minimum Rehab Cost/ton	$ 149.70
Rehab	Avg. Barge Offloading Costs	$ 158,961.00
Rehab	Avg. Dredging Cost	$ 108,845.00
Rehab	Avg. Jetty Haul Road Costs	$ 1,093,097.00
Rehab	Avg. Mob/demob Costs	$ 744,552.00
Rehab	Avg. Mitigation Costs	$ 586,649.00
Rehab	Avg. Offloating Factor Costs	$ 384,959.00
Rehab	Avg. Added Fixed Rehab Costs (sum of shaded)	$ 3,077,063.00
Rehab	Spur Cost	$ 4,194,971.00
O&M Component		
Base Repair	Inner Cost/ton	$ 199.20
Base Repair	Middle Cost/ton	$ 214.40
Base Repair	Outer Cost/ton	$ 243.10
Normal Dredging	Cost/CY	$ 3.12

Table C- 12. Unit Cost Components of South Jetty Alternatives (3 of 5)

MCR_LifeCycleCosts_SJ_fut22_immed_rehab_**small**.xls		
Expedited Repair	Inner Cost/ton	$ 216.60
Expedited Repair	Middle Cost/ton	$ 236.60
Expedited Repair	Outer Cost/ton	$ 256.20
Rehab	Small Rehab Cost/ton	$ 156.90
Rehab	Head Capping Cost/ton	$ 239.50
Rehab	Avg. Barge Offloading Costs	$ 158,961.00
Rehab	Avg. Dredging Cost	$ 108,845.00
Rehab	Avg. Jetty Haul Road Costs	$ 1,093,097.00
Rehab	Avg. Mob/demob Costs	$ 744,552.00
Rehab	Avg. Mitigation Costs	$ 586,649.00
Rehab	Avg. Offloating Factor Costs	$ 384,959.00
Rehab	Avg. Added Fixed Rehab Costs (sum of shaded)	$ 3,077,063.00
Rehab	Spur Cost	$ 4,194,971.00
O&M Component		
Base Repair	Inner Cost/ton	$ 199.20
Base Repair	Middle Cost/ton	$ 214.40
Base Repair	Outer Cost/ton	$ 243.10
Normal Dredging	Cost/CY	$ 3.12

MCR_LifeCycleCosts_SJ_fut22_immed_rehab_**small_hold**.xls		
Expedited Repair	Inner Cost/ton	$ 216.60
Expedited Repair	Middle Cost/ton	$ 236.60
Expedited Repair	Outer Cost/ton	$ 256.20
Rehab	Small Rehab Cost/ton	$ 156.90
Rehab	Avg. Barge Offloading Costs	$ 158,961.00
Rehab	Avg. Dredging Cost	$ 108,845.00
Rehab	Avg. Jetty Haul Road Costs	$ 1,093,097.00
Rehab	Avg. Mob/demob Costs	$ 744,552.00
Rehab	Avg. Mitigation Costs	$ 586,649.00
Rehab	Avg. Offloating Factor Costs	$ 384,959.00
Rehab	Avg. Added Fixed Rehab Costs (sum of shaded)	$ 3,077,063.00
Rehab	Spur Cost	$ 4,194,971.00
O&M Component		
Base Repair	Inner Cost/ton	$ 199.20
Base Repair	Middle Cost/ton	$ 214.40
Base Repair	Outer Cost/ton	$ 243.10
Normal Dredging	Cost/CY	$ 3.12

MCR_LifeCycleCosts_SJ_fut23_immed_rehab_**moderate**.xlsx		
Expedited Repair	Inner Cost/ton	$ 216.60
Expedited Repair	Middle Cost/ton	$ 236.60
Expedited Repair	Outer Cost/ton	$ 256.20
Rehab	Moderate Rehab Cost/ton	$ 159.50
Rehab	Head Capping Cost/ton	$ 239.50
Rehab	Avg. Barge Offloading Costs	$ 158,961.00
Rehab	Avg. Dredging Cost	$ 108,845.00
Rehab	Avg. Jetty Haul Road Costs	$ 1,093,097.00
Rehab	Avg. Mob/demob Costs	$ 744,552.00
Rehab	Avg. Mitigation Costs	$ 586,649.00
Rehab	Avg. Offloating Factor Costs	$ 384,959.00
Rehab	Avg. Added Fixed Rehab Costs (sum of shaded)	$ 3,077,063.00
Rehab	Spur Cost	$ 4,194,971.00
O&M Component		
Base Repair	Inner Cost/ton	$ 199.20
Base Repair	Middle Cost/ton	$ 214.40
Base Repair	Outer Cost/ton	$ 243.10
Normal Dredging	Cost/CY	$ 3.12

MCR_LifeCycleCosts_SJ_fut23_immed_rehab_**moderate_hold**.xlsx		
Expedited Repair	Inner Cost/ton	$ 216.60
Expedited Repair	Middle Cost/ton	$ 236.60
Expedited Repair	Outer Cost/ton	$ 256.20
Rehab	Moderate Rehab Cost/ton	$ 159.50
Rehab	Avg. Barge Offloading Costs	$ 158,961.00
Rehab	Avg. Dredging Cost	$ 108,845.00
Rehab	Avg. Jetty Haul Road Costs	$ 1,093,097.00
Rehab	Avg. Mob/demob Costs	$ 744,552.00
Rehab	Avg. Mitigation Costs	$ 586,649.00
Rehab	Avg. Offloating Factor Costs	$ 384,959.00
Rehab	Avg. Added Fixed Rehab Costs (sum of shaded)	$ 3,077,063.00
Rehab	Spur Cost	$ 4,194,971.00
O&M Component		
Base Repair	Inner Cost/ton	$ 199.20
Base Repair	Middle Cost/ton	$ 214.40
Base Repair	Outer Cost/ton	$ 243.10
Normal Dredging	Cost/CY	$ 3.12

Table C- 13. Unit Cost Components of South Jetty Alternatives (4 of 5)

MCR_LifeCycleCosts_SJ_fut24_immed_rehab_**large**.xlsx		
Expedited Repair	Inner Cost/ton	$ 216.60
Expedited Repair	Middle Cost/ton	$ 236.60
Expedited Repair	Outer Cost/ton	$ 256.20
Rehab	Large Rehab Cost/ton	**$ 153.50**
Rehab	Head Capping Cost/ton	$ 239.50
Rehab	Avg. Barge Offloading Costs	$ 158,961.00
Rehab	Avg. Dredging Cost	$ 108,845.00
Rehab	Avg. Jetty Haul Road Costs	$ 1,093,097.00
Rehab	Avg. Mob/demob Costs	$ 744,552.00
Rehab	Avg. Mitigation Costs	$ 586,649.00
Rehab	Avg. Offloating Factor Costs	$ 384,959.00
Rehab	Avg. Added Fixed Rehab Costs (sum of shaded)	$ 3,077,063.00
Rehab	Spur Cost	$ 4,194,971.00
O&M Component		
Base Repair	Inner Cost/ton	$ 199.20
Base Repair	Middle Cost/ton	$ 214.40
Base Repair	Outer Cost/ton	$ 243.10
Normal Dredging	Cost/CY	$ 3.12

MCR_LifeCycleCosts_SJ_fut24_immed_rehab_**large_hold**.xlsx		
Expedited Repair	Inner Cost/ton	$ 216.60
Expedited Repair	Middle Cost/ton	$ 236.60
Expedited Repair	Outer Cost/ton	$ 256.20
Rehab	Large Rehab Cost/ton	**$ 153.50**
Rehab	Avg. Barge Offloading Costs	$ 158,961.00
Rehab	Avg. Dredging Cost	$ 108,845.00
Rehab	Avg. Jetty Haul Road Costs	$ 1,093,097.00
Rehab	Avg. Mob/demob Costs	$ 744,552.00
Rehab	Avg. Mitigation Costs	$ 586,649.00
Rehab	Avg. Offloating Factor Costs	$ 384,959.00
Rehab	Avg. Added Fixed Rehab Costs (sum of shaded)	$ 3,077,063.00
Rehab	Spur Cost	$ 4,194,971.00
O&M Component		
Base Repair	Inner Cost/ton	$ 199.20
Base Repair	Middle Cost/ton	$ 214.40
Base Repair	Outer Cost/ton	$ 243.10
Normal Dredging	Cost/CY	$ 3.12

MCR_LifeCycleCosts_SJ_fut30_immed_rehab_comp1_**large**.xlsx		
Expedited Repair	Inner Cost/ton	$ 216.60
Expedited Repair	Middle Cost/ton	$ 236.60
Expedited Repair	Outer Cost/ton	$ 256.20
Rehab	Minimum Rehab Cost/ton	$ 149.70
Rehab	Small Rehab Cost/ton	$ 156.90
Rehab	Moderate Rehab Cost/ton	$ 159.50
Rehab	Large Rehab Cost/ton	$ 153.50
Rehab	Head Capping Cost/ton	$ 239.50
Rehab	Avg. Barge Offloading Costs	$ 158,961.00
Rehab	Avg. Dredging Cost	$ 108,845.00
Rehab	Avg. Jetty Haul Road Costs	$ 1,093,097.00
Rehab	Avg. Mob/demob Costs	$ 744,552.00
Rehab	Avg. Mitigation Costs	$ 586,649.00
Rehab	Avg. Offloating Factor Costs	$ 384,959.00
Rehab	Avg. Added Fixed Rehab Costs (sum of shaded)	$ 3,077,063.00
Rehab	Spur Cost	$ 4,194,971.00
O&M Component		
Base Repair	Inner Cost/ton	$ 199.20
Base Repair	Middle Cost/ton	$ 214.40
Base Repair	Outer Cost/ton	$ 243.10
Normal Dredging	Cost/CY	$ 3.12

MCR_LifeCycleCosts_SJ_fut30_immed_rehab_comp1_**large_hold**.xlsx		
Expedited Repair	Inner Cost/ton	$ 216.60
Expedited Repair	Middle Cost/ton	$ 236.60
Expedited Repair	Outer Cost/ton	$ 256.20
Rehab	Large Rehab Cost/ton	**$ 153.50**
Rehab	Avg. Barge Offloading Costs	$ 158,961.00
Rehab	Avg. Dredging Cost	$ 108,845.00
Rehab	Avg. Jetty Haul Road Costs	$ 1,093,097.00
Rehab	Avg. Mob/demob Costs	$ 744,552.00
Rehab	Avg. Mitigation Costs	$ 586,649.00
Rehab	Avg. Offloating Factor Costs	$ 384,959.00
Rehab	Avg. Added Fixed Rehab Costs (sum of shaded)	$ 3,077,063.00
Rehab	Spur Cost	$ 4,194,971.00
O&M Component		
Base Repair	Inner Cost/ton	$ 199.20
Base Repair	Middle Cost/ton	$ 214.40
Base Repair	Outer Cost/ton	$ 243.10
Normal Dredging	Cost/CY	$ 3.12

Table C- 14. Unit Cost Components of South Jetty Alternatives (5 of 5).

MCR_LifeCycleCosts_SJ_fut30_**immed**_rehab_comp3_**small**.xlsx		
MCR_LifeCycleCosts_SJ_fut30_**sched**_rehab_comp5_modi2.xlsx		
MCR_LifeCycleCosts_SJ_fut30_**immed**_rehab_comp5_modi2.xlsx		
MCR_LifeCycleCosts_SJ_fut30_**immed**_rehab_comp4_medium.xlsx		
MCR_LifeCycleCosts_SJ_fut30_**immed**_rehab_comp2_modi1.xlsx		
MCR_LifeCycleCosts_SJ_fut30_**immed**_rehab_comp1_large.xlsx		
Expedited Repair	Inner Cost/ton	$ 216.60
Expedited Repair	Middle Cost/ton	$ 236.60
Expedited Repair	Outer Cost/ton	$ 256.20
Rehab	Minimum Rehab Cost/ton	$ 149.70
Rehab	Small Rehab Cost/ton	$ 156.90
Rehab	Moderate Rehab Cost/ton	$ 159.50
Rehab	Large Rehab Cost/ton	$ 153.50
Rehab	Head Capping Cost/ton	$ 239.50
Rehab	Avg. Barge Offloading Costs	$ 158,961.00
Rehab	Avg. Dredging Cost	$ 108,845.00
Rehab	Avg. Jetty Haul Road Costs	$ 1,093,097.00
Rehab	Avg. Mob/demob Costs	$ 744,552.00
Rehab	Avg. Mitigation Costs	$ 586,649.00
Rehab	Avg. Offloating Factor Costs	$ 384,959.00
Rehab	Avg. Added Fixed Rehab Costs (sum of shaded)	$ 3,077,063.00
Rehab	Spur Cost	$ 4,194,971.00
O&M Component		
Base Repair	Inner Cost/ton	$ 199.20
Base Repair	Middle Cost/ton	$ 214.40
Base Repair	Outer Cost/ton	$ 243.10
Normal Dredging	Cost/CY	$ 3.12

MCR_LifeCycleCosts_SJ_fut30_**immed**_rehab_comp3_**small_hold**.xlsx		
MCR_LifeCycleCosts_SJ_fut30_**sched**_rehab_comp5_modi2_hold.xlsx		
MCR_LifeCycleCosts_SJ_fut30_**immed**_rehab_comp5_modi2_hold.xlsx		
MCR_LifeCycleCosts_SJ_fut30_**immed**_rehab_comp4_medium_hold.xlsx		
MCR_LifeCycleCosts_SJ_fut30_**immed**_rehab_comp2_modi1_hold.xlsx		
MCR_LifeCycleCosts_SJ_fut30_**immed**_rehab_comp1_large.xlsx		
Expedited Repair	Inner Cost/ton	$ 216.60
Expedited Repair	Middle Cost/ton	$ 236.60
Expedited Repair	Outer Cost/ton	$ 256.20
Rehab	Minimum Rehab Cost/ton	$ 149.70
Rehab	Small Rehab Cost/ton	$ 156.90
Rehab	Moderate Rehab Cost/ton	$ 159.50
Rehab	Large Rehab Cost/ton	$ 153.50
Rehab	Avg. Barge Offloading Costs	$ 158,961.00
Rehab	Avg. Dredging Cost	$ 108,845.00
Rehab	Avg. Jetty Haul Road Costs	$ 1,093,097.00
Rehab	Avg. Mob/demob Costs	$ 744,552.00
Rehab	Avg. Mitigation Costs	$ 586,649.00
Rehab	Avg. Offloating Factor Costs	$ 384,959.00
Rehab	Avg. Added Fixed Rehab Costs (sum of shaded)	$ 3,077,063.00
Rehab	Spur Cost	$ 4,194,971.00
O&M Component		
Base Repair	Inner Cost/ton	$ 199.20
Base Repair	Middle Cost/ton	$ 214.40
Base Repair	Outer Cost/ton	$ 243.10
Normal Dredging	Cost/CY	$ 3.12

Table C- 15. Unit Cost Components of Jetty A Alternatives (1 of 2)

MCR_LifeCycleCosts_JA_fut1_base.xlsx		
Expedited Repair	Inner Cost/ton	$ 287.20
Expedited Repair	Outer Cost/ton	$ 311.90
O&M Component		
Base	Inner Cost/ton	$ 263.50
Base	Outer Cost/ton	$ 291.70
Normal Dredging	Cost/CY	$ 3.12
ILW Dredging	Cost/CY	$ 9.46
Repairs to NJ from JA Head Recession	Cost/ton	$ 217.40

MCR_LifeCycleCosts_JA_fut1_fix-as-fail_repair.xlsx		
Expedited Repair	Inner Cost/ton	$ 287.20
Expedited Repair	Outer Cost/ton	$ 311.90
O&M Component		
Fix-as-fails	Inner Cost/ton	$ 266.60
Fix-as-fails	Outer Cost/ton	$ 288.00
Normal Dredging	Cost/CY	$ 3.12
ILW Dredging	Cost/CY	$ 9.46
Repairs to NJ from JA Head Recession	Cost/ton	$ 217.40

MCR_LifeCycleCosts_JA_fut1_sched_repair.xlsx		
Expedited Repair	Inner Cost/ton	$ 287.20
Expedited Repair	Outer Cost/ton	$ 311.90
O&M Component		
Scheduled	Inner Cost/ton	$ 270.10
Scheduled	Outer Cost/ton	$ 305.20
Normal Dredging	Cost/CY	$ 3.12
ILW Dredging	Cost/CY	$ 9.46
Repairs to NJ from JA Head Recession	Cost/ton	$ 217.40

MCR_LifeCycleCosts_JA_fut1_base_hold.xlsx		
Expedited Repair	Inner Cost/ton	$ 287.20
Expedited Repair	Outer Cost/ton	$ 311.90
O&M Component		
Base	Inner Cost/ton	$ 263.50
Base	Outer Cost/ton	$ 291.70
Normal Dredging	Cost/CY	$ 3.12

MCR_LifeCycleCosts_JA_fut1_sched_repair_hold.xlsx		
Expedited Repair	Inner Cost/ton	$ 287.20
Expedited Repair	Outer Cost/ton	$ 311.90
O&M Component		
Scheduled	Inner Cost/ton	$ 270.10
Scheduled	Outer Cost/ton	$ 305.20
Normal Dredging	Cost/CY	$ 3.12

Table C- 16. Unit Cost Components of Jetty A Alternatives (2 of 2)

MCR_LifeCycleCosts_JA_fut23_immed_rehab_small.xlsx MCR_LifeCycleCosts_JA_fut22_immed_rehab_small.xlsx		
Rehab	Small/Moderate Rehab Cost/ton	$ 154.70
Rehab	Head Capping Cost/ton	$ 251.20
Rehab	Avg. Barge Offloading Costs	$ 666,349.00
Rehab	Avg. Dredging Cost	$ 464,986.00
Rehab	Avg. Jetty Haul Road Costs	$ 440,973.00
Rehab	Avg. Mob/demob Costs	$ 1,922,761.00
Rehab	Avg. Mitigation Costs	$ 1,104,822.00
Rehab	Avg. Offloating Factor Costs	$ 402,197.00
Rehab	Avg. Added Fixed Rehab Costs (sum of shaded)	$ 5,002,088.00
Rehab	Spur	$ 3,008,949.00
Expedited Repair	Inner Cost/ton	$ 287.20
Expedited Repair	Outer Cost/ton	$ 311.90
O&M Component		
Base	Inner Cost/ton	$ 263.50
Base	Outer Cost/ton	$ 291.70
Normal Dredging	Cost/CY	$ 3.12
ILW Dredging	Cost/CY	$ 9.46
Repairs to NJ from JA Head Recession	Cost/ton	$ 217.40

MCR_LifeCycleCosts_JA_fut23_immed_rehab_small_hold.xlsx MCR_LifeCycleCosts_JA_fut22_immed_rehab_small_hold.xlsx		
Rehab	Small/Moderate Rehab Cost/ton	$ 154.70
Rehab	Avg. Barge Offloading Costs	$ 666,349.00
Rehab	Avg. Dredging Cost	$ 464,986.00
Rehab	Avg. Jetty Haul Road Costs	$ 440,973.00
Rehab	Avg. Mob/demob Costs	$ 1,922,761.00
Rehab	Avg. Mitigation Costs	$ 1,104,822.00
Rehab	Avg. Offloating Factor Costs	$ 402,197.00
Rehab	Avg. Added Fixed Rehab Costs (sum of shaded)	$ 5,002,088.00
Rehab	Spur	$ 3,008,949.00
Expedited Repair	Inner Cost/ton	$ 287.20
Expedited Repair	Outer Cost/ton	$ 311.90
O&M Component		
Base	Inner Cost/ton	$ 263.50
Base	Outer Cost/ton	$ 291.70
Normal Dredging	Cost/CY	$ 3.12
Repairs to NJ from JA Head Recession	Cost/ton	$ 217.40

Table C- 17. Example of Life Cycle Cost Spreadsheet

Alternative	fut1_sched_repair_hold

Governing parameters

Jetty (NJ, SJ, JA)	Project Life (Years)	Base Year	Federal Discount Rate	Monthly Compound Interest Factor	Amortization factor, 50 yrs
NJ	50	2015	4.00%	1.003274	0.046550

Unit Cost for Repairs

Activity (Index)	Emergency Repair (1)			Expedite Repair (2)		
Jetty	Inner Cost/ton	Middle Cost/Ton	Outer Cost/ton	Inner Cost/ton	Middle Cost/Ton	Outer Cost/ton
NJ	$ 237.30	$ -	$ 265.50	$ 216.00	$ -	$ 241.50
SJ	$ 216.60	$ 236.60	$ 256.20	$ 216.60	$ 236.60	$ 256.20
JA	$ 287.20	$ -	$ 311.90	$ 287.20	$ -	$ 311.90

Unit Cost for Repairs

Activity (Index)	Base Repair (4)			Scheduled Repair (5)		
Jetty	Inner Cost/ton	Middle Cost/Ton	Outer Cost/ton	Inner Cost/ton	Middle Cost/Ton	Outer Cost/ton
NJ	$ 194.50	$ -	$ 217.40	$ 202.80	$ -	$ 228.80
SJ	$ 199.20	$ 214.40	$ 243.10	$ 205.40	$ 218.60	$ 258.90
JA	$ 263.50	$ -	$ 291.70	$ 270.10	$ -	$ 305.20

Unit Cost for Rehab

Jetty	Minimum Rehab Cost/ton	Small Rehab Cost/ton	Moderate Rehab Cost/ton	Large Rehab Cost/ton	Head Capping Cost/ton	Avg. Barge Offloading Costs
NJ	$ 157.20	$ -	$ 173.80	$ 193.50	$ 254.80	$ 912,920.00
SJ	$ 149.70	$ 156.90	$ 159.50	$ 153.50	$ 239.50	$ 158,961.00
JA	$ -	$ 154.70	$ 154.70	$ -	$ 251.20	$ 666,349.00

Unit Cost for Rehab

Jetty	Avg. Dredgeing Cost	Avg. Jetty Haul Road Costs	Avg. Mob/demob Costs	Avg. Mitigation Costs	Avg. Offloating Factor Costs
NJ	$ 238,570.00	$ 431,607.00	$ 1,292,097.00	$ 356,956.00	$ 89,994.00
SJ	$ 108,845.00	$ 1,093,097.00	$ 744,552.00	$ 586,649.00	$ 384,959.00
JA	$ 464,986.00	$ 440,973.00	$ 1,922,761.00	$ 1,104,822.00	$ 402,197.00

Unit Cost for Dredging

Jetty	Normal Cost/CY	ILW Cost/CY	Annual Normal Dredge Mob/Demob
NJ	$ 2.50	$ -	$ -
SJ	$ 3.12	$ -	$ -
JA	$ 3.12	$ 9.46	$ -

Unit Cost for NJ Repairs due to JA Head Recession

Jetty	Cost/ton	Annual Mob/Demob
NJ	$ -	$ -
SJ	$ -	$ -
JA	$ 217.40	$ -

Project Life (Years)	Inner Cost/ton	Middle Cost/ton	Outer Cost/ton	Federal Discount Rate	Monthly Compound Interest Factor	Amortization factor, 50 yrs	Activity Index
50	$ 216.00	$ -	$ 241.50	4.00%	1.003274	0.046550	2

Alternative: NJ_fut1_sched_repair_hold
Activity: Expedite Repair

Totals over Project Life 2015-2064

Year	2015	Inner Annual Repair Volume (ton)	Middle Annual Repair Volume (ton)	Outer Annual Repair Volume (ton)	Total Annual Repair Cost ($)	Present Work Equivalent ($)
Totals		24,216	-	41,691	$ 15,299,033	$ 8,227,048
2007	-7	-	-	-	$ -	$ -
2008	-6	81	-	98	$ 41,163.00	$ 41,163.00
2009	-5	1,213	-	175	$ 304,270.50	$ 304,270.50
2010	-4	7,170	-	1,559	$ 1,925,218.50	$ 1,925,218.50
2011	-3	5,511	-	2,618	$ 1,822,623.00	$ 1,822,623.00
2012	-2	5,965	-	2,078	$ 1,790,277.00	$ 1,790,277.00
2013	-1	7,275	-	1,060	$ 1,827,390.00	$ 1,827,390.00
2014	0	6,868	-	631	$ 1,635,874.50	$ 1,635,874.50
2015	1	4,192	-	287	$ 974,782.50	$ 937,290.87
2016	2	3,602	-	568	$ 915,204.00	$ 846,157.54
2017	3	2,083	-	604	$ 595,794.00	$ 529,658.70
2018	4	1,711	-	1,004	$ 612,042.00	$ 523,176.07
2019	5	1,442	-	1,028	$ 559,734.00	$ 460,060.55
2020	6	1,264	-	1,687	$ 680,434.50	$ 537,757.27
2021	7	1,077	-	1,566	$ 610,821.00	$ 464,173.76
2022	8	1,627	-	910	$ 571,197.00	$ 417,368.05
2023	9	1,216	-	831	$ 463,342.50	$ 325,538.29
2024	10	752	-	240	$ 220,392.00	$ 148,888.94
2025	11	834	-	118	$ 208,641.00	$ 135,529.22
2026	12	200	-	331	$ 123,136.50	$ 76,910.69
2027	13	367	-	497	$ 199,297.50	$ 119,692.91
2028	14	279	-	300	$ 132,714.00	$ 76,639.03
2029	15	345	-	1,006	$ 317,469.00	$ 176,279.27
2030	16	289	-	849	$ 267,457.50	$ 142,797.75
2031	17	421	-	1,207	$ 382,426.50	$ 196,327.53
2032	18	169	-	1,105	$ 303,361.50	$ 149,747.77
2033	19	85	-	1,332	$ 340,038.00	$ 161,396.46
2034	20	144	-	1,571	$ 410,500.50	$ 187,347.07
2035	21	113	-	1,149	$ 301,891.50	$ 132,480.13
2036	22	219	-	1,126	$ 319,233.00	$ 134,702.08
2037	23	42	-	564	$ 145,278.00	$ 58,943.11
2038	24	27	-	476	$ 120,786.00	$ 47,121.21
2039	25	-	-	434	$ 104,811.00	$ 39,316.37
2040	26	146	-	420	$ 132,966.00	$ 47,959.40
2041	27	55	-	330	$ 91,575.00	$ 31,759.73
2042	28	266	-	528	$ 184,968.00	$ 61,682.66
2043	29	136	-	494	$ 148,677.00	$ 47,673.49
2044	30	55	-	679	$ 175,858.50	$ 54,220.46
2045	31	-	-	798	$ 192,717.00	$ 57,132.93
2046	32	56	-	976	$ 247,800.00	$ 70,637.36
2047	33	-	-	1,042	$ 251,643.00	$ 68,973.88
2048	34	55	-	1,193	$ 299,989.50	$ 79,062.86
2049	35	28	-	955	$ 236,680.50	$ 59,978.50
2050	36	-	-	930	$ 224,595.00	$ 54,726.78
2051	37	30	-	1,114	$ 275,511.00	$ 64,551.36
2052	38	-	-	707	$ 170,740.50	$ 38,465.35
2053	39	-	-	260	$ 62,790.00	$ 13,601.61
2054	40	-	-	356	$ 85,974.00	$ 17,907.44
2055	41	58	-	268	$ 77,250.00	$ 15,471.47
2056	42	249	-	697	$ 222,109.50	$ 42,772.72
2057	43	92	-	901	$ 237,463.50	$ 43,970.69
2058	44	68	-	1,118	$ 284,685.00	$ 50,687.12
2059	45	115	-	799	$ 217,798.50	$ 37,286.76
2060	46	165	-	1,536	$ 406,584.00	$ 66,929.36
2061	47	58	-	841	$ 215,629.50	$ 34,130.39
2062	48	55	-	1,162	$ 292,503.00	$ 44,517.43
2063	49	-	-	1,264	$ 305,256.00	$ 44,671.50
2064	50	29	-	1,533	$ 376,483.50	$ 52,975.98
2065	51	502	-	1,594	$ 493,383.00	$ 66,755.01
2066	52	-	-	904	$ 218,316.00	$ 28,402.20
2067	53	62	-	506	$ 135,591.00	$ 16,961.49
2068	54	28	-	336	$ 87,192.00	$ 10,487.60
2069	55	-	-	560	$ 135,240.00	$ 15,641.25
2070	56	-	-	512	$ 123,648.00	$ 13,750.55
2071	57	-	-	-	$ -	$ -

Project Life (Years)	Inner Cost/ton	Middle Cost/ton	Outer Cost/ton	Federal Discount Rate	Monthly Compound Interest Factor	Amortization factor, 50 yrs	Activity Index
50	$ -	$ -	$ -	4.00%	1.003274	0.046550	4

Alternative: NJ_fut1_sched_repair_hold
Activity: Base Repair

Totals over Project Life 2015-2064

Year	2015	Inner Annual Repair Volume (ton)	Middle Annual Repair Volume (ton)	Outer Annual Repair Volume (ton)	Total Annual Repair Cost ($)	Present Work Equivalent ($)
		-	-	-	$ -	$ -
2007	-7	-	-	-	$ -	$ -
2008	-6	-	-	-	$ -	$ -
2009	-5	-	-	-	$ -	$ -
2010	-4	-	-	-	$ -	$ -
2011	-3	-	-	-	$ -	$ -
2012	-2	-	-	-	$ -	$ -
2013	-1	-	-	-	$ -	$ -
2014	0	-	-	22,814	$ -	$ -
2015	1	-	-	-	$ -	$ -
2016	2	-	-	-	$ -	$ -
2017	3	-	-	-	$ -	$ -
2018	4	-	-	-	$ -	$ -
2019	5	-	-	-	$ -	$ -
2020	6	-	-	-	$ -	$ -
2021	7	-	-	-	$ -	$ -
2022	8	-	-	-	$ -	$ -
2023	9	-	-	-	$ -	$ -
2024	10	-	-	-	$ -	$ -
2025	11	-	-	-	$ -	$ -
2026	12	-	-	-	$ -	$ -
2027	13	-	-	-	$ -	$ -
2028	14	-	-	-	$ -	$ -
2029	15	-	-	-	$ -	$ -
2030	16	-	-	-	$ -	$ -
2031	17	-	-	-	$ -	$ -
2032	18	-	-	-	$ -	$ -
2033	19	-	-	-	$ -	$ -
2034	20	-	-	-	$ -	$ -
2035	21	-	-	-	$ -	$ -
2036	22	-	-	-	$ -	$ -
2037	23	-	-	-	$ -	$ -
2038	24	-	-	-	$ -	$ -
2039	25	-	-	-	$ -	$ -
2040	26	-	-	-	$ -	$ -
2041	27	-	-	-	$ -	$ -
2042	28	-	-	-	$ -	$ -
2043	29	-	-	-	$ -	$ -
2044	30	-	-	-	$ -	$ -
2045	31	-	-	-	$ -	$ -
2046	32	-	-	-	$ -	$ -
2047	33	-	-	-	$ -	$ -
2048	34	-	-	-	$ -	$ -
2049	35	-	-	-	$ -	$ -
2050	36	-	-	-	$ -	$ -
2051	37	-	-	-	$ -	$ -
2052	38	-	-	-	$ -	$ -
2053	39	-	-	-	$ -	$ -
2054	40	-	-	-	$ -	$ -
2055	41	-	-	-	$ -	$ -
2056	42	-	-	-	$ -	$ -
2057	43	-	-	-	$ -	$ -
2058	44	-	-	-	$ -	$ -
2059	45	-	-	-	$ -	$ -
2060	46	-	-	-	$ -	$ -
2061	47	-	-	-	$ -	$ -
2062	48	-	-	-	$ -	$ -
2063	49	-	-	-	$ -	$ -
2064	50	-	-	-	$ -	$ -
2065	51	-	-	-	$ -	$ -
2066	52	-	-	-	$ -	$ -
2067	53	-	-	-	$ -	$ -
2068	54	-	-	-	$ -	$ -
2069	55	-	-	-	$ -	$ -
2070	56	-	-	-	$ -	$ -
2071	57	-	-	-	$ -	$ -

Project Life (Years)	Inner Cost/ton	Middle Cost/ton	Outer Cost/ton	Federal Discount Rate	Monthly Compound Interest Factor	Amortization factor, 50 yrs	Activity Index
50	$ 202.80	$ -	$ 228.80	4.00%	1.003274	0.046550	5

Alternative: NJ_fut1_sched_repair_hold
Activity: Scheduled Repair

Totals over Project Life 2015-2064

		306,777	-	196,267	$ 107,120,265	$ 52,624,881
Year	2015	Inner Annual Repair Volume (ton)	Middle Annual Repair Volume (ton)	Outer Annual Repair Volume (ton)	Total Annual Repair Cost ($)	Present Work Equivalent ($)
2007	-7	-	-	-	$ -	$ -
2008	-6	-	-	4,033	$ 922,750.40	$ 922,750.40
2009	-5	-	-	2,384	$ 545,459.20	$ 545,459.20
2010	-4	9,571	-	14,783	$ 5,323,349.20	$ 5,323,349.20
2011	-3	7,178	-	10,187	$ 3,786,484.00	$ 3,786,484.00
2012	-2	4,757	-	9,731	$ 3,191,172.40	$ 3,191,172.40
2013	-1	5,815	-	9,966	$ 3,459,502.80	$ 3,459,502.80
2014	0	7,820	-	1,551	$ 1,940,764.80	$ 1,940,764.80
2015	1	9,472	-	2,811	$ 2,564,078.40	$ 2,465,460.00
2016	2	10,748	-	3,590	$ 3,001,086.40	$ 2,774,673.08
2017	3	13,269	-	3,861	$ 3,574,350.00	$ 3,177,584.13
2018	4	14,383	-	3,540	$ 3,726,824.40	$ 3,185,705.12
2019	5	13,932	-	2,524	$ 3,402,900.80	$ 2,796,936.41
2020	6	16,575	-	2,139	$ 3,850,813.20	$ 3,043,353.61
2021	7	16,286	-	1,456	$ 3,635,933.60	$ 2,763,010.71
2022	8	16,302	-	659	$ 3,456,824.80	$ 2,525,868.02
2023	9	17,010	-	575	$ 3,581,188.00	$ 2,516,095.19
2024	10	14,932	-	699	$ 3,188,140.80	$ 2,153,793.69
2025	11	13,212	-	825	$ 2,868,153.60	$ 1,863,097.89
2026	12	9,719	-	1,219	$ 2,249,920.40	$ 1,405,293.64
2027	13	8,337	-	1,542	$ 2,043,553.20	$ 1,227,305.10
2028	14	7,527	-	1,675	$ 1,909,715.60	$ 1,102,813.17
2029	15	7,669	-	1,916	$ 1,993,654.00	$ 1,107,005.30
2030	16	6,791	-	2,226	$ 1,886,523.60	$ 1,007,230.37
2031	17	6,050	-	1,455	$ 1,559,844.00	$ 800,782.18
2032	18	5,917	-	1,755	$ 1,601,511.60	$ 790,551.16
2033	19	6,605	-	1,733	$ 1,736,004.40	$ 823,981.34
2034	20	6,453	-	2,116	$ 1,792,809.20	$ 818,214.72
2035	21	5,772	-	3,188	$ 1,899,976.00	$ 833,773.31
2036	22	4,891	-	3,671	$ 1,831,819.60	$ 772,946.15
2037	23	4,543	-	5,225	$ 2,116,800.40	$ 858,841.66
2038	24	4,468	-	6,622	$ 2,421,224.00	$ 944,571.48
2039	25	3,830	-	6,224	$ 2,200,775.20	$ 825,547.76
2040	26	3,449	-	7,025	$ 2,306,777.20	$ 832,029.70
2041	27	3,368	-	7,581	$ 2,417,563.20	$ 838,450.98
2042	28	2,745	-	6,547	$ 2,054,639.60	$ 685,176.02
2043	29	2,155	-	6,547	$ 1,934,987.60	$ 620,456.51
2044	30	2,276	-	6,836	$ 2,025,649.60	$ 624,545.59
2045	31	1,438	-	5,643	$ 1,582,744.80	$ 469,220.93
2046	32	1,209	-	5,458	$ 1,493,975.60	$ 425,869.61
2047	33	1,020	-	3,966	$ 1,114,276.80	$ 305,416.78
2048	34	1,069	-	3,390	$ 992,425.20	$ 261,555.74
2049	35	1,212	-	2,228	$ 755,560.00	$ 191,470.59
2050	36	1,620	-	1,957	$ 776,297.60	$ 189,159.44
2051	37	2,035	-	2,119	$ 897,525.20	$ 210,287.33
2052	38	2,840	-	2,742	$ 1,203,321.60	$ 271,090.82
2053	39	2,667	-	3,053	$ 1,239,394.00	$ 268,478.28
2054	40	3,606	-	4,260	$ 1,705,984.80	$ 355,337.94
2055	41	2,989	-	4,940	$ 1,736,441.20	$ 347,770.84
2056	42	3,998	-	6,766	$ 2,358,855.20	$ 454,256.38
2057	43	3,796	-	6,337	$ 2,219,734.40	$ 411,024.23
2058	44	3,521	-	6,361	$ 2,169,455.60	$ 386,263.65
2059	45	3,471	-	7,361	$ 2,388,115.60	$ 408,841.60
2060	46	3,474	-	7,064	$ 2,320,770.40	$ 382,030.97
2061	47	2,700	-	6,915	$ 2,129,712.00	$ 337,096.26
2062	48	2,268	-	6,408	$ 1,926,100.80	$ 293,142.46
2063	49	1,899	-	6,520	$ 1,876,893.20	$ 274,666.65
2064	50	1,259	-	4,997	$ 1,398,638.80	$ 196,806.12
2065	51	1,202	-	4,100	$ 1,181,845.60	$ 159,904.41
2066	52	1,326	-	3,752	$ 1,127,370.40	$ 146,667.19
2067	53	1,120	-	3,248	$ 970,278.40	$ 121,375.04
2068	54	1,741	-	3,566	$ 1,168,975.60	$ 140,606.41
2069	55	2,398	-	4,333	$ 1,477,704.80	$ 170,904.71
2070	56	2,754	-	4,840	$ 1,665,903.20	$ 185,260.47
2071	57	-	-	-	$ -	$ -

Project Life (Years)	Normal Cost/CY	ILW Cost/CY	Annual Normal Dredge Mob/Demob	Federal Discount Rate	Monthly Compound Interest Factor	Amortization factor, 50 yrs
50	$ 2.50	$ -	$ -	4.00%	1.003274	0.046550

Alternative: NJ_fut1_sched_repair_hold
Activity: Normal Dredging

Totals over Project Life 2015-2064

Year	2015	Normal Dredging Volume (CY)	ILW Dredging Volume (CY)	Total Annual Dredging Cost ($)	Present Work Equivalent ($)
Totals		1,176,050	-	$ 2,940,125	$ 1,263,206
2007	-7	-	-	$ -	$ -
2008	-6	91,952	-	$ 229,880.00	$ 229,880.00
2009	-5	23,521	-	$ 58,802.50	$ 58,802.50
2010	-4	23,521	-	$ 58,802.50	$ 58,802.50
2011	-3	23,521	-	$ 58,802.50	$ 58,802.50
2012	-2	23,521	-	$ 58,802.50	$ 58,802.50
2013	-1	23,521	-	$ 58,802.50	$ 58,802.50
2014	0	23,521	-	$ 58,802.50	$ 58,802.50
2015	1	23,521	-	$ 58,802.50	$ 56,540.87
2016	2	23,521	-	$ 58,802.50	$ 54,366.22
2017	3	23,521	-	$ 58,802.50	$ 52,275.21
2018	4	23,521	-	$ 58,802.50	$ 50,264.62
2019	5	23,521	-	$ 58,802.50	$ 48,331.37
2020	6	23,521	-	$ 58,802.50	$ 46,472.47
2021	7	23,521	-	$ 58,802.50	$ 44,685.07
2022	8	23,521	-	$ 58,802.50	$ 42,966.41
2023	9	23,521	-	$ 58,802.50	$ 41,313.86
2024	10	23,521	-	$ 58,802.50	$ 39,724.86
2025	11	23,521	-	$ 58,802.50	$ 38,196.98
2026	12	23,521	-	$ 58,802.50	$ 36,727.87
2027	13	23,521	-	$ 58,802.50	$ 35,315.26
2028	14	23,521	-	$ 58,802.50	$ 33,956.98
2029	15	23,521	-	$ 58,802.50	$ 32,650.94
2030	16	23,521	-	$ 58,802.50	$ 31,395.14
2031	17	23,521	-	$ 58,802.50	$ 30,187.63
2032	18	23,521	-	$ 58,802.50	$ 29,026.57
2033	19	23,521	-	$ 58,802.50	$ 27,910.16
2034	20	23,521	-	$ 58,802.50	$ 26,836.69
2035	21	23,521	-	$ 58,802.50	$ 25,804.51
2036	22	23,521	-	$ 58,802.50	$ 24,812.03
2037	23	23,521	-	$ 58,802.50	$ 23,857.72
2038	24	23,521	-	$ 58,802.50	$ 22,940.12
2039	25	23,521	-	$ 58,802.50	$ 22,057.81
2040	26	23,521	-	$ 58,802.50	$ 21,209.43
2041	27	23,521	-	$ 58,802.50	$ 20,393.68
2042	28	23,521	-	$ 58,802.50	$ 19,609.31
2043	29	23,521	-	$ 58,802.50	$ 18,855.10
2044	30	23,521	-	$ 58,802.50	$ 18,129.91
2045	31	23,521	-	$ 58,802.50	$ 17,432.60
2046	32	23,521	-	$ 58,802.50	$ 16,762.12
2047	33	23,521	-	$ 58,802.50	$ 16,117.42
2048	34	23,521	-	$ 58,802.50	$ 15,497.52
2049	35	23,521	-	$ 58,802.50	$ 14,901.46
2050	36	23,521	-	$ 58,802.50	$ 14,328.33
2051	37	23,521	-	$ 58,802.50	$ 13,777.24
2052	38	23,521	-	$ 58,802.50	$ 13,247.35
2053	39	23,521	-	$ 58,802.50	$ 12,737.83
2054	40	23,521	-	$ 58,802.50	$ 12,247.92
2055	41	23,521	-	$ 58,802.50	$ 11,776.84
2056	42	23,521	-	$ 58,802.50	$ 11,323.89
2057	43	23,521	-	$ 58,802.50	$ 10,888.35
2058	44	23,521	-	$ 58,802.50	$ 10,469.57
2059	45	23,521	-	$ 58,802.50	$ 10,066.89
2060	46	23,521	-	$ 58,802.50	$ 9,679.71
2061	47	23,521	-	$ 58,802.50	$ 9,307.41
2062	48	23,521	-	$ 58,802.50	$ 8,949.43
2063	49	23,521	-	$ 58,802.50	$ 8,605.22
2064	50	23,521	-	$ 58,802.50	$ 8,274.25
2065	51	23,521	-	$ 58,802.50	$ 7,956.01
2066	52	23,521	-	$ 58,802.50	$ 7,650.01
2067	53	23,521	-	$ 58,802.50	$ 7,355.78
2068	54	23,521	-	$ 58,802.50	$ 7,072.87
2069	55	23,521	-	$ 58,802.50	$ 6,800.83
2070	56	23,521	-	$ 58,802.50	$ 6,539.26
2071	57	-	-	$ -	$ -

Please refer to the Engineering Appendix for a statistical description of variance, standard deviation, risk and uncertainty, etc., based on the model prepared by the Hydrologic, Coastal, and Riverine Section of the Hydraulics and Hydrology Branch. Also, refer to the Engineering Appendix for an explanation on the relationship and interaction between the cost streams related to Jetty A and the North Jetty.

REVISED CLEAN WATER ACT SECTION 404(b) (1) EVALUATION

For

MAJOR REHABILITATION OF THE JETTY SYSTEM AT THE MOUTH OF THE COLUMBIA RIVER
IN PACIFIC COUNTY, WASHINGTON AND CLATSOP COUNTY, OREGON

I. Introduction and Project Description

This 404(b) (1) evaluation describes unavoidable impacts to wetlands and other waters of the U.S. that could occur as a result of proposed actions related to the Major Rehabilitation of the Jetty System at the Mouth of the Columbia River. This action involves repair and rehabilitation at all three jetties in the system, North Jetty, Jetty A, and South Jetty. It also involves lagoon and wetland fill, as well as shoreline foredune stabilization, dredging, and rock placement activities. Further details are described in the proposed action.

Section 404 of the Clean Water Act (CWA) of 1977, as amended, requires that all projects involving the discharge of dredged or fill material into waters of the United States be evaluated for water quality and other effects prior to making the discharge. All dredge and fill materials associated with the major rehabilitation activities at the Mouth of the Columbia River (MCR) jetty system are activities undertaken by or at the direction of the Corps of Engineers. Federal regulations, at 33 CFR 336.1, provide that a Section 404 permit will not be issued for such fill material by the Corps to itself; however, the Corps shall apply the Section 404(b) (1) guidelines to the project. This evaluation assesses the effects of dredge and fill actions described below utilizing guidelines established by the U.S. Environmental Protection Agency (USEPA) in conjunction with the Secretary of the Army under the authority of Section 404(b)(1) of the Act. Guidelines for conducting a 404(b) (1) evaluation are described at 40 CFR 230.1-12.

II. Description of Proposed Action

a. <u>Location</u>

The North Jetty and Jetty A are located in Pacific County, Washington, near Ilwaco and Long Beach on the Long Beach Peninsula. The 2.3-mile long North Jetty was completed in 1917. Three repairs to the North Jetty have been made with the last one completed in 2005. To date, jetty rock placement totals approximately 3.4 million tons. Since initial construction, about 0.4 miles of the North Jetty head has eroded and is no longer functional. Jetty A, positioned on the south side of the North Jetty, was constructed in 1939 to a length of 1.1 miles and is located upstream of the North Jetty. Jetty A was constructed to direct river and tidal currents away from the North Jetty foundation.

The South Jetty is located in Clatsop County, Oregon near Warrenton/Hammond and Astoria. The South Jetty is about 6.6 miles long. The initial 4.5-mile section of the South Jetty was completed in 1896, with a 2.4-mile extension completed in 1914. Currently, approximately 3 miles of jetty extends seaward of the shoreline. To stabilize the jetty foundation, six groins perpendicular to the South Jetty were constructed with lengths from about 100 to 1,000 feet. Over 6,100 feet of head loss has occurred at the South Jetty. Nine repairs to the South Jetty have been completed with the latest one in 2007. To date, jetty rock placement at the South Jetty totals approximately 8.8 million tons.

b. Project Description

The Proposed Action is generally composed of four categories applicable to each jetty: **(1)** engineered designs elements and features of the physical structures; **(2)** construction measures and implementation activities; **(3)** proposed Clean Water Act (CWA) 404 mitigation actions for impacts to wetlands and waters of the US, and **(4)** proposed establishment of and coordination with an Adaptive Management Team (AMT) composed of representatives from the Corps and appropriate federal and state agencies. More detailed descriptions of the proposed action, base condition, effects, and discussions can be found in the 2012 revised Final Environmental Assessment as well as the associated Biological Assessments and Biological Opinions from the resource agencies.

The duration of the revised construction schedules is 8 years with a 50-year operational lifetime for the MCR jetty system. Therefore, an inherent level of uncertainty exists regarding dynamic environmental conditions and actual conditions of and at each of the jetties. For this reason, in all cases where areas, weights, and volumes (tons, acres, cubic yards, etc.) or other metrics are indicated, these are best professional estimates and may vary by greater or lesser amounts within a 20% range when final designs are completed. These amounts represent Corps' best professional judgment of what the range of variability could entail as the design is further developed and as on-the-ground conditions evolve over the 8-year construction schedule. The Corps maintains an active jetty monitoring and surveying program that will further inform the timing and design of the proposed action in order to facilitate efficient completion of the project and whenever possible to avoid emergency repair scenarios.

(1.) Design elements and structural features specific to each jetty include the following:

- North Jetty –Scheduled repairs addressing the existing loss of cross section and head stabilization to minimize future cross section instability are proposed. The cross-section repairs are primarily above MLLW, with a majority of stone placement not likely to extend beyond -5 feet below MLLW. To address the structural instability the jetty head (western-most section) would be stabilized with armoring of large stone, but to a lesser extent than capping that was previously proposed. The head stabilization measure at approximately station 101 would be placed on relic and jetty stone that is above MLLW. The shore-side measures that have been identified are culvert replacement and lagoon fill (STA 20-60). These actions are designed to stop the current ongoing erosion of the jetty root and are considered part of the base condition, along with interim repairs between stations 86-99.

The cross-section design from stations 20+00 to 99+00 would have a crest width of approximately 30 feet and would lie essentially within the existing jetty footprint based on the configuration of the original cross section, previous repair cross sections, and redistribution of jetty rock by wave action. About 429,000 tons (268,125 cy) of new rock (221,000 tons for

Major Rehabilitation; 65,000 tons for Major Repairs; and 109,000 for lagoon fill) and reworked rock will be placed on relic armor stone, with the majority of stone placement above MLLW. About three repair events were predicted over the next 50 years. Each repair action is expected to cover a length range of up to 1,500 feet and include stone volumes and rework in the range of 53,000 to 103,000 tons (~33,125-64,375 cy) per season.

Approximately 109,000 tons (~68,125 cy) of gravel and sand will be added to the jetty's beach side as lagoon fill to eliminate the tidal flow through the jetty that is destabilizing the foundation. A recent berm repair action now precludes lagoon inundation by tidal waters coming from the shoreline. Scouring has taken place on the north side of the North Jetty resulting in formation of a backwater area (lagoon) that was previously inundated both by tidal waters that come through the jetty and from the shoreline, and by freshwater that drains from the O'Neil Lake-McKenzie Head lagoon and wetland complex area through the accreted land to the north of the jetty and North Jetty Road. This area drains through a culvert under the road and provides some of the freshwater flow to the lagoon. The surrounding lagoon resembles a scoured-out tidal channel and is a non-vegetated (and non-wetland) area of bare sand comprising approximately 8.02 acres. These wetlands and waters will be filled to protect and stabilize the foundation of the North Jetty and to serve as a location for rock stockpiles and construction staging activities.

The aging culvert draining south from the wetland complex north of the roadway will be replaced, as it provides required drainage under the roadway. The design of the inlet, elevation, and culvert size will be determined so that hydrologic function in the adjacent wetland system is not negatively impacted. The outlet channel downstream of the culvert will not be filled. This area may provide an opportunity for minor stream and bank enhancement which will be evaluated when the culvert design is finalized, but this is uncertain until possible benefits can be further assessed. Under the proposed action, the existing channel will outlet to an engineered sump area comprised of newly placed lagoon fill material. In addition to infiltration through the jetty structure, this small portion of the creek currently connects the wetland to the lagoon and likely also receives some backwater flow from jetty infiltration.

- South Jetty – Under the base condition, interim repair scenario, the cross-section design from stations 167+00 to 258+00 would have a crest width of approximately 30 feet and would lie essentially within the existing jetty footprint based on the configuration of the original cross section, previous repair cross sections, and redistribution of jetty rock by wave action. The majority of the stone placement would be conducted above the MLLW. Each repair action is expected to cover a length up to 2,300feet and include stone volumes in the range of 50,261 to 130,353 tons per season (31,329 to 81,471 cy). Augmentation of the foredune at the western shoreline extending south from the jetty root has been included in the base condition, but is describe in detail under the selected plan. This action is intended to prevent the degradation of the jetty root and prevent the potential breaching of the fore dune.

About 40,000 to 70,000 cy of cobble is proposed at the South Jetty root in order to fortify the toe of the foredune and to improve the foreshore fronting to resist wave-induced erosion/recession (Figure 24). Maximum crest width of the template is estimated to extend 70 feet seaward from the seaward base of the present foredune. Construction of the foredune augmentation would require 2 to 6 weeks. To adequately protect the foredune during storm conditions, this requires that the top of the stone berm (crest) extend vertically to approximately 25 feet NAVD and have an alongshore application length of approximately 1,100 feet, extending southward from the South Jetty root. This is equivalent to about 3 acres. The constructed template crest would be 10 to 15 feet above the current beach grade and have a 1 vertical to 10 horizontal slope aspects from crest to existing grade. Cobble is not expected to extend below MHHW. A layer of sand may be placed over this berm or natural accretion may facilitate sand recruitment after construction of the adjacent spur groin.

Cobble material would be procured from upland sources and placed using haul trucks and dozers. The material would be transported on existing surface roads and through Fort Stevens State Park to a beach access point at the project site. There is an existing relic access road along the jetty root that will be refurbished and used to transport stone to the dune augmentation area.

The dune augmentation may require maintenance every 4 to 10 years (assume 40% replacement volume). Consideration will be given to development of revegetation plans which incorporate native dune grasses to supplement foredune stabilization in the augmentation area. This bioengineering component could help restore vegetated dune habitat and take advantage of natural plant rooting functions that provide greater protection from erosive forces.

• Jetty A – The cross-section design from stations 48+00 to 84+00 would have a crest width of approximately 40 feet and would lie mostly within the existing jetty footprint based on the configuration of the original cross section, previous repair cross sections, and redistribution of jetty rock by wave action. About 80,375 tons (~50,234 cy) of new rock would be placed on the existing jetty cross section and relic armor stone. Most of the work would occur above MLLW.

(2.) Construction measures and implementation activities for all three jetties include the following:

- Storage and staging areas for rock stockpiles and all associated construction and placement activities such as: roadways, parking areas, turn-outs, haul roads, weigh stations, yard area for sorting and staging actions, etc.
- Stone delivery from identified quarries either by barge or by truck. Possible transit routes have been identified. This also includes the construction and use of permanent barge offloading facilities and causeways with installation and removal of associated piles and dolphins.
- Stone placement either from land or water, which includes the construction, repair, and maintenance of a haul road on the jetty itself, crane set-up pads, and turnouts on jetty road. Placement by water could occur via the use of a jack-up barge on South Jetty, but will not occur by other means or on North Jetty to avoid impacts to crab and juvenile salmon migration.
- Regular dredging and disposal of infill at offloading facilities with frequency dependent on a combination of the evolving conditions at the site and expected construction scheduling and delivery. Disposal will occur at existing designated and evaluated approved in-water sites.

(3.) In addition, the Corps has identified specific and potential mitigation for impacts to CWA 404 wetlands and waters of the US. Wetland mitigation opportunities have been identified adjacent to the impacted wetlands at the North Jetty. Wetland mitigation for Jetty A would also be implemented at the North Jetty because space is unavailable at Jetty A. Mitigation for wetland impacts at the South Jetty would occur within the State Park but southwest of the impact area in a location south of Trestle Bay. The mitigation for the impacted wetlands would be creation of wetlands of similar type and function. Specific mitigation for impacts to waters other than wetlands has not been determined, but a suite of potential projects and examples has been identified. Depending on further development of both the project and potential mitigation alternatives and commensurate with final impacts, a specific mitigation project or combination of projects would be selected and constructed concurrently. Mitigation would provide environmental benefits to offset impacts as portions of the proposed action are completed over time. This EA has identified and quantified the maximum amount of impacts and mitigation likely under the Preferred Alternative, and further details and selection of specific appropriate mitigation actions for waters other than wetlands would be refined as the project moves forward. Depending on the method of project implementation, commensurate mitigation could also be reduced if impacts are avoided. Generally, possible mitigation measures could include but are not limited to an individual project or a combination of projects and actions such as the following list.

- Excavation and creation of tidal channel and wetlands to restore and improve hydrologic functions including water quality, flood storage, and salmonid refugia.
- Culvert and tide gate replacements or retrofits to restore or improve fish passage and access to important spawning, rearing, and resting habitat.
- Beneficial uses of dredged material from MCR hopper dredge to replenish littoral cells.
- Invasive species removal and control and revegetation of native plants to restore ecological and food web functions that benefit fisheries.

Mitigation meets compliance obligations under the Clean Water Act and would be commensurate with impacts from construction activities. It also complements Corps obligations to protect and restore critical habitat for ESA listed species. More specifics regarding mitigation are described in that section.

(4.) Due to the dynamic conditions at MCR and the long duration of the MCR Jetty Rehabilitation schedule, the Corps proposes formation of a modified interagency Adaptive Management Team (AMT). The Corps suggests annual meetings and more as needed to discuss relevant design and construction challenges and modifications, technical data, new species listings or critical habitat designations, evolving environmental conditions, and adaptive management practices as needed. The primary purpose of the proposed AMT and its implementation is to ensure construction, operation, and maintenance actions have no greater impacts than those described in the Biological Assessments and this Environmental Assessment, and that Corps obligations and terms and conditions are being met. This will also allow confirmation that any necessary construction or design refinements remain within the range and scope of effects described during Consultations and that compliance obligations are being met and efforts are being made to adjust mitigation once final impacts are fully understood. These adjustments could result in a reduction in mitigation based on actual impacts occurring. This forum would provide an opportunity for periodic evaluation as to whether or not the proposed actions, ESA listings, or environmental conditions result in any re-initiation triggers. It would also facilitate continued coordination and updating and allow the Corps to inform agency partners when unforeseen changes arise. Results regarding marine mammal and fish monitoring, mitigation monitoring, as well as water quality monitoring would be made available to the AMT in order to fulfill reporting requirements and to address any unexpected field observations. Results of jetty monitoring surveys would also inform the AMT of the repair schedule and design refinements that may become necessary as the system evolves over time. This venue would provide transparency and allow opportunities for additional agency input. Final selection and design of the mitigation proposal would be determined by the Corps and would be vetted through this forum to facilitate obtaining final environmental clearance documents for this component of the MCR proposed action. Potential principal partners include federal (National Marine Fisheries Service, U.S. Fish and Wildlife Service) and State (Washington and Oregon) resource management agencies.

c. Authority, Purpose, and Need

For the authorization for the actual construction of the MCR jetties, the present navigation channel and configuration of the inlet at the mouth of the Columbia River are the result of continuous improvement and maintenance efforts have been undertaken by the Corps Portland District since 1885. Congress has authorized the improvement of the MCR for navigation through the following legislation: Senate Executive Document 13, 47th Congress, 2nd Session (5 July 1884) authorized the Corps to construct the South Jetty (first 4.5 miles) for the purpose of attaining a 30-foot channel across the bar at the MCR; House Document 94, 56th Congress, 1st Session (3 March 1905) authorized the Corps to extend the South Jetty (to 6.62 miles) and construct a North Jetty (2.35 miles long) for the purpose of attaining a 40-foot channel (0.5 mile wide) across the bar at the MCR; House Document 249, 83rd Congress, 2nd Session (3 September 1954) authorized a bar channel of 48 feet in depth and a spur jetty ("B") on the north shore of the inlet. Funds for Jetty "B" construction were not appropriated. Public Law 98-63 (30 July 1983) authorized the deepening of the northern most 2,000 feet of the MCR channel to a depth of 55 feet below mean lower low water (MLLW). The MCR federal navigation project was originally authorized (in 1884) before formulation of local sponsor cost sharing agreements; therefore, all navigation maintenance and improvements at MCR are borne by the Federal Government.

The authority for maintenance of the MCR jetties comes from the original authority for construction of the project and then with Corps' policies for the operations, maintenance, and management of a Corps' project (Chapter 11 of EP 1165-2-1). For navigation, completed projects like the MCR have established that operations and maintenance (O&M) is solely a federal responsibility to be accomplished at federal cost.

When maintaining a Corps' project, there is regular O&M, major maintenance, and major rehabilitation. Major rehabilitation consists of either one or both of two mutually exclusive categories, reliability or efficiency improvements.

- Reliability. Rehabilitation of a major project feature that consists of structural work on a Corps operated and maintained facility to improve reliability of an existing structure, the result of which will be a deferral of capital expenditures to replace the structure. Rehabilitation will be considered as an alternative when it can significantly extend the physical life of the feature (such as a jetty) and can be economically justified by a benefit/cost relationship. Each year the budget EC delineates the dollar limits and construction seasons (usually two construction seasons).

- Efficiency Improvements. This category will enhance operational efficiency of major project components. Operational efficiency will increase outputs beyond the original project design.

Thus, the authority for maintenance of the MCR jetties comes from the authorization documents for the project and/or the authority to operate and maintain the structures.

The purpose of the proposed action is to perform modifications and repairs to the North and South jetties and Jetty A at the MCR that would strengthen the jetty structures, extend their functional life, and maintain deep-draft navigation.

Structural degradation of the +100-year old MCR jetty system has accelerated in recent years because of increased storm activity and loss of sand shoal material upon which the jetties are constructed. In addition, beaches on the ocean sides of the North and South jetties, which formed as a result of jetty construction, have been receding gradually over the years, exposing previously protected sections of the jetties at the beach line to storm waves. Taking no action to protect and to extend the functional life of the jetties will result in further deterioration of the jetties and the sand shoals upon which they rest, increasing the likelihood of a jetty breach. Recent jetty repairs have addressed immediate critical needs. Additional modifications and repairs to the jetties are necessary to address critical near- and long-term needs and to reduce the potential for emergency repairs, emergency dredging, and impacts to navigation.

d. General Description of Fill and Dredged Material

The repair and rehabilitation project would require placement of clean armor and fill stone. This would also be required for construction of barge offloading facilities. The material would come from an approved quarry. The Corps intends to use operating quarries rather than opening any new quarries. The Contractor and quarry owner/operator will be responsible for ensuring that quarries selected for use are appropriately permitted and in environmental compliance with all state and federal laws.

Depending on site-specific circumstances, barge offloading facilities may be partially removed and rebuilt, may be permanently removed, or may remain as permanent facilities upon project completion. Facility removal will depend on access needs, removal and mitigation costs, and evolving hydraulic, wave, and jetty cross-section conditions at each offloading locations.

Offloading facilities will range from approximately 200- to 500-feet long and 20- to 50-feet wide, which ranges from about 0.48 to 2.41 acres in total area. For initial construction of all four facilities combined, approximately up to 96 Z- or H-piles that are 12-16-inches in diameter could be installed as dolphins, and up to 373 sections of Z- or H-piles installed to retain rock fill. They will be located within 200-ft of the jetty structure. Facilities will have a 15-foot NGVD crest elevation and will be installed at channel depths between -20 and -30 feet NGVD. Because the sediments in the region are soft (sand), a vibratory hammer will be used for pile installation and only untreated wood or steel piles installed to a depth of approximately 15 to 25 feet below grade. Removal and replacement of the facilities could occur within the duration of the construction schedule. Volume and acreage of fill for these facilities are shown in below.

Rock Volume and Area of Barge Offloading Facilities and Causeways

Location	Approximate Length (ft)	Approximate Rock Volume (cy) Below 0 MLLW	Total Approximate Rock Volume (cy)	Approximate Square Feet	Acres
North Jetty	200	7,778	29,640 cy	21,000	0.48
Jetty A near head	200	7,778	29,640 cy	21,000	0.48
Jetty A mid-section causeway	5000	38,888	38,888	105,000	2.41
South Jetty Parking Area D	450	17,417	33,688 cy	47,250	1.08
South Jetty along jetty turn-out	200		18,640 cy	21,000	0.48

Dredging activities will entail the following. Transport of rock would most likely be done by ocean-going barges that require deeper draft (20-22 feet) and bottom clearance when fully loaded than river-going barges. Therefore, dredging will be required to develop each of the barge offloading facilities. Under-keel clearance should be no less than 2 feet. The elevation at barge offloading sites should have access to navigable waters and a dredge prism with a finish depth no higher than -25 feet MLLW, with advance maintenance and disturbance zone depths not to extend below -32 feet MLLW. These facilities should also provide for a maneuvering footprint of approximately 400 feet x 400 feet. The depth along the unloading sites would be maintained during the active period for which the rock barges will be unloaded. The volume of material to be dredged is shown; these estimates are based on current bed morphology and may change. Also, maintenance dredging to a finish depth of -25 feet MLLW will be needed before offloading during each year of construction. Dredging is likely to occur on a nearly annual basis for the duration of the project construction period, but this will be intermittent per jetty, depending on which one is scheduled for construction in a particular year.

Estimated Dredging Volumes for Barge Offloading Facilities

Location*	Estimated Dredging Volume (cy)		Approximate Acres
	Initial	Est. Maintenance**	
North Jetty	30,000	30,000	3.73
Jetty A	60,000	80,000	3.73
South Jetty	20,000	20,000	4.19
South Jetty - Parking Area D	20,000	20,000	4.19

* Some of the locations will not be used on an annual basis; it depends on the construction schedule for each jetty.
**All dredging will be based on surveys that indicate depths shallower than -25 feet MLLW.

Approximately 109,000 tons (~68,125 cy) of gravel and sand will be added to the North Jetty's beach side as lagoon fill to eliminate the tidal flow through the jetty that is destabilizing the foundation. This fill could be derived from dredge material, upland excavation, as well as quarry stone. The aging culvert draining south from the wetland complex north of the North Jetty Access roadway will also be replaced. At the South Jetty there will be some temporary fill in the lagoon and culverts will be installed in the marsh wetland to maintain hydraulic connectivity while allowing access up to the jetty and to areas identified for construction staging and stock piling. At the area identified for dune augmentation adjacent to and south of the root, cobble material would be procured from upland sources and placed using haul trucks and dozers. About

40,000 to 70,000 cy of cobble in the shape of angular or rounded graded stone is proposed, and could require periodic supplementation.

In order to place stones, a haul road will be constructed on the 30-foot crest width of each jetty to allow crane and construction vehicle access. Roads will consist of an additional 3 feet of top fill material, which could also entail an additional 2 feet of width spill-over. These roads would remain in place for the duration of construction. Due to ocean conditions and the wave environment, these roads would likely need yearly repair and replacement. They will not be removed upon completion. Ramps from the beach up to the jetty road will also be constructed to provide access at each jetty.

At approximately 1,000-foot intervals, turnouts to allow equipment access and passage will be constructed on the North and South jetties. These would consist of 50-foot long sections that are an additional 20-feet wide. Some of this stone for these facilities may encroach below MLLW. On the North Jetty, there will be approximately two turnouts. South Jetty could have approximately eight turnouts with two additional larger-sized turnouts. These larger turnouts will be in the range of 300-feet long with an additional 20-foot width. One of these larger turnouts will function as an offloading facility on South Jetty. At Jetty A, the causeway will function as the turnout facility.

Towards the head of each jetty, additional crane set up pads will be constructed at approximately 40-ft increment to allow crane operation during the placement of the larger armoring stones. Set-up pads will roughly entail the addition of 8 feet on each side of the crest for a length of about 50 feet. Some of this stone for these facilities may encroach below MLLW. Approximately five set-up pads will be required to construct each jetty head.

e. <u>Description of the Proposed Discharge Site</u>
A dredged material disposal site called the North Jetty Site is entirely within inland waters. It is located about 400 feet south of the North Jetty, occupies an area of 1,000 feet by 5,000 feet, and has an average water depth of 35-55 feet. This site was evaluated and established in 1999 under Section 404 of Clean Water Act to allow the placement of dredged material along the toe of the North Jetty to protect it from excessive waves and current scour. Use of the site is limited to disposal of MCR dredged material. From 1999-2008, about 4.4 million cubic yards (mcy) of dredged material was placed in the North Jetty site.

An ocean disposal site called the Shallow Water Site (SWS) lies within 2 miles offshore from the MCR and was evaluated and designated in 2005 by the U.S. Environmental Protection Agency (USEPA) under Section 102 of the Marine Protection, Research and Sanctuaries Act. The SWS occupies a trapezoidal area of 3,100- to 5,600 feet in width by 11,500 feet in length and lies within a water depth of 45-75 feet. The SWS is used for disposal of material dredged from either the MCR or the lower Columbia River. The SWS is dispersive, which means that material placed there is transported away from the site by waves and currents. Active monitoring and evaluation determined that 80% to 95% of the dredged sand annually placed at the SWS moves northward onto Peacock Spit. From 1997-2008, approximately 29 mcy of dredged sand has been placed in the SWS. The SWS is of strategic importance to the region; its continual use has supplemented Peacock Spit with sand, sustained the littoral sediment budget north of the MCR, protected the North Jetty from scour and wave attack, and stabilized the MCR inlet.

There is also an active deep water disposal site 7 miles off shoreline in Pacific Ocean, west of the Columbia R., as well as an active disposal site in the estuary at RM 7 called the Chinook Channel Area D, the latter of which receives materials from the Columbia and Lower Willamette reaches. There may also be potential future proposed dredge material disposal sites near both the North and South Jetties.

Two dredged material disposal sites, the Shallow Water Site and the North Jetty site, are the most likely sites to be used for disposal of dredged material. Modeling has showed that the potential changes to the two disposal sites from the proposed action would not inhibit their use as disposal sites. These sites have been previously vetted through the appropriate regulatory agencies, were evaluated for their effects, and were subsequently designated or approved after such review. The current proposed action and use of these disposals sites will maintain compliance with approved use.

These disposal sites would be used seasonally, likely between May and October, in order to maintain barge offloading facilities at the required depths. Depending on in-fill rates, dredging and disposal could occur one or more times per season. Any rock placement or road maintenance would also likely occur on a daily basis but be limited seasonally to the spring and summer months, as weather conditions at the jetties preclude safe working conditions in the winter and fall months. Localized turbidity in the immediate vicinity of the work or placement sites is also expected to occur on a seasonally limited daily basis during daylight hours. However, due to the nature of the materials and the conditions at the jetties, this is not expected to exceed background levels in any significant manner. Conditions of the State Water Quality Certifications will also likely include limited exceedence durations to protect aquatic life, with which the Corps and its contractor will comply. Lagoon fill, wetland fill, and foredune augmentation will all occur in a single season and will occur during a limited amount of time during daylight hours.

f. Description of the Disposal Method

Placement of armor stone and jetty rock on the MCR jetties would be accomplished by land or limited water-based equipment. Only clean stone will be used for rock placement, where appropriate and feasible. Where appropriate, there may also be some re-working and reuse of the existing relic and jetty prism stone. Fill for the jetty haul roads will not be cleaned prior to installation. Dropping armor stone from a height greater than 2 feet will be prohibited. During placement there is a very small chance of stone slippage down the slope of the jetty. However, this is unlikely to occur due to the size and cost of materials and placement.

Another approach to water-based rock placement would be via a jack-up barge. This would only be applicable at the South Jetty. For armor stone and rock placement at the head, a jack-up barge with crane could be used to serve as a stable work platform (Figure 36). Once into place, the jack-up barge would be jacked up on six legs so that the deck is at the same elevation as the jetty. The legs are designed to use high-pressure water spray from the end of the legs to agitate the sand and sink the legs under their own weight. The jacking process does not use any lubricants that contain oils, grease, and/or other hydrocarbons. The stone and rock will be barged to the jack-up barge and offloaded onto the jetty head. The jack-up barge will keep moving around the head of the jetty to complete the work. A jack-up barge would not be used on the North Jetty or Jetty A to avoid interference with navigation of fishing boats and crab and fish migrations.

For land-based rock placement, a crane or a large track-hoe excavator could be situated on top of the jetty. The placement operation would require construction of a haul road along the jetty crest within the proposed work area limits. The crane or excavator would use the haul road to move along the top of jetty. Rock would be supplied to the land-based placement operation by land and/or marine-based rock delivery. For marine-based rock, the land-based crane or excavator would pick up rock directly from the barge or from a site on the jetty where rock was previously offloaded and stockpiled, and then place the rock within the work area. For land-based rock, the crane or excavator would supply rock via a truck that transports rock from the stockpile area. The crane or excavator would advance along the top of the jetty via the haul road as the work is completed.

A clamshell dredge would likely be used for all dredging, although there is a small chance that a pipeline dredge could be used. The material to be dredged is medium to fine-grained sand, typical of MCR marine sands. Disposal of material would occur in-water at an existing previously evaluated and designated approved disposal site. Clamshell dredging is done using a bucket operated from a crane or derrick that is mounted on a barge or operated from shore. Sediment removed from the bucket is generally placed on a barge before disposal. This type of dredge is typically used in shallow-water areas.

The following overall impact minimization practices and best management practices (BMPs) will be used for all maintenance dredging for offloading facilities.

1. To reduce the potential for entrainment of juvenile salmon or green sturgeon, the cutter-heads on pipeline dredges will remain on the bottom to the greatest extent possible and only be raised 3 feet off the bottom when necessary for dredge operations.

2. To reduce turbidity, if a clamshell bucket is used, all digging passes shall be completed without any material, once in the bucket, being returned to the wetted area. Not dumping of partial or half-full buckets of material back into the project area will be allowed. No dredging of holes or sumps below minimum depth and subsequent redistribution of sediment by dredging dragging or other means will be allowed. All turbidity monitoring will comply with State 401 Water Quality Certification Conditions.

3. If the Captain or crew operating the dredges observes any kind of sheen or other indication of contaminants, he/she will immediately stop dredging and notify the Corps' environmental staff to determine appropriate action.

4. If routine or other sediment sampling determines that dredged material is not acceptable for unconfined, in-water placement, then a suitable alternative disposal plan will be developed in cooperation with the NMFS, EPA, Oregon Department of Environmental Quality (ODEQ), Washington Department of Ecology (WDOE), and other agencies.

A vibratory hammer will be used to install pilings for offloading facilities. At the South Jetty, cobble material would be procured from upland sources and placed using haul trucks and dozers. At the North Jetty, lagoon fill will also be placed using haul trucks and dozers or pump ashore.

III. Alternatives

The Preferred Alternative for repair and rehabilitation of the MCR jetties has been developed and refined to take advantage of opportunities to avoid and minimize, to the maximum extent practicable, the proposed project's ecological impacts to wetland, aquatic habitats, and species per requirements under the Clean Water Act and Executive Order (EO) No. 11990. Efforts were made to reduce the project footprint and to locate staging areas away from wetland and waters areas. However, there would be unavoidable effects to wetlands and waters as aquatic habitat would be filled and converted as a result of the project. The process used to determine mitigation was to first maximize avoidance of the impacts. However, some impacts to wetlands and waters remained unavoidable. Mitigation for unavoidable impacts was then based on the extent and quality of the habitat affected.

The discharge of dredge and fill materials to wetlands and other waters of the U.S. will occur via the following project activities: stone placement for the jetty structures and associated engineering features; lagoon fill for jetty root stabilization and construction staging and access; stone placement and pile installation for barge offloading facilities; fill of wetlands for construction staging, rock stockpiles, and sorting; and discharge during inwater construction activities and dredge disposal actions. The Corps has evaluated and taken advantage of all practicable alternatives as well as minimization measures to avoid significant adverse environmental consequences. Some of these actions are water dependent or require proximity to special aquatic sites. These circumstances are described for each of the actions.

Stone placement for the jetty structures and associated engineering features: Various jetty rehabilitation and repair design alternatives have been considered. These are described further in the associated June 2012 *Revised Final Environmental Assessment for the Major Rehabilitation of the MCR Jetty System*, which is incorporated herein. Alternatives considered for jetty design included variations in the timing, sequencing, and extent of cross-section repairs and rehabilitation actions at each of the jetties, as well as variations with type and size of stone, slope, spur groin size and locations, head capping and armoring, etc.

The "no action" alternative was considered in the alternatives analysis and was determined to be unacceptable due to the risk of jeopardizing the long-term functional integrity of the jetty system, possible effects to navigation, and possible loss of interdependent landforms. To allow the jetties to continue to deteriorate could eventually lead to breaching and sediment transport into the estuary and navigation channel, which could increase offshore shoaling outside of the channel entrance and result in loss of beach areas and accreted habitat. As the jetties continue to deteriorate, waves are predicted to move further into the inner harbor adding to the difficulty of maintaining a reliable, year-round navigation channel, particularly one that accommodates larger, ocean-going vessels. There could also be a resulting increase boating hazards and necessary dredging actions. Repair and rehabilitation of the jetty system will facilitate maintenance of the current river entrance location and navigational function, as well as the accreted landforms, habitats, and recreational uses that have developed along the shoreline.

Should the condition of the jetty worsen to the point an emergency is declared (which becomes much more likely under a “no action” scenario), repairs and dredging would commence as soon as possible. Environmental documentation would follow, if was not completed prior to emergency construction.

However, this emergency situation is unlikely as the final selected plan addresses these functional issues and minimizes the amount of fill material because it has the smallest footprint practicable. Additionally, this fill is unavoidable because this is a project to maintain the jetty system at its current location at the river’s mouth, which also preserves accessibility for navigation at the MCR. Therefore these actions are by nature water-dependent. The purpose of the project could not be achieved without the level of stone fill to meet the repair and rehabilitation goals and needs.

The method of stone placement does reduce the amount of fill to some degree, as placement by land reduces the need for additional pilings and mooring facilities. When placement by water does occur, it will happen via a jack-up barge, which provides a stable platform without the addition of other facilities.

Lagoon fill for jetty root stabilization and construction staging and access: Lagoon fill will occur at both the North and South Jetty. At the North Jetty, this fill is required to arrest the scour that is undermining the jetty root at the lagoon, which could contribute to its structural deterioration. As a structural component in each of the repair and rehabilitation alternatives, it is a water-dependent feature that is identified as a critical component in any of the alternatives carried forward to maintain the North Jetty.

Partial fill of the lagoon is necessary at the South Jetty because it allows access to the jetty itself for the necessary construction activities. Some logistical staging and preparation activities require proximity to the jetty access road. Additionally, an access road is necessary to ramp up to the jetty itself, and this best occurs in the proximity of the lagoon and marsh inlet area. The farther out on the jetty on the seaward side that the access road can be constructed prior to ramping-up to the jetty, the more resilient and lower its cost. A longer road on the jetty (which would be the case if ramping-up nearer inland) is less feasible, more costly because of the additional fill material needed, and requires more maintenance and repairs because of exposure to wave action. To minimize impacts to waters, the road will be constructed immediately adjacent to the jetty to avoid any marsh channels or wetlands as much as possible. Additionally, a culvert or series of culverts will be installed in the access road as necessary to maintain hydrologic connectivity into the marsh wetland system.

Stone placement and pile installation for barge offloading facilities: Barge offloading facilities will likely be necessary for the transport and delivery of large stones, particularly those used for jetty head stabilization. Logistically and feasibly, the size of stone that could be used may in some cases preclude efficient or safe transport of stone by land. Offloading facilities also benefit from being in proximity to the jetties, because this reduces the redundancy of re-handling and moving the stones prior to placement. Besides increasing efficiency, this reduces the likelihood of stone breakage, which can be very costly.

Though private offloading facilities exist locally, there is no guarantee that these facilities will be available during the timing and in the duration that would be required to efficiently complete the entire project. Areas selected for facilities were chosen because of their proximity to the jetties, their likelihood for safer sea conditions, and their proximity to deeper waters to reduce maintenance dredging. Additionally, in the case of Jetty A, the transportation network to the jetty itself may preclude safe passage of vehicles sized to carry the specified tonnage of rock necessary to complete the project. At the North Jetty, the facility was placed in an area that is presumed to have feasible sea conditions and deeper bathymetry to allow safe offloading. This is the same for the facility located along the South Jetty. At the South Jetty, Parking Area D was selected over the Social Security Beach area also under consideration because it provides some additional shelter from ocean conditions while reducing the footprint and impacts to shallow water.

Finally, in order to maintain appropriate side-slopes, to reduce the in-water footprint of the facilities, and to provide a location for barges to tie-up, the installation of sheet pile and dolphins will be required in conjunction with these facilities. In summary, these facilities ensure availability to feasible offloading sites that allow efficient delivery alternatives, which in the case of large stones may be the only existing technological option to delivery very large stones.

Fill in wetlands for construction staging, rock stockpiles, and sorting: Variations regarding locations for construction staging and rock stockpiling were considered in order to avoid and minimize potential impacts from wetland fill. The current proposed plan reduces these impacts to the maximum extent practicable.

In order to efficiently sequence work, purchase and sort stones, and efficiently place rock each season, it was determined that a maximum two-year supply of stones would be required at each site. This amount was then translated into an acreage that included a minimum area needed to meet basic construction staging needs for things like scales, parking, equipment preparation and storage, etc. Proximity of these activities to the jetty structures is required for feasibility of project execution so that stone is near the placement site for the purposes of proper sorting, stone sizing and selection, minimization of stone breakage, minimization of re-handling stone, and efficient work flows.

Official wetland delineations were completed at all jetties to determine wetland locations that could be avoided. At Jetty A, there is little available space to access the jetty itself, so adequate desired staging and stockpiling is already unavailable. The location of the wetlands in the middle of the site, the isolation and steep topography of the site, the somewhat limited large-vehicle access, and the use of the site by the Coast Guard further preclude availability of staging and storage areas as practicable alternatives to avoid these wetlands.

At North Jetty, the structural lagoon fill is also likely to affect adjacent wetlands, as will also occur to a smaller degree with the culvert replacement. In order to concentrate effects and reduce impacts to additional higher-value wetlands in the complex north of the North Jetty

Access Road, this fill area south of the road was selected to serve the dual purpose of structural fill as well as staging and stockpiling. Most of the wetlands were avoided north of the road, and areas were selected that preserved adequate conserved wetland and shoreline buffers while also providing adequate space necessary for efficient and feasible construction activities.

At the South Jetty, staging and stockpile areas were required to be in proximity to the jetty and the second barge offloading site near Parking Area D. This allows efficient offloading, sizing, and sorting that is necessary prior to placement at the jetty. Parts of a relic access road were included to minimize any new impacts, and several of these areas have been used during previous repairs. Stone sizes are very large, and are easily broken. To reduce re-handling, to minimize interference with construction traffic flows, and to avoid interactions between construction vehicles and park visitors, staging areas closer to the work site are required. The amount and size of the stone and the need for several available sizes during placement precludes the feasibility of staging areas located off-site from the jetties and offloading structures.

However, adequate areas available for stockpiling and staging were constrained to the north by the recent development of the Oregon Parks and Recreation Snowy Plover Habitat Conservation Plan. The project area abuts and overlaps with the southern boundary of this area, but manages to avoid a majority of the designated HCP area. Wetlands and mudflats on the Trestle Bay side, the need to maintain an adequate shoreline dune buffer on the western side, and park recreation activities are also constraints for locating construction staging and stockpiles.

In the current configuration, the marsh wetland will be crossed, but culverts will maintain hydrologic connectivity between the wetland complexes. By allowing this crossing, there is a chance that portions of the park may be able to remain open to the public while certain stages of construction are occurring. Otherwise, additional closures may be necessary which could be more disruptive to park visitors. The selected configuration also allows a safer and more efficient flow of construction traffic that reduces interactions between construction and visitor traffic while somewhat reducing travel time for stone delivery between the jetty, stockpiles, and offloading sites.

The areas around the neck of the Spit and to the south would have provided less available space and would have resulted in a larger park closure. Environmental and wetland impacts for this area were not assessed. Staging and stockpiling any further away from the jetty structure would not be feasible.

Overall, wetland impacts were avoided and minimized to the maximum extent practicable, including providing adequate buffers for conserved wetlands. However, some wetland fill was unavoidable to achieve an adequate and contiguous construction area that allowed access and proximity to implement the project. For the reasons described in the discussion above, no other practicable alternatives allowed full avoidance of wetland impacts.

Wetland mitigation has been identified at both the North Jetty and in proximity to the South Jetty in Trestle Bay to offset these impacts. This is discussed further under the section: *Aquatic Ecosystems and Organism Determination*.

Dredging of barge offloading facilities: Maintaining the functionality of the offloading facilities may require regular dredging when they are seasonally in use. Barges delivering jetty stones are likely to be larger, ocean-going vessels that require under-keel clearances in excess of depths that are likely currently available and self-maintainable at the offloading sites. Dredging and in-water disposal will be required to maintain adequate depths that avoid bottom collisions and allow safe offloading in sometimes rough and unforeseen channel, ocean, wind, and wave conditions. This dredged material will be placed at a pre-approved designated Ocean Dredge Material Disposal Site for which the Corps through its Annual Use Plan will seek permission for use from the EPA prior to any dredge or disposal activities.

Discharge during inwater construction activities: During stone placement, pile installation, and dredging activities, there is likely to be some level of discharge and associated turbidity levels. However, this is unavoidable and will likely be minimal. The size of the stones and the sandy substrate ensure that any suspended sediments are likely to be negligible and to settle out quickly. Additionally, BMPs have been described that will further avoid and minimize any runoff, spill, or discharge potential. Turbidity monitoring and Conditions of the State Water Quality Certification will also be protective of species and will limit the duration of any such discharge. Conserved wetlands will be adequately buffered to avoid and unintended discharge.

IV. Factual Determinations (40 CFR § 230.11)

The actions evaluated in this analysis and the associated EA include South Jetty dune augmentation, actions at the North Jetty described in the *North Jetty Major Maintenance Report* (MMR), May 2011, and actions described in the Major Rehabilitation Report (MRR) (*MCR Jetty System Major Rehabilitation Evaluation Report*, June 2012). Though these actions will be funded as separate projects, they were analyzed together. The following mitigation is required as a result of their associated cumulative effects. The breakdown of effects from fill are indicated in the table below and then described in further detail.

Area Affected	Impacted Acreage	Mitigation Acreage	Comment
North Jetty			
Wetland	1.14	2.28	Base Condition: Major Maintenance Report
404 Waters Lagoon	8.02	12.03	Base Condition: Major Maintenance Report
Other 404 Waters	4.36	6.54	
South Jetty			
Wetlands	2.65	5.30	
404 Waters	13.84	20.76	
Jetty A			
Wetlands	0.91	1.82	
404 Waters	6.60	9.90	

Impacts associated with wetlands had a known and quantified footprint and were the same under all the construction alternatives. Specific wetland mitigation sites and methods were identified and developed. The exact extent of impacts to 404 waters of the US remained unknown because they were contingent upon the delivery method of the rock which would be determined during contract bidding. Therefore, the extent of mitigation for impacts to 404 waters remained uncertain and variable based on the mode of stone delivery and placement. Impacts would be greater if the contractor chooses to use offloading facilities; hence, the maximum potential effects were evaluated in this EA (and in the BAs). Because of this, maximum mitigation requirements were also assumed for 404 waters. Mitigation requirements would be further coordinated with the AMT and may be reduced if offloading facilities are not constructed.

Staging and rock stockpile areas are required to work with the large stone and to construct the repairs. A balance was struck to provide and locate such staging areas that allowed project completion in an efficient and timely manner while minimizing both the areal and temporal extent of project impacts to wetlands and waters. This also includes siting offloading facilities in areas that minimize the extent of dredging and impacts to critical shallow water habitat. To avoid and reduce shallow-water impacts, the Corps determined that offloading facilities would avoid locations within Baker Bay as well as in the small bay area along the north shore of Clatsop Spit. Further, by potentially utilizing barging operations to supply and place the large-sized and large volume of stone, this both reduces the impacts of traffic and somewhat avoids and reduces safety issues with large trucks entering and exiting the Coast Guard and State Park facilities, respectively.

It is assumed all wetlands are expected to be impacted for more than 1 year. Impacts to 404 waters of the US would also occur for more than one year with maintenance dredging and continuous use. Facilities may be removed or left in as permanent fixtures depending on hydraulic conditions at the offloading sites and along the adjacent jetties. For these reasons, this analysis assumed a worst-case scenario so the impacts were considered permanent. Mitigation would be commensurate with the project footprint, which may be reduced further depending on whether or not the final implementation requires barge offloading facilities.

a. <u>Physical Substrate Determinations</u>

Rock placement will occur on an annual basis starting in the late spring through the late to early fall seasons. Fill will be comprised mostly of mostly clean, large armor stones. Placement may occur at more than one jetty per season and will occur regularly throughout the duration of the construction schedule. Some permanent habitat conversion and modification will occur as a result of stone placement for repair and rehabilitation of jetty features. Along specific portions of North and South jetties and along the entire length of Jetty A, substrate will be converted to rocky sub and intertidal habitat, and associated benthic communities will be covered. In addition, crane set-up pads and turnouts will require placement of rock that could extend slightly off the current centerline of the jetty trunk. However, this total area is a relatively small percentage of the existing jetty structures, and conversion is mostly limited to the spur groin locations. Some crushed roadway fill will be placed to form a road on the jetty. This will be mostly above the MHHW mark to avoid deterioration of the roadway.

Generally, effects to in-water habitat could include the following: sub-tidal and intertidal habitat conversion from sandy to rocky substrate and potential unforeseen indirect far-field effects from hydraulic influence (slight, localized changes to accretion, currents, velocities, etc). However, relatively little habitat conversion and footprint expansion will occur because a majority of the stone placement for construction of the jetty head, trunk, and root features will occur on existing relic jetty stone and within the existing structural prism. Moreover, aquatic species would experience limited exposure since stone placement for cross-section repair and rehabilitation actions occurs mostly above the MHHW elevation.

Indirect disturbance effects due to placement activities will be localized and occur mostly during daylight hours in the summer months. Disturbance effects are expected to be of limited duration and minimal, since a majority of the placement is above MHHW and on existing relic stone. There may be temporary disturbance to species using the jetty structure in the vicinity of placement activities. However, the Corps does not expect long-term negative effects from these actions. Finally, the selected plans include cross-sections that avoid and minimize additional habitat conversion that would have resulted from a larger selected cross section.

Dredging will be needed for construction and maintenance of barge offloading facilities and is likely during early summer prior to rock delivery; it may not occur at all facilities annually. If all facilities were dredged, this would total about 16 acres near the jetties. However, it is likely only one or two facilities would be used seasonally for short durations and would be dredged on a periodic basis as needed. The effects of dredging on physical habitat features include modification of bottom topography, which in the vicinity of the jetties is extremely dynamic. Dredging may convert intertidal habitats to subtidal, or shallow subtidal habitats to deeper subtidal. Such conversions may affect plant and animal assemblages uniquely adapted to the particular site conditions these habitats offer. However, the dredge prisms would be very small as a relative percentage of the ~19,575 acres of shallow-water habitat available within a 3-mile proximity to the MCR. The proposed dredging of offloading facilities would affect bottom topography, but is unlikely to cause large-scale or long-term effects to habitat features. Dredging activities will also have some contribution to increased acoustic disturbance that could occur for a limited duration while dredging is underway. These effects are expected to attenuate rapidly such that they return to background levels within a short distance from the source.

Disposal is likely to occur on an annual basis originating from one or more of the offloading facilities. The duration of disposal will be limited and will likely occur earlier in the construction season prior to use of offloading facilities. All disposal of dredged material will be placed in previously evaluated and USEPA-approved ODMDS or Clean Water Act disposal sites. No new or different impacts to species or habitats than those previously evaluated by USEPA or other resource agencies for disposal approval are expected from these actions. Per USEPA guidelines, the ODMDS have a Site Management and Monitoring Plan that is aimed at assuring that disposal activities will not unreasonably degrade or endanger the marine environment. This involves regulating the time, quantity, and physical/chemical characteristics of dredged material that is placed in the site; establishing disposal controls; and monitoring the site environs to verify that unanticipated or significant adverse effects are not occurring from past or continued use of the site and that permit terms are met. The relative quantities, characteristics, and effects of the proposed action would not be expected to have different or significant negative impacts to these sites.

The effects of disposal on physical habitat features include modification of bottom topography. In some cases, disposal may result in the mounding of sediments on the bed of the disposal site. Such conversions may affect plant and animal assemblages uniquely adapted to the particular site conditions these habitats offer. However, the area impacted by disposal would be relatively small and would occur in deeper habitat offshore, in the littoral cell, or near the North Jetty vicinity. The proposed disposal is unlikely to cause large-scale or long-term effects to habitat features.

b. Water Circulation, Fluctuation and Salinity Determinations

Water quality characteristics such as salinity, water chemistry, clarity, color, odor, taste, dissolved gas levels and nutrients are not likely to be affected. Hydraulic features such as current patterns, water circulation, velocity and salinity would remain unchanged.

The USGS and ERDC conducted numerical modeling to evaluate changes in circulation and velocity, salinity, and sediment transport at the MCR for various rehabilitation design scenarios for the MCR jetty system. A 2007 USGS model evaluation assessed the functional performance for rebuilding the jetty lengths in order to aid in the assessment of potential impacts to fish from the rebuilt lengths. Ultimately, even in the larger rebuild scenario only negligible and insignificant changes were predicted to the overall hydraulic and hydrological process at the MCR.

For the proposed action addressed in the current EA, rebuilding of the jetty lengths is not included. However, model results under the larger jetty length rebuild scenario are still relevant for comparing and evaluating potential changes to the MCR system as a whole. This earlier modeling work also remains valid because the current proposed action in this EA holds the jetties at their present lengths, which is essentially the same length as the "base condition" used in the models.

Modeling by the USGS was performed for two time periods, August-September and October-November. Existing conditions were established using actual data collected in August-September 2005. The October-November model period was established for engineering purposes as this time period represents extreme conditions at the MCR. Plots were produced to show existing and post-rehabilitation conditions for the following parameters: residual (average for all tides) velocity and current direction for bed and near surface, residual bed load transport, residual total load transport (bed load + suspended load), and mean salinity for bed and near surface.

The ERDC analyzed the impacts of the presence of spur groins at the MCR in 2007. This analysis was done independently of the USGS modeling and was conducted with the coastal modeling system (CMS) and other models that operate within the surface water modeling system (SMS). A regional circulation model (ADCIRC) provided the tidal and wind forcing for the boundaries of project-and local-scale wave, current, sediment transport, and morphology change calculated by the CMS. The half-plane version of the wave transformation model, STWAVE, was coupled with two-dimensional and three-dimensional versions of the CMS, which calculates current, sediment transport, and morphology change. These models were coupled to provide wave forcing and update calculated bathymetry used in both models at regular intervals (Connell and Rosati 2007).

In summary, the 2007 modeling work and assessment remains valid because the current proposed action holds the jetties at their present lengths, which is essentially the same length as the "base condition" used in the 2007 modeling. Modeling results showed that the changes to velocities, currents, salinity, plume dynamics, and bed morphology would be small to negligible under the larger jetty length rebuild scenario with spur groins. Any small changes to the system would be even less unlikely under the current proposed action because it does not involve rebuilding the length of the jetties. Therefore, no significant overall changes to the hydraulics or hydrology of the MCR system are anticipated under the current proposed action. Additionally, relative to earlier plans which restored the length of the jetties and capped the heads at a significantly longer restored length, the current revised plan selection further reduces any potential impacts to currents, velocities, or bathymetry.

c. Suspended Particulate/Turbidity Determinations

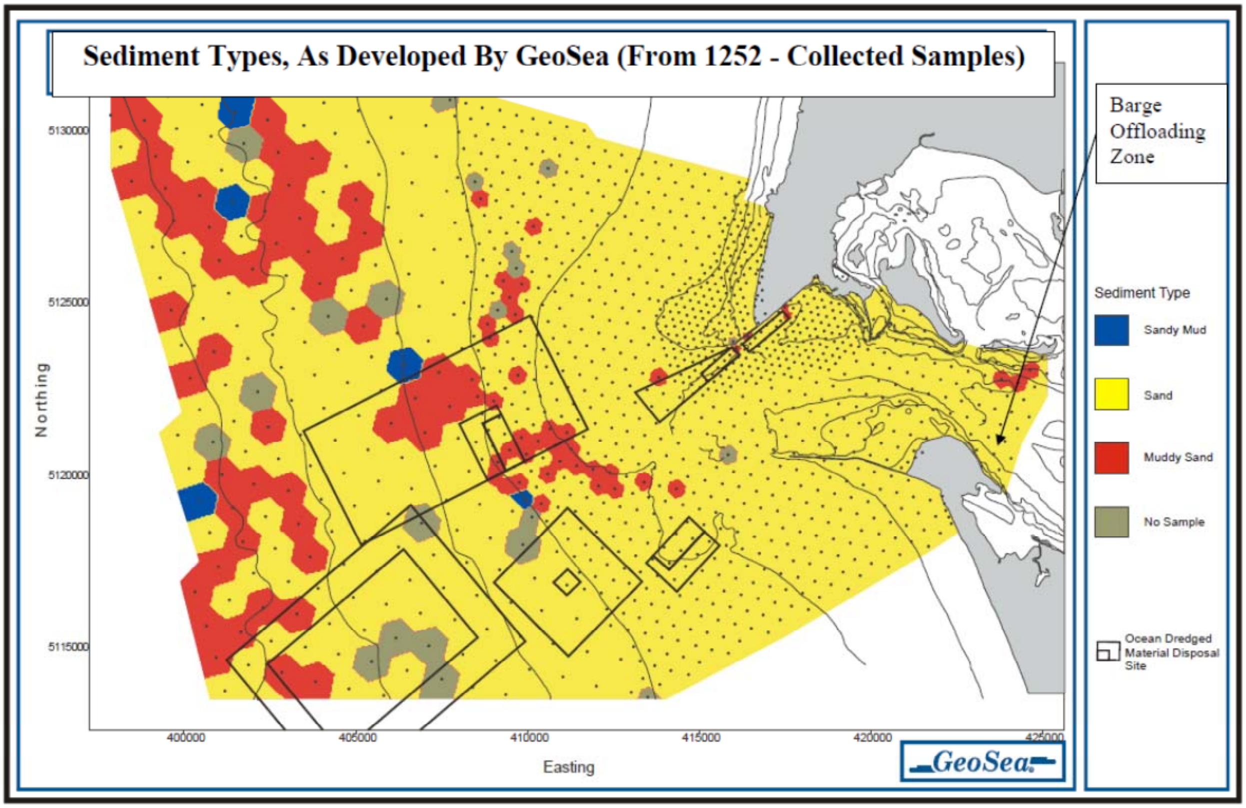
An unavoidable but minimal increase in suspended sediments in the water column is expected during the construction period; however, this impact is expected to stay within acceptable levels for fish and wildlife species of concern. Short-term turbidity is expected to occur with the placement of the temporary dolphins, offloading facilities, and dredging. Long-term adverse impacts are not anticipated.

In 2000, a sediment trend analysis was conducted in the MCR and surrounding off-shore locations by GeoSea Consulting, under contract to the Corps (McLaren and Hill 2000, Corps 2005). Over twelve hundred (1,252) samples were collected. Physical analyses of the samples surrounding the area (6 samples selected) indicated that the sediments consisted of +99% sand. Select samples from study in the MCR area were analyzed for physical and chemical contamination. Results indicated that no contaminates were detected at or near the screening levels in the *Dredge Material Evaluation Framework for the Lower Columbia River Management Area* (DMEF 1998). For a complete report on chemical results, see http://www.nwp.usace.army.mil/docs/d_sediment/Reports/Mcr/mouth00.pdf

In 2005, the Corps conducted a Tier I evaluation near the proposed the South Jetty barge offloading site following procedures set forth in the Inland Testing Manual and the Upland Testing Manual (Corps October 2005). The methodologies used were those adopted for use in the 1998 DMEF and its update, the *Northwest Regional Sediment Evaluation Framework, Interim Final* (SEF 2006). This Tier I evaluation of the proposed dredged material showed that the material was acceptable for both unconfined in-water and upland placement. No significant, adverse ecological impacts in terms of sediment toxicity were expected from disposal.

In 2008 using USEPA's *OSV Bold*, 10 sediment grab samples were collected from sites previously sampled in the 2000 sediment trend analysis (Corps 2008). In 2008, percent sand averaged 98.45% with a range of 99.3% to 97.0% and percent silt and clay averaged 1.59% (range from 3.0% to 0.7%). Per the Project Review Group approved Sediment Analysis Plan, no chemical analyses were conducted. Physical results for the 2000 and 2008 sampling events were compared. The mean percent sand for all samples in September 2000 was 98.11% and for June 2008 was 98.45%. In both data sets, sediments towards the outer portion of the mouth are finer than sediments towards the center of the mouth.

Sediment Trend Analysis in the MCR Area



Placement of rock by heavy equipment, jetty access road construction, dredging, disposal, and pile installation and removal could all cause temporary and local increases in suspended sediment. This is expected to have minimal and limited effects on the environment. Previous tests have confirmed that material to be dredged will be primarily sand with little or no fines, which does not stay suspended in the water column for a significant length of time. During infrequent and limited duration dredging and disposal, suspended sediments may increase locally for a short time. However, light attenuation and water quality effects from increased suspended sediments are expected to be minimal and fleeting. Pile driving is also expected to occur in sand and therefore have similar transient and minimal effects to water quality. Jetty roads could also contribute suspended sediments that would create turbidity, but since they are above MHHW this will likely be an infrequent occurrence. Increases in turbidity from construction activities on the jetties will likely occur on a nearly daily basis but will be of limited extent and duration, as rock placement will involve clean fill. Wave and current conditions in the action area naturally contribute to higher background turbidity levels; and such conditions also preclude the effective use of isolating measures to minimize turbidity. Effects from potential stormwater runoff will be avoided by implementation of an Erosion and Sediment Control Plan or Stormwater Pollution Prevention Plan that avoids and minimizes runoff and pollutant loading associated with upland construction activities. Therefore, impact from suspended sediments should be insignificant.

Temporally, effects to water quality from suspended sediment and turbidity could occur on a daily basis, but are not expected to be continuous throughout the day. Turbidity levels and durations will be limited to conditions required in the State Water Quality Certifications which include exceedence windows that are protective of beneficial uses such as salmonids and other aquatic life. Spills or leaks are expected to be infrequent and unlikely. Although the repetition of disturbance may be greater, it is still expected to remain within safe ranges that would not have long-term or significant effects. Furthermore, effects are expected to be geographically limited, short term, and minor.

Effects of the proposed action to water quality could occur by increasing suspended sediments, increasing the potential occurrence of spills and leaks, and increasing the potential for contamination. However, most of the discharged material will be large stone and coarser materials like sand. The Corps is also requiring a spill prevention and response plan along with additional BMPs and stormwater control measures that reduce the potential for leak or runoff exposure. Therefore, the Corps does not expect these effects to be likely or significant.

d. Contaminant Determinations

The Corps will require the contractor to provide a spill prevention and management plan that will include measures to avoid and minimize the potential for spills and leaks and to respond quickly to minimize damages should spills occur. Good construction practices, proper equipment maintenance, appropriate staging set-backs, and use of a fast fueling system would further reduce the likelihood of leak and spill potential and exposure extent and its associated effects.

Test results on dredge material described earlier further indicated that materials in the area are approved for unconfined in-water disposal and do not contain contaminants in concentrations harmful to organisms occupying the action area. The prohibition of treated wood will also avoid contamination from the migration of creosote and its components (e.g., copper and PAHs) from treated wood in the lotic environments.

e. Aquatic Ecosystems and Organism Determination

Fill and Removal in 404 Waters of the U.S. The Corps does not anticipate significant affects to the aquatic ecosystem. Some short-term loss of microhabitat will occur during the construction period but will be replaced by the completion of the proposed action. Avoidance of the area may occur throughout the construction period as a result of the increased activities and noise, but all species would be expected to return following project completion. Construction is expected to occur year-round. Some work would occur during appropriate in-water work periods determined by fishery agencies to minimize impacts to fish, wildlife and habitat; however, most of the work would occur outside these periods due to weather constraints. The Corps received a Biological Opinion from National Marine Fisheries Service (NMFS). The Opinion evaluated former proposed actions of the same nature that resulted in a larger temporal and geographic footprint than that associated with the current proposed action. Therefore, the Biological Assessments and resulting Opinion and Letter of Concurrence remain relevant for the scope of effects expected from the smaller project footprint. The Services concluded the previous proposed action was not likely to adversely affect any of the listed species in the action area, with the exception of eulachon, Stellar sea lions, and humpback whales. For these species, NMFS determined that Corps actions would not result in jeopardy to the species. The U.S. Fish and Wildlife Service (USFW) also concurred with the Corps' determination that its proposed actions would have no effect or were not likely to adversely affect any of the listed species under their jurisdiction in the action area.

In-water habitats (below MHHW), both shallow intertidal and deeper sub-tidal areas would also be affected by the project. These waters are also considered "waters of the US" as defined by the Clean Water Act. Habitat conversions and impact to 404 waters would occur from lagoon fill, maintenance dredging, jetty cross-sections, turnouts, barge offloading facilities, and causeways. Effects to waters and the aquatic resources residing there would occur on a temporal and spatial scale. Though dredged areas may refill over time and some facilities and fill may be removed, there would still be repeated and chronic site disturbance in these waters over the duration of the project. There would also be permanent lagoon fill at the North Jetty root and temporary, partial lagoon fill at the South Jetty for construction access. Fill would be in place for several years. Barge offloading facilities are a potential method of delivery for stone and other construction materials. If barge offloading facilities are used, this would create the largest impacts to 404 waters of the US and associated aquatic habitat. Therefore, the associated fill acreages and volumes represent the worst-case scenario for spatial and temporal effects.

The calculated extents of impacts were strictly based on the area of habitat that was converted by fill or removal. They did not include value or functional assignments regarding the significance of the conversion, whether it was a beneficial, neutral, or detrimental effect to specific species, nor if conversions created unforeseen, indirect far-field effects. For example, acreage of conversion for shallow sandy sub-tidal habitat to rocky sub-tidal habitat was calculated in the same manner as conversion from shallow intertidal habitat to shallow sub-tidal habitat. Multiple aquatic species utilize these waters, including macro-invertebrates like crabs, benthic organisms, marine mammals, and various other fish and wildlife species. It is also notable that impacts to 404 waters of the US would occur in an area that is listed as Essential Fish Habitat (EFH) for various species as well as in Critical Habitat for several listed ESA species. This impact was described in the 404 (b) (1) analysis.

In WA at MCR, the CWA beneficial use designations for fresh waters by Water Resource Inventory Area (WRIA) include the following general and specific uses: Aquatic Life Uses - Spawning/Rearing; Recreation Uses; Water Supply Uses; Misc. Uses - Wildlife Habitat, Harvesting, Commerce/Navigation, Boating, and Aesthetics. In OR, the following list of beneficial uses were identified: Anadromous Fish Passage; Drinking Water; Resident Fish and Aquatic Life; Estuarine Water; Shellfish Growing; Human Health; and Water Contact Recreation. These designated beneficial uses also include specific water quality criteria to protect the most sensitive uses, which includes use by salmonids for rearing and migration. For this reason, mitigation under the CWA also complements protections and conservation measures under the ESA for salmon and steelhead.

Without drawing a distinction between depths or tidal elevations, initial acreage estimates for all in-water impacts and habitat conversions in 404 waters of the US include:

- North Jetty ~12.38 acres (8.02 lagoon fill – this would occur during Major Maintenance; 0.63. barge offloading facilities, crane set-up pads, and turnouts; 3.73 dredging at offloading facility – the latter actions would occur during the Major Rehabilitation scenario.)
- South Jetty ~13.84 acres (3.5 lagoon fill; 0.4 crane set-up pads, and turnouts; 1.56 barge offloading facilities; 8.38 dredging at offloading facilities – all actions would occur during the Major Rehabilitation scenario.)
- Jetty A ~ 6.62 acres (2.89 barge offloading facility and causeway; 3.73 dredging at offloading facility– all actions would occur during the Major Rehabilitation scenario.)

This results in an estimated total of ~ 32.84 acres of potential in-water conversions and effects to 404 waters of the US other than wetlands.

Shallow-water habitat is especially important to several species in the estuary; thus, specific initial estimates were calculated regarding shallow-water habitat (shallow here defined as -20-feet or -23-feet below MLLW). About 21 acres at these depths would be affected by maintenance dredging and construction of the causeways and barge offloading facilities. About 12 acres would be affected by lagoon fill. However, this estimate does NOT include any expansion of the jetty's existing footprint or overwater structures from barge offloading facilities. For this analysis, there was no distinction drawn between periodically exposed intertidal habitat and shallow-water sandflat habitat. These approximations would be updated as project designs are refined and as additional surveys are completed to quantify changes in jetty and dune cross sections. However, these shallow-water footprints are very small as a relative percentage of the ~19,575 acres of shallow-water habitat available within a 3-mile proximity to the MCR.

Because of these impacts, the Corps has proposed mitigation actions at a ratio of 1.5:1 to offset temporal and spatial impacts to 404 waters and associated aquatic resources. This ratio was determined with input from the resource agencies considering several factors including: beneficial use listings that involve species with EFH and critical habitat designations in the impacted areas, the duration of the construction period, the number of different beneficial uses in the area impacted by the project, and the temporal and spatial extent of the actions. These actions are not proposed to directly mitigate or compensate for any project-related impacts to ESA-listed species but will mitigate for effects to CWA 404 waters of the US. However, the 404 mitigation actions would also complement but are not driven by Conservation Recommendations in the NMFS BiOp for recovery of ESA-listed salmonid habitats and ecosystem functions and processes.

Mitigation features would be commensurate with impacts and would be designed to create or improve aquatic habitat. In-kind mitigation opportunities for impacts to 404 waters were investigated specifically tidal marsh, swamp, and shallow water and flats habitat. Though a specific site or action has yet to be determined for mitigation of impacts to waters other than wetlands, if possible fish access to these mitigation features would be an important consideration.

From the list of possible mitigation features, one or a combination of actions would be selected for further development and implementation in order to offset actions affecting 404 waters. Selection would occur by the Corps with input from the AMT regarding appropriate design and completion of supplementary compliance documentation, and work is anticipated to be completed concurrent with jetty repair actions.

Impacts of fill and discharge to the structure and function of the aquatic ecosystem and organisms are expected to be minor, in that the disposal would temporarily disrupt feeding and food sources of organisms present within the site. Aquatic ecosystem functions would essentially remain unchanged within the high-energy environments of the site. Some organisms would be buried or temporarily displaced by the fill and discharge. It is expected that benthic organisms would rapidly reestablish at the sites within a short time following disposal and rock placement.

Specific opportunities were investigated in the Columbia River estuary and Youngs Bay and several are under consideration to mitigate for impacted aquatic functions in 404 waters of the US. Depending on further development and determination of appropriate mitigation siting for final impacts to 404 waters, a specific project or combination of projects would be designed and constructed concurrently as the proposed repair and rehabilitation options are completed over time. Proposed projects are subject to further analysis, and unforeseen circumstances may preclude further development of any specific project. In all cases, final selection, design, and completion of specific mitigation features is contingent on evolving factors and further analyses including: potential reduction in estimated impact acreage due to alterations in project implementation, hydraulic and hydrologic conditions, cultural resource issues, etc. For this reason a suite of potential proposals has been identified and subsequent selection of one or some combination of these or other projects and designs would occur during continued discussion with resource agencies participating on the AMT. The Corps would make a decision regarding the specific mitigation proposal for waters other than wetlands and then would vet the final designs through the AMT in order to obtain any potential additional clearances, if necessary.

Actions considered and investigated to provide mitigation for in-water habitat impacts include levee breaches, inlet improvements, or tide gate retrofits. However, mitigation efforts must consider in-kind mitigation and are constrained by the project's O&M authority, which precludes acquisition of private property and does not authorize breaches of federal levees. Additional associated actions that were investigated and may be implemented with the wetland mitigation include: excavation in sand dunes and uplands to specified design elevations in order to create additional intertidal shallow-water habitat with dendritic channels and mud flats, and excavation for potential expansion of the floodplain terraces. Though conceptually considered, other specific opportunities for mitigation projects such as the following were not identified but warrant further investigation if none of the projects in the list is determined to be feasible: removal of overwater structures and fill in the estuary; removal of relic pile-dike fields; removal of fill from Trestle Bay or elsewhere; removal of shoreline erosion control structures and replacement with bioengineering features; beneficial use of dredge material to create shallow water habitat features; and restoration of eelgrass beds. Certain pile fields and engineering features may be providing current habitat benefits that could be lost with removal, and such actions would require appropriate hydraulic analysis coordination with engineers and resource agencies.

For potential mitigation projects located in Trestle Bay, there is additional monitoring and assessment opportunity. A separate hydraulic/engineering study under a different project authority could investigate whether or not an expansion of low-energy, intertidal habitat near Swash Lake could effectively provide additional storage capacity and affect circulation in the bay such that erosive pressure at neck of Clatsop Spit could be reduced. This would not be covered under the existing project authority. A previous Section 1135 action that breached a section of the relic jetty structure is speculated to have been the cause of increased circulation and erosion. It would be worth evaluating whether or not projects that expand floodplain and intertidal areas in Trestle Bay provide demonstrable energy dissipation and additional low-energy storage capacity to offset or redirect erosive pressures. Alternatively, if other mitigation concepts are pursued that include removal of additional piles or creation of additional inlets, it would be worth investigating whether these actions could have indirect positive impacts that further reduce concern with erosion at the neck. Evaluating actions in this light would provide valuable information and insight regarding possible solutions and concerns for erosion and breaching at the neck area of Clatsop Spit on Trestle Bay.

Fill in 404 Wetlands. Some wetland fill will be required in order to conduct construction staging, storage, and rock stockpiling activities. Selection of appropriate sites has greatly avoided and reduced the amount wetland fill proposed. After avoidance and minimization measures, the following impacts will be appropriately mitigated per State and Federal requirements:

Wetlands near North Jetty.
All wetlands as well as the lagoon area south of the North Jetty Access Road will be impacted and filled in order to allow construction staging and to reduce processes eroding and undermining the jetty root, to which the lagoon also contributes. Additionally, a few small wetlands north of the roadway will be impacted in order to provide the necessary space for adequate rock storage (enough for 2 years-worth of rock placement) and efficient construction, staging, and access areas. The location of these staging and stockpiling areas have been selected in order to minimize impacts to the higher quality, more extensive wetland complex north of the North Jetty Access Road. There will also be some wetland impacts during replacement of the damaged culvert crossing under the North Jetty Access Road. After avoidance and minimization measures, including implementation of an 80-ft buffer around conserved wetlands north of the roadway and a 200-ft shoreline buffer beyond the Highest High Tide, unavoidable total wetland impacts come to about 1.14 acres out of the 31 acres identified for construction actions, and impacts to other waters of the U.S. via the lagoon equals about 8.02 acres.

Of the wetlands impacted, 0.11 acres are part of a wetland mosaic complex which rated as Category IV Interdunal, Depressional wetlands. 0.65 acres are part of a wetland mosaic complex which rated as Category III Interdunal, Depressional wetlands. 0.25 acres rated as Category II Interdunal Riverine wetlands; and 0.13 acres rated as Category 1 Estuarine, Freshwater Tidal Fringe.

These wetlands all will be mitigated onsite, in an area north of the North Jetty Access Road adjacent to the conserved wetland fringe that extends further north. At a 2:1 mitigation ratio, this equals about 2.28 acres of wetland mitigation, plus the required buffer. This amount of upland area is available, and wetland creation via excavation to appropriate depths, appropriate native plantings, invasive species removal, and buffer requirements will offset impacts to wetland within the same vicinity in which they are proposed. This 2:1 ratio also aligns with mitigation requirements in WA that were developed in partnership with WA Department of Ecology, EPA, and the Corps (WADOE 2006). According to this guidance, estuarine ratios are developed on a case-by-case basis (WADOE 2006). Given the ample rainfall and close proximity to higher functioning wetlands, the likelihood of successful wetland establishment further supports the proposed amount of compensatory wetland mitigation. Though these buffers, ratios, and acreages are likely close to the final amounts, they are subject to change depending on review by WA Department of Ecology and receipt of Conditions in the WA State Clean Water Act 401 Water Quality Certification and the determination of Coastal Zone Management Act Consistency.

Wetlands near South Jetty (on Clatsop Spit).
In order to acquire the 44 acres needed for staging and rock stockpiles, 2.65 acres of unavoidable wetland impacts will occur at the South Jetty. However, by slightly revising locations, maintaining hydrologic connections at wetland crossings, and by maintaining a 50-ft wetland, shoreline, and riparian buffer for preserved areas whenever possible, these impacts have been greatly reduced and minimized relative to initial conservative impact estimates. This includes limiting the roads required to cross wetlands to a 20-ft width and requiring culverts to maintain hydrologic connectivity at crossings. In addition to wetlands, about 3.5 of the existing 5.2 acres of other waters of the US will be impacted in the form of fill in a lagoon area adjacent to and along the jetty. There will be a road and crossing over these waters, which will be culverted in order to maintain flows into and out of the marsh wetland complex; and the 40-ft wide causeway/jetty access roadway will be constructed immediately adjacent to the jetty in order to minimize interference with and impacts to the inlet of the marsh complex.

According to the Cowardin Classification system (1979), of the wetlands impacted, approximately: 0.77 acres are classified as Estuarine-Intertidal-Emergent-Persistent; 0.66 acres are classified as Palustrine-Forested-Needled-leaved-Evergreen; 0.75 are classified as Palustrine-Emergent-Non-persistent; and, 0.47 acres are classified as Palustrine-Forested-Broad-leaved-Deciduous.

Wetlands were scored for grouped service functions as define by the 2010 Oregon Rapid Wetland Assessment Protocol (ORWAP), and the categories depressional and estuarine were identified.

Following this method in determining the types of wetland impacts, this brings the totals under the ORWAP categories to 1.15 acres of impacts to depressional wetlands at the South Jetty, which were ranked relatively as follows: low for hydrologic function and fish support group; and high for water quality, carbon sequestration, aquatic support, and terrestrial support. Alternatively, the relative scores for the grouped service values were: low for hydrologic function, terrestrial support, and public use and recognition; equal for provisioning services, and high for water quality, fish support, and aquatic support. The wetlands also ranked relatively high for ecological condition and sensitivity, and low for stressors.

In comparison to State wetland scores for grouped service functions as define by ORWAP (2010), 1.49 acres of impacts would affect estuarine wetlands at the South Jetty which are ranked relatively as follows: low for hydrologic function, aquatic support, and terrestrial support; and high for water quality, carbon sequestration, and fish support group. Alternatively, the relative scores for the grouped service values were: low for hydrologic function, aquatic support, terrestrial support, and public use and recognition; equal for provisioning services, and high for water quality and fish support. The wetlands also ranked relatively high for ecological condition, and low for stressors and sensitivity.

These wetlands will be mitigated near the impact site in an area identified in Trestle Bay near the channel entrance to Swash Lake. At a 2:1 mitigation ratio, this equals about 5.3 acres of wetland mitigation. Anecdotally, it is thought that the uplands in this area are the result of previous historic fill from the dredging the adjacent channel, so that excavation of uplands would result in restoration of wetland that are likely to be intertidal. There is also a former ODOT mitigation site that the Corps will likely abut. This is an appropriate mitigation site because it is within the same subwatershed (HUC 7), and per the ORWAP scoring and Cowardin classification, the adjacent areas have wetland types similar to those being impacted.

In comparison to State wetland scores for grouped service functions as define by ORWAP (2010), depressional wetlands at the South Jetty mitigation area are ranked relatively as follows: low for hydrologic function, carbon sequestration, fish support group, and aquatic support; and high for terrestrial support; and equal for water quality. Alternatively, the relative scores for the grouped service values were: low for hydrologic function, aquatic support, terrestrial support, and public use and recognition; equal for provisioning services, and high for water quality and fish support. The wetlands also ranked relatively high for ecological condition and sensitivity, and low for stressors.

In comparison to State wetland scores for grouped service functions as define by ORWAP (2010), estuarine wetlands at the South Jetty mitigation area are ranked relatively as follows: low for hydrologic function and water quality; and high for carbon sequestration, fish support group, aquatic support, and terrestrial support. Alternatively, the relative scores for the grouped service values were: low for hydrologic function, aquatic support, terrestrial support, and public use and recognition; equal for provisioning services, and high for water quality and fish support. The wetlands also ranked relatively high for ecological condition and stressors, and low for sensitivity.

Proximity of the uplands to existing wetlands from both classes that had similar ORWAP scores at the mitigation site, in addition to tidal and precipitation hydrology should serve as reasonable indicators for potential success of the mitigation site. For all proposed mitigation, detailed designs, plans, and specifications will be further determined in the next stages of project development and will be constructed concurrent with wetland impacts.

Wetlands near Jetty A.
A total of about 0.91 acres of wetland at Jetty A will also be filled due to rock storage and construction staging activities. Unfortunately, these wetlands cannot be avoided, but impacts to adjacent water of the U.S. will be minimized by implementing a 100-ft buffer beyond the Highest High Tide elevation, which is consistent with the setbacks required for lands designated by Pacific County as Conservancy. Of the wetlands impacted, 0.74 acres rated as a Category III Interdunal, Depressional wetlands with scores under 26. 0.17 acres rated as Category 1 Estuarine, Freshwater Tidal Fringe wetlands.

Because of onsite space constraints and site conditions, these wetlands will be mitigated in the same vicinity as the mitigation area identified at the North Jetty, north of the North Jetty Access Road. At a 2:1 mitigation ratio, this equals about 1.82 acres of wetland mitigation, plus the required buffer. These requirements were determined as described for the North Jetty and align with WADOE guidance (2006). Wetland creation will occur in conjunction with and in addition to the area and process described for compensatory mitigation at the North Jetty. Reduced disturbance coupled with improved potential hydrology and adjacent functioning wetlands at North Jetty compared to at Jetty A make the success of wetland creations more likely at the location at the North Jetty compared to any creation at Jetty A. The total compensatory mitigation acreage at the North Jetty is 4.1 acres, and this area is available as described. As with the North Jetty, though these mitigation ratios and acreages are likely close to the final amounts, they are subject to change depending on review by WA Department of Ecology and receipt of Conditions in the WA State Clean Water Act 401 Water Quality Certification and the determination of Coastal Zone Management Act Consistency.

Wetland fills and culvert installations at all jetties will occur once and could happen during anytime in the construction season depending on weather. Sequentially, these actions will be required prior to several of the other features of the proposed action. Subsequent removal of construction-related culverts would be likely to occur once and could also happen during anytime in the construction season depending on weather and construction needs. Periodic culvert maintenance may be required during construction. Temporally, this limits the repetition of disturbance activities to single event and season on separate jetties.

Where possible, the construction, access, and staging areas at all jetties have been planned so that the footprint would minimize impacts to wetlands and higher value habitat features. Protections and BMPs will be implemented for the identified rare and ranked vegetative communities within the area. Strategic use of uplands and lower quality wetlands for rock storage would be undertaken to the most practical extent in order to avoid and minimize these impacts. However, permanent and temporary wetland fill would occur as a result of construction staging, storage, and rock stockpiles at all three jetties. Fill used to protect the North Jetty root would also affect wetlands. Long-term direct and indirect impacts to wetlands could include permanent wetland fill, potential fragmentation of and between existing wetlands, soil compaction, loss of vegetation, altered hydrology, conversion to upland, and loss of ecosystem functions (water quality, flood storage, nitrogen cycling, habitat, etc.). However, it is expected that effects from wetland impacts and lagoon fill would be insignificant on river functions, as the wetlands are not within the channel prism of the Columbia River. Although these wetlands are connected hydrologically to the Columbia River, wetland fill impacts would not be likely to negatively alter groundwater-stream exchange or hyporheic flow because the wetlands are on accreted land that has formed on stabilized sand shoals behind the jetties. Wetland hydrology is mostly elevation and rainfall dependent, and fill impacts would be relatively insignificant to the Columbia channel. Culverts will be installed to maintain wetland hydrology and connectivity with permanent replacement at the North Jetty and when temporary construction roadways cross wetlands.

The current culvert under the North Jetty Access Road is perched and the regularly disconnected nature of the lagoon system does not appear to support anadromous fish use. Fish surveys were not completed for the stream inlet leading into this wetland complex and creek. An initial sampling survey will be conducted during peak juvenile salmon outmigration to determine whether or not fish salvage and fish exclusion efforts for ESA-listed species is warranted. The Corps will coordinate with NMFS if listed species are identified. Redesign of this system may provide an opportunity to accommodate improved hydrology to newly created wetlands excavated adjacent to the existing wetland complex, and will be further investigated during the hydraulic/hydrologic design analysis.

Though there is an existing razor clam bed adjacent to the vicinity of the proposed dune augmentation, species impacts are not expected because all of the stone placement will occur above MHHW, and haul traffic will be precluded from using Parking Lot B and from driving on the beach during material delivery. Excavator and bulldozer work will be mostly confined to the dry sand areas to further avoid negative species effects.

Because vibratory hammers will be implemented in areas with velocities greater than 1.6 feet per second, the need for hydroacoustic attenuation is not an anticipated issue. Piling will be fitted with pointed caps to prevent perching by piscivorous birds to minimize opportunities for avian predation on listed species. Some of the pilings and offloading facilities will be removed at the end of the construction period.

As mentioned, wetlands at Jetty A and North Jetty would be mitigated immediately north of the North Jetty Road adjacent to the project site. This is an appropriate location for the North Jetty impacts because mitigation remains as near the impact area as possible and compensates for mostly the same wetland types, of which the majority are interdunal depressional. For Jetty A, space is unavailable near the jetty, and the likelihood of successful creation is higher in the North Jetty location due to the land use requirements and disturbance from Coast Guard activities at Jetty A. Based on adjacent reference wetlands at the North Jetty of the same type, appropriate elevations would be determined, and existing uplands would be cleared of invasive species and excavated and graded to the appropriate depths and contours.

Materials removed from impacted wetlands would be reused in the created wetlands as appropriate to take advantage of the existing wetland seed bank and hydrologic soils constituents. Plantings, revegetation, and invasive species removal would also be implemented, including the required buffer around the new wetland area. It is anticipated that upland material removed during wetland creation would be placed as part of the lagoon fill. With ample precipitation, functioning adjacent reference sites, and appropriate plantings, the likelihood of successful wetland establishment is reasonably high.

At the South Jetty, wetland mitigation would take place adjacent to an existing mitigation site further southwest of the impact area at the bottom of Trestle Bay such that there are reference elevations and hydrophytic species to facilitate design planning and vegetation establishment, respectively. The mitigation location near Swash Lake is not as close to the area of impacts as the site at the North Jetty, but the proposed location is further away from areas experiencing heavy recreation and all-terrain vehicle (ATV) use such as is occurring in the existing wetlands on Clatsop Spit. Therefore, the likelihood of successful wetland establishment is greater in the proposed location.

The process for creating the wetlands at the South Jetty site would be similar to that at the North Jetty, but an additional dendritic channel may also be included as appropriate such that newly created wetlands experience an estuarine connection like those that are being impacted by the project. This would also involve excavation to create hydrologic conditions based on tidal and reference site elevations

Monitoring of all mitigation sites is expected to occur prior to, during, and for three years after mitigation implementation. For wetlands, sample reference plots would be established along with a photo point, and success criteria would be based on achievement similar or better functions and values scores relative to those indicated by the delineations for those impacted by the project. Monitoring components would likely include the following elements, which may be modified as further mitigation development details are available: percent survival; percent cover; percent of native vs. non-native species; and achievement of appropriate hydrology. Hydrologic indicators would include establishment of topography and contouring/geomorphology that is similar to adjacent representative sites, and in the case of South Jetty, achievement of regular tidal inundation. Appropriate monitoring criteria would also be developed for the mitigation to waters other than wetlands.

Refinement and implementation of this overall mitigation plan would help protect species and habitats while restoring wetland, inwater, and upland functions affected by the proposed action. Monitoring and maintenance of mitigation will be required to ensure successful establishment of mitigation goals and satisfactory return on investment. These mitigation actions and monitoring results would also be recorded on the Corps mitigation website at: https://sam-db01mob.sam.ds.usace.army.mil:4443/pls/apex/f?p=107:1:1390572094248259. Regular coordination with the AMT would further facilitate implementation of appropriate mitigation for impacts to wetlands and waters that appropriately offset affected habitat and are complementary to the framework for successful protection and preservation of aquatic resources, ESA listed species, and high-value habitat.

No significant or long-term adverse affects on any listed/candidate threatened or endangered species are anticipated. More thorough effects analyses can be found in the associated Biological Assessments and the subsequent Biological Opinion from NMFS and Letter of Concurrence from USFW, herein incorporated.

f. Proposed Disposal Site Determinations

The effects of disposal on physical habitat features include modification of bottom topography. In some cases, disposal may result in the mounding of sediments on the bed of the disposal site. Such conversions may affect plant and animal assemblages uniquely adapted to the particular site conditions these habitats offer. However, the area impacted by disposal would be relatively small and would occur in deeper habitat offshore, in the littoral cell, or near the North Jetty vicinity. The proposed disposal is unlikely to cause large-scale or long-term effects to habitat features.

Disposal is likely to occur on an annual basis originating from one or more of the offloading facilities. The duration of disposal will be limited and will likely occur earlier in the construction season prior to use of offloading facilities. All disposal of dredged material will be placed in previously evaluated and USEPA-approved ODMDS or Clean Water Act disposal sites. No new or different impacts to species or habitats than those previously evaluated by USEPA or other resource agencies for disposal approval are expected from these actions. Per USEPA guidelines, the ODMDS have a Site Management and Monitoring Plan that is aimed at assuring that disposal activities will not unreasonably degrade or endanger the marine environment. This involves regulating the time, quantity, and physical/chemical characteristics of dredged material that is placed in the site; establishing disposal controls; and monitoring the site environs to verify that unanticipated or significant adverse effects are not occurring from past or continued use of the site and that permit terms are met. The relative quantities, characteristics, and effects of the proposed action would not be expected to have different or significant negative impacts to these sites.

Determination of Compliance with Applicable Water Quality Standards

Oregon and Washington have classified the lower Columbia River as water quality-limited and placed it on the Clean Water Act Section 303(d) list for the following parameters: RM 0 to 35.2 for temperature and polychlorinated biphenyls (PCBs); RM 35.2 to 98 for arsenic, dichlorodiphenyl trichloroethane (DDT), PCBs, and temperature; and RM 98 to 142 for temperature, arsenic, DDT, PCBs, and polynuclear aromatic hydrocarbons (PAHs). In Washington, the river also is on the Section 303(d) list for dichloro-diphenyl-dichloroethane, Alpha BHC (a pesticide), mercury, dissolved gas, dieldrin, chlordane, aldrin, dichloro-diphenyl-dichloroethylene, fecal coliforms, and sediment bioassay. In addition, the entire river is subject to an USEPA total maximum daily load for dioxin.

The proposed action is not anticipated to contribute to the pollutant load or degradation of any of these listed water quality parameters. Effects to turbidity have been further described elsewhere and will remain in compliance with forthcoming State 401 Water Quality Certification Conditions. Therefore, the proposed actions are expected to be in compliance with all State and Federal water quality standards.

Potential Effects on Human Use Characteristics

Municipal and Private Water Supplies: There are no municipal or private water supply intakes in the vicinity of the disposal areas.

Recreational and Commercial Fisheries: Crab fishermen generally crab in the area adjacent to the North Jetty. There will be an impact to recreational fisheries along the channel sides of the jetties as a result of barge traffic to and from the barge off-loading platforms. The recreational crab fisherman will be notified as to when the construction activities will take place and they will need to limit their crab pots in the area to accommodate barge traffic.

Water-related recreation:
The proposed action would have minor adverse impacts to recreationists at Cape Disappointment State Park and Fort Stevens State Park, those participating in water-sports and beach activities near the jetties, and those using the jetty structures for fishing and crabbing. Heavy equipment using park roads and parking lots will delay or inconvenience park visitors and water sport and beach recreationists. Park visitors and recreationists are likely to be disturbed by construction noise. A number of restrictions would be in place near the construction zones at each jetty to protect park visitors, water sport and beach recreationists, and the public. Some park roads and parking lots would likely be closed at times during construction. Access to the jetties and nearby beaches would be closed periodically at different times during construction of the individual jetties, which would impact water sport and beach recreationists and anglers. However, large portions of the parks and beaches will remain open and accessible to the public, and the bulk of the construction activities are likely to be seasonally concentrated. The long-term reduction in the levels of recreational activity could also affect the local economy of the Long Beach peninsula and the Warrenton/Hammond area, which are highly dependent on tourism. However, the recreation and local economy impacts are not expected to be significant.

Rehabilitation of the MCR jetty system is expected to have a long-term, positive effect on recreational vessel safety. Maintenance of the shoreline at Clatsop Spit and Benson Beach is also expected, which preserves these areas for recreational opportunities mentioned above. The proposed action would have no effect on utilities and public services in the area. The MCR is the gateway to the Columbia-Snake River system, accommodating commercial traffic with an approximate annual value of $20 billion dollars a year. The proposed action would have a long-term, positive effect on maintaining this vital transportation link and associated economy for the states of Oregon, Washington, Idaho, and Montana, as well as for the Nation as a whole.

Aesthetics: No impacts to aesthetics are anticipated.

Parks, etc: Impacts to both Cape Disappointment State Park and Fort Canby State Park will involve the placement of jetty stone, construction traffic, temporary beach and road closures, and temporary staging areas for construction equipment. The impact will be repaired and any placement of construction material will be removed and the site restored to its pre-construction state. The Corps will coordinate with both Parks to avoid and minimize recreational effects as much as feasible while still accommodating an efficient completion of the project actions.

g. Determination of Cumulative and Secondary Effects on the Aquatic Ecosystem

For a determination of cumulative effects, the effects of the proposed activity have to be viewed in the context of past, present and reasonably foreseeable future actions that may impact environmental resources in the vicinity of the work. The cumulative effects of basin-wide actions are addressed in detail in the 2012 *Revised Final EA for the Major Rehabilitation of the Columbia River Jetty System*.

There have been significant impacts to the Lower Columbia River and MCR from historic actions such as the Federal Columbia River Power System which has greatly modified flow patterns of the Columbia River, the jetty system at the MCR which has altered ocean currents and wave patterns in the vicinity of the proposed activity, and dredging which has prevented meandering of the channel as would be expected in a more natural, dynamic river system. Because the current proposed impacts are intermittent and in a small area relative to the overall size of the MCR and adjacent beaches, this proposed activity will have only a small temporary impact on the aquatic ecosystem in the MCR.

Cumulative effects are defined as, “The impact on the environment which results from the incremental impact of an action when added to other past, present, and reasonably foreseeable future actions regardless of what agency (federal or non-federal) or person undertakes such other actions” (Code of Federal Regulations Title 40, Section 1508.7). Cumulative impacts can result from individually minor, but collectively significant actions taking place over a period of time. The past actions that have occurred in and near the MCR jetties are identified below. Together, these actions have resulted in the existing conditions in the vicinity of the MCR jetties (see Section 2).

- European settlement and associated modifications in the vicinity of the MCR.
- Residential, commercial, and industrial development that occurred in upland areas.
- Original construction of the MCR jetty system and subsequent rehabilitation and repairs.
- Development and recreational use of Fort Stevens and Cape Disappointment State Parks.
- Operation and maintenance of the Columbia River federal navigation channel including navigational structures, periodic dredging and disposal, surveying, etc.
- Designation and use of dredge material disposal sites. Several active and historic disposal sites occur in the vicinity of the MCR. A North Jetty site was established in 1999 to allow placement of dredged material along the jetty toe to protect it from excessive waves and current scour. Its use is limited to disposal of MCR dredged material. From 1999-2008, about 4.4 mcy of dredged material was placed in this site. The shallow water ocean disposal site (SWS) was designated in 2005 by USEPA and lies about 2 miles offshore from the MCR. The SWS is used for disposal of material dredged from the MCR and is of strategic importance to the region; its continual use has supplemented Peacock Spit with sand, sustained the littoral sediment budget north of the MCR, protected the North Jetty from scour and wave attack, and stabilized the MCR inlet. There is a deep water ocean disposal site further offshore from the MCR and a proposed dredge material disposal site near the South Jetty.
- Disposal of dredged material (marine sand) at Benson Beach.
- Deepening of the Columbia River federal navigation channel.

The reasonably foreseeable future actions under consideration in this analysis are identified below. The listing includes relevant foreseeable actions in and near the MCR including those by the Corps, other federal agencies, state and local agencies, and private/commercial entities.

- Mitigation associated with the proposed action.
- Operation and maintenance of the federal navigation channel for authorized project purposes.
- Protection and restoration of existing natural areas and potential acquisition, restoration and protection of natural areas in the vicinity of the MCR by federal, state, and local agencies.
- Operation and maintenance of existing recreational facilities in Fort Stevens and Cape Disappointment State Parks.
- Continued use and development in upland areas for residential, commercial and industrial use in proportion to future increases in population throughout the area.
- Water quality improvements with implementation of more stringent non-point source pollution standards, such as total maximum daily loads (TMDLs).
- The Corps has recently proposed designation of three dredge disposal areas that would provide potential benefit in restoring a sediment budget to the littoral cells in the vicinity of MCR. These sites include: South Jetty Nearshore site (sub-tidal), Benson Beach Intertidal site, and the North Head Nearshore site (sub-tidal). As with the existing North Jetty 404 Site, these additional sites could also help to alleviate some to the scour occurring at the jetty structures.

  The proposed sites are somewhat removed from the immediate geographic vicinity of the jetty Major Rehabilitation proposed actions. These beneficial use sites could also help rebuild the sand shoals at the North and South Jetty foundations. However, it is uncertain in what priority, frequency, and timeframe these new disposal sites would be implemented. Currently, the South Jetty Nearshore site is top priority, followed by Benson Beach, and then the North Head site. The specifics for these sites have been described and evaluated in the Corps' April 2012 *Draft EA for Proposed Nearshore Disposal Locations at the Mouth of the Columbia River Federal Navigation Project, Oregon and Washington*.

The potential cumulative effects associated with the proposed Major Rehabilitation actions were evaluated with respect to each of the resource evaluation categories in this Environmental Assessment. For the proposed action, water quality impacts (suspended sediment and turbidity increases) are expected to be temporary and localized, and BMPs would further reduce effects. Water quality impacts from the proposed action are not expected to be cumulatively significant. Stricter controls placed on foreseeable future projects would reduce short-term, adverse impacts and are anticipated to provide a long-term, cumulative benefit to the water quality in the vicinity of the MCR.

Future development, construction activities, and other foreseeable future projects, in combination with population growth, would produce changes in the amount of impervious surfaces and associated runoff in the vicinity of the MCR. However, all projects are required to adhere to local, state, and federal stormwater control regulations and best management practices that are designed to limit surface water inputs.

Biological resources include fish and wildlife, vegetation, wetlands, federal threatened and endangered species, other protected species, and natural resources management. While historic development in the vicinity of the MCR has caused losses of aquatic and riparian habitats, especially in the lower Columbia River and estuary with resulting adverse impacts to fish and wildlife resources, these actions occurred in a regulatory landscape that is very different from that which exists today. While future development will likely have localized impacts on these resources, under the current regulatory regime these resources are unlikely to suffer significant losses. Moreover, initiatives by federal, state, and local agencies and groups would operate to mitigate the unavoidable environmental impacts of any future development. In addition, there are a number of actions that are ongoing or planned that would provide a cumulative, long-term improvement to aquatic resources and habitat, especially for ESA-listed salmonid species, including the implementation of the Conservation Recommendations and Reasonable and Prudent Alternatives specified in the 2008 NMFS Federal Columbia River Power System Biological Opinion and more stringent non-point source pollution standards. Any future federal actions would require additional evaluation under the National Environmental Policy Act at the time of their development.

In the long term, mitigation associated with the proposed action would provide the benefits previously described, including an increase in the overall square footage of wetlands and improve uplands, potentially also improving wetland-stream hydrologic functions in the Columbia River estuary.

A long-term reduction in the levels of recreational activities near the MCR jetties would occur during the proposed action and future activities. This reduction in recreation activity could also affect the local economy of the Long Beach peninsula and the Warrenton/Hammond area, which are highly dependent on tourism. These recreation and local economy impacts are not expected to be significant. The proposed action and future activities are not expected to cause a cumulative, adverse change to population or other indicators of social well being, and should not result in a disproportionately high or adverse effect on minority populations or low-income populations. No cultural and historic resources are expected to be impacted by the proposed action. Reasonably foreseeable future actions will be subject to review and approval by State Historic Preservation Officer.

The proposed action would facilitate effective maintenance of the Columbia River navigation channel, as it would improve and restore the function of the MCR jetty system. The jetty system helps reduce shoaling in the main channel and directs and concentrates currents in order to preserve sufficient depths in the main channel. While operations and maintenance dredging would continue at the MCR, the proposed action is intended to reduce the migration of littoral drift into the channel; upon completion, this may reduce the volumes and frequency of future operation and maintenance dredging at the MCR. Another benefit of reducing littoral drift into the MCR is the preservation of Benson Beach and Clatsop Spit. The dredge disposal at Benson Beach and the other existing SWS, North Jetty 404 site, and proposed North Head beneficial use sites may complement the proposed infill actions that are intended to protect the North Jetty root. Similarly, this may also be the case if new disposal sites are implemented at both the South Jetty Nearshore and Intertidal sites near the South Jetty trunk, root, and dune augmentation areas.

Shoreline preservation could be complemented by the infill activities, dredge disposal, and further stabilization and augmentation efforts at the spit.

In conclusion, this cumulative effects analysis considered the effects of implementing the proposed action in association with past, present, and reasonably foreseeable future Corps' and other parties' actions in and near the MCR. The potential cumulative effects associated with the proposed action were evaluated with respect to each resource evaluation category and no cumulatively significant, adverse effects were identified. In addition, there are a number of actions that are ongoing or planned that would provide a cumulative, long-term improvement to aquatic and wildlife resources and habitat.

Coordination

The proposed work has been coordinated with the following agencies:

Federal
U.S. Environmental Protection Agency
U.S. Fish and Wildlife
National Oceanic and Atmospheric Administration

State of Oregon
Oregon Department of Fish and Wildlife
Oregon Department of State Lands
Oregon Department of Environmental Quality
Oregon Parks and Recreation Department
Oregon Department of Land Conservation and Development
Washington Department of Fish and Wildlife
Washington Parks and Recreation Department
Washington Department of Ecology

An agency coordination meeting was held on May 25, 2006 for the purpose of introducing the project to several agencies that will be involved with review of environmental documents. Staff from the USACE Portland District presented the current state of environmental review and engineering modeling to the NMFS, USFWS, WDOE, ODEQ, and Oregon Department of Land Conservation and Development.

On April 13, 2007 the USACE met with the U.S. Geological Survey (USGS) and Portland State University regarding numerical modeling in support of the MCR rehabilitation project. Also in 2007, four resource agency meetings and presentations were held regarding the MCR project on April 27, May 30, July 11, and September 5. A public information meeting was held in Astoria, Oregon on July 31, 2006. After a presentation about the MCR jetty rehabilitation project, the public was invited to ask questions and talk to USACE staff about the project. In addition, the USACE Portland District established a web site to keep the public informed about the repair/rehabilitation of the MCR jetties located at https://www.nwp.usace.army.mil/issues/jetty/home.asp.

An initial draft EA was distributed for a 30-day public review in June 2006. Due to changes in the project description, a revised draft EA was prepared. The revised 2010 draft EA (*Revised Draft Environmental Assessment Columbia River at the Mouth, Oregon and Washington Rehabilitation of the Jetty System at the Mouth of the Columbia River, January 2010*) was informed by and revised to reflect and address comments received, as appropriate. The revised draft EA was issued for a 30-day public review period in January 2010. The revised draft EA was provided to federal and state agencies, organizations and groups, and various property owners and interested publics. In addition, a public information meeting was held in Astoria, Oregon on February 3, 2010. After a presentation by the Corps about the MCR jetty rehabilitation project, the public was invited to ask questions and talk to USACE staff about the project. Another public information meeting to describe likely construction techniques was also held on June, 4, 2010, at Fort Vancouver, WA to solicit input from potential construction contractors and to provide additional information regarding the feasibility of the Major Rehabilitation and Repair approach. The original EA was finalized and posted on the Corps website along with the 404 (b) (1) evaluation in May 2011.

After additional project developments, the 2012 revised final EA updates and corrects the 2011 final EA by updating the alternative plans considered and the Preferred Alternative actions proposed for the North Jetty, South Jetty and Jetty A. The 2011 and 2012 EAs were also informed by and revised to reflect and address the above public notice comments, as appropriate. After the previous 30-day public review period and receipt of comments from federal and state agencies, organizations and groups, and various property owners and interested publics, public concerns identified in comments were addressed.

Besides these official public information meetings and distribution of the EA, the Corps has also had multiple meetings with various regulatory agencies to ensure regular coordination throughout project development. Also as mentioned, the Corps has proposed formation of a modified interagency Adaptive Management Team to keep resource agency partners apprised of any potential project changes or challenges that arise during implementation.

V. Findings of Compliance (40 CFR § 230.12)

a. Adaptations: No significant adaptations of the guidelines were made relative to this evaluation.

b. Alternatives: The No Action alternative was considered and subsequently rejected. Breaching and deterioration of the jetties would cause severe ecological and economic damage to the region. Multiple other options and alternatives were also evaluated resulting in the Preferred Alternative described in the 2012 *Revised Final Environmental Assessment Columbia River at the Mouth, Oregon and Washington Rehabilitation of the Jetty System at the Mouth of the Columbia River* incorporated herein.

c. Water Quality Standards [40 CFR § 230.10(b) (1)]. Water quality certification from both the States of Washington and Oregon will be requested. The Corps does not anticipate its actions will degrade any of the water quality parameters, including those listed for the Columbia.

d. Toxic Effluent Standards [40 CFR § 230.10(b) (2)]. The proposed action would not violate the toxic effluent standards of Section 307 of the Clean Water Act.

e. Endangered Species [40 CFR § 230.10(b) (3)]. The dredging of materials and placement of fill would not harm any endangered species or their habitat as discussed under the Endangered Species Act of 1973. This is further demonstrated in the associated Biological Assessments and Biological Opinion and Letter of Concurrence from the Services.

f. Marine Sanctuaries [40 CFR § 230.10(b) (4)]. No marine sanctuary designated under Title III of the Marine Protection, Research, and Sanctuaries Act of 1972 will be affected by the proposed action.

g. No Significant Degradation [40 CFR § 230.10(c)].

   1) The proposed action would not result in significant adverse effects on human health or welfare, including municipal water supplies, plankton, fish, shellfish, or wildlife.

   2) Significant adverse effects on life stages of aquatic life and other wildlife dependent on the aquatic ecosystem, on ecosystem diversity, productivity, or stability, or on recreational, esthetic, or economic values would not occur.

   3) No significant adverse effects on aquatic ecosystem diversity, productivity and stability are expected due to avoidance, impact minimization, and implementation of best management practices, mitigation, and monitoring actions, to assess project-related impacts throughout the project life.

   4) No significant adverse effects of the fill material are expected on recreational, aesthetic and economic values.

h. Minimization of Impacts [40 CFR § 230.10(d)]. Appropriate actions to minimize potential adverse impacts would be specified in the construction contract.

   1) Other alternatives were considered including the "no action" alternative for the project. These alternatives were dismissed for reasons detailed in Section III above and for reasons further described in the Revised 2012 EA.

   2) The proposed action is in compliance with applicable State water quality standards. . The Corp will obtain State 401 Water Quality Certifications prior to any inwater work or wetland fill. In addition, a National Pollutant Discharge Elimination System permit will be required from the USEPA and obtained prior to disturbance and work performed on federal lands in Washington, and the Corps intends to use the Construction General Permit (CGP) after development of an appropriate Stormwater Pollution Prevention Plan (SWPPP). The Corps has a general 1200-CA permit (#14926) through the ODEQ that, though expired, has been administratively extended indefinitely by ODEQ and remains in effect. The Corps intends to maintain compliance with its terms and conditions,

including development of an Erosion and Sediment Control Plan prior to disturbance and work performed on federal, state, and local lands in the Oregon State.

3) The proposed action would not violate the toxic effluent standards of Section 307 of the Clean Water Act. State water quality certification has been requested for the project.

4) Information on federally listed species and designated critical habitat was presented in the EA. Biological Assessments (BAs) were also prepared for the proposed action to address federally listed species under the jurisdiction of the NMFS and USFWS. The BAs were provided to the respective agencies for review and consultation.

   On March 18, 2011, The Corps received a Biological Opinion from NMFS indicating that the Corps' proposed actions were not likely to adversely affect any listed species, with the exception of eulachon, humpback whales, and Stellar sea lions (2010/06104). For these species, NMFS determined that Corps actions were not likely to jeopardize the existence of the species. NMFS also concluded that Corps actions were not likely to adversely affect any of the current or proposed critical habitats. There was a Conservation Recommendation to carry out actions to reverse threats to species survival identified in the Columbia River Estuary ESA Recovery Plan Module for Salmon and Steelhead.

   On February 23, 2011 the Corps received a Letter of Concurrence from USFW regarding potential effects to species under their jurisdiction (13420-2011-I-0082). The Corps' determined its actions would have no effect on listed species, with the exception of bull trout, marbled murrelets, and snowy plover. The Corps concluded that its actions were not likely to adversely affect these species or their critical habitat. The USFW concurred with the Corps' determination. USFW also included four Conservation Recommendations to protect and improve snowy plover habitat and manage attractant waste derived from construction actions.

5) The proposed project would not result in significant adverse effects on human health and welfare, including municipal and private water supplies, recreational and commercial fishing, plankton, fish, shellfish, and wildlife. Significant adverse effects on aquatic ecosystem diversity, productivity, and stability, and recreational, esthetic, and economic values would not occur. Any unavoidable wetland or 404 waters impacts will be appropriately mitigated.

6) Appropriate steps to minimize potential adverse impacts have been further detailed in the EA and will be specified in the Environmental Protection standards prepared for the project.

With the inclusion of appropriate and practical measures to minimize adverse effects to the aquatic ecosystem, the proposed action is determined to be in compliance with the requirements of the Section 404(b) (1) guidelines.

VI. Conclusions

On the basis of the factual determinations and findings made above, the proposed fill materials comply with the Guidelines at 40 CFR Part 230 and with the requirements of Executive Order 11990 (Protection of Wetlands) and based on the factual determinations and findings made above that the proposed fill material associated with this project is in the overall public interest.

Endangered Species Act
Biological Assessment

for

Anadromous Salmonids, Green Sturgeon, Pacific Eulachon, Marine Mammals, & Marine Turtles

and

Magnuson-Stevens Fishery Conservation and Management Act
Essential Fish Habitat Assessment

for the

Major Rehabilitation of the Jetty System at the Mouth of the Columbia River

in
Pacific County, Washington
and
Clatsop County, Oregon

Prepared by
U.S. Army Corps of Engineers
Portland District, Portland, Oregon

December 2010

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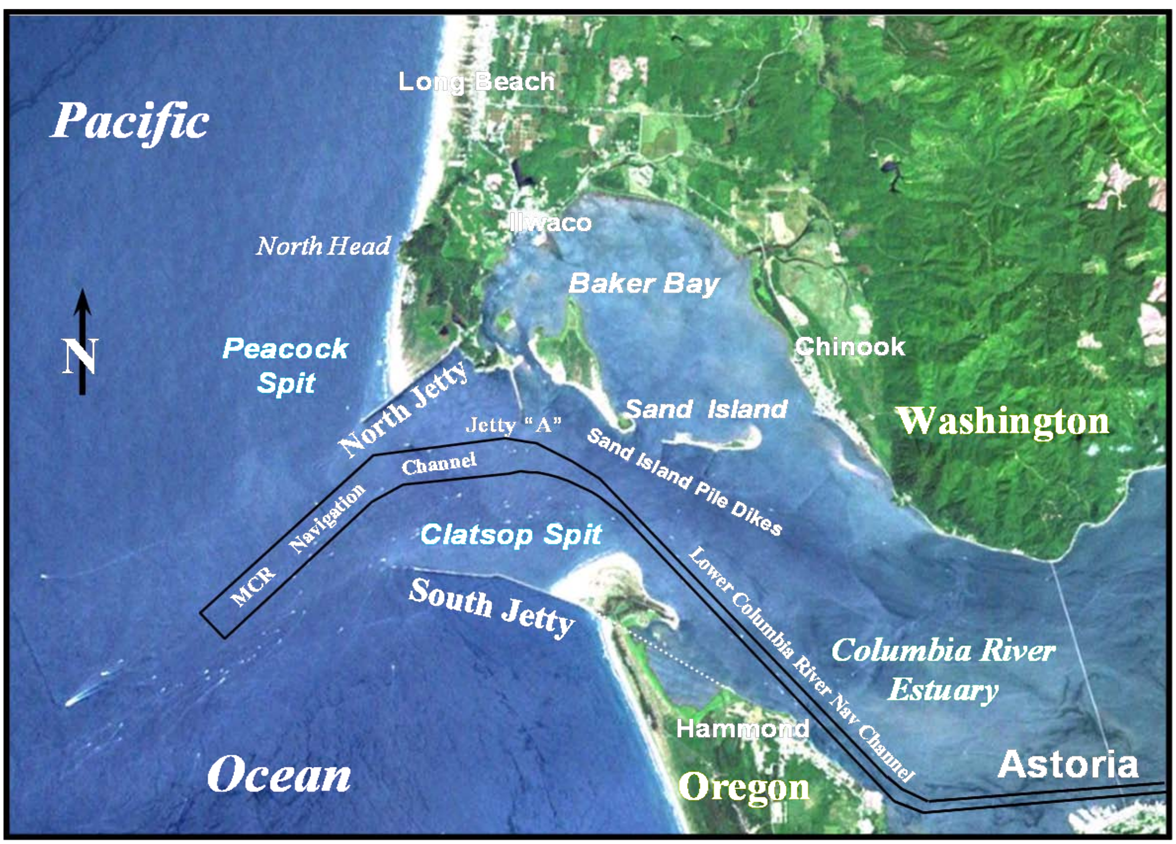
INTRODUCTION

The U.S. Army Corps of Engineers (Corps) prepared and is submitting this Biological Assessment (BA) to the National Marine Fisheries Service (NMFS) in compliance with the requirements of Section 7(c) of the Endangered Species Act of 1973, as amended. This BA evaluates effects to species listed on the Endangered Species Act (ESA) and their designated and proposed critical habitat, as well as an Essential Fish Habitat (EFH) analysis, in accordance with the Magnuson-Stevens Fishery Conservation and Management Act (MSA) for the Major Rehabilitation of the Jetty System at the mouth of the Columbia River (MCR). Federally listed marine and anadromous fish, mammal, and turtle species are present in the vicinity of the proposed action, as well as EFH species including five coastal pelagic species, numerous Pacific Coast groundfish species, and coho and Chinook salmon. The Corps also requests a Conference Opinion regarding effects to proposed critical habitat for leatherback turtles. Additionally, prior to construction activities, an incidental harassment authorization (IHA) for marine mammals at the South Jetty will be obtained. The Corps did not request a species list from NMFS. The Corps maintains this jetty system and navigational channels as appropriate based on necessity and appropriations. The Corps is currently proposing major repair and rehabilitation for the North Jetty, South Jetty, and Jetty A located at the MCR (Figure 1).

Figure 1. Location of the Jetty System at the MCR



PROJECT AUTHORITY

For the authorization for the actual construction of the MCR jetties, the present navigation channel and configuration of the inlet at the mouth of the Columbia River are the result of continuous improvement and maintenance efforts have been undertaken by the Corps Portland District since 1885. Congress has authorized the improvement of the MCR for navigation through the following legislation. Senate Executive Document 13, 47th Congress, 2nd Session (5 July 1884) authorized the Corps to construct the South Jetty (first 4.5 miles) for the purpose of attaining a 30-foot channel across the bar at the MCR. House Document 94, 56th Congress, 1st Session (3 March 1905) authorized the Corps to extend the South Jetty (to 6.62 miles) and construct a North Jetty (2.35 miles long) for the purpose of attaining a 40-foot channel (0.5 mile wide) across the bar at the MCR. House Document 249, 83rd Congress, 2nd Session (3 September 1954) authorized a bar channel of 48 feet in depth and a spur jetty ("B") on the north shore of the inlet. Funds for Jetty "B" construction were not appropriated. Public Law 98-63 (30 July 1983) authorized the deepening of the northern most 2,000 feet of the MCR channel to a depth of 55 feet below mean lower low water (MLLW). The MCR federal navigation project was originally authorized (in 1884) before formulation of local sponsor cost sharing agreements; therefore, all navigation maintenance and improvements at MCR are borne by the Federal Government.

The authority for maintenance of the MCR jetties comes from the original authority for construction of the project and then with Corps' policies for the operations, maintenance, and management of a Corps' project (Chapter 11 of EP 1165-2-1). For navigation, completed projects like the MCR have established that operations and maintenance (O&M) is solely a federal responsibility to be accomplished at federal cost.

When maintaining a Corps' project, there is regular O&M, major maintenance, and major rehabilitation. Major rehabilitation consists of either one or both of two mutually exclusive categories, reliability or efficiency improvements.

- <u>Reliability</u>. Rehabilitation of a major project feature that consists of structural work on a Corps operated and maintained facility to improve reliability of an existing structure, the result of which will be a deferral of capital expenditures to replace the structure. Rehabilitation will be considered as an alternative when it can significantly extend the physical life of the feature (such as a jetty) and can be economically justified by a benefit/cost relationship. Each year the budget EC delineates the dollar limits and construction seasons (usually two construction seasons).
- <u>Efficiency Improvements</u>. This category will enhance operational efficiency of major project components. Operational efficiency will increase outputs beyond the original project design.

Thus, the authority for maintenance of the MCR jetties comes from the authorization documents for the project and/or the authority to operate and maintain the structures.

CONSULTATION HISTORY

As the project's preferred alternative has evolved, the Corps has been coordinating with NMFS since 2005. On November 5, 2007, the Corps submitted an earlier version of this Biological Assessment (BA) proposing a larger jetty rebuilds. On January 11, 2008, the Corps provided a memo responding to inquiries NMFS had made regarding the BA. Subsequently, the BA was withdrawn later in January of 2008 due to significant changes in the project description.

Regular coordination with NMFS and was reinstituted in the spring of 2010 after publication of the revised Draft Environmental Assessment in which a new proposed action with a smaller project footprint was determined to be the preferred alternative with which the Corps of Engineers would be moving forward. In August of 2010, a site visit to view construction activities on the Tillamook North Jetty was conducted with NMFS and Corps representatives in order to observe and to compare construction activities and design elements associated with a similar, smaller-scale jetty rehabilitation project. To ensure development of the updated Biological Assessment fully addressed ESA Consultation requirements and expectations, since July 2010 the Corps also has been meeting on a nearly weekly basis with NMFS to further discuss and describe proposed actions, related studies, and jetty design model runs.

The Corps has determined that the proposed action will have **no effect** on the following species of marine turtles: loggerhead sea turtles (*Caretta caretta*), green sea turtles (*Chelonia mydas*), and olive ridley sea turtles (*Lepidochelys olivacea*). The Corps is also seeking a Conference Opinion regarding proposed critical habitat for leatherback sea turtles, and has determined the proposed actions may affect but are **not likely to adversely affect** (NLAA) leatherback sea turtles. The Corps has determined that the proposed action is **not likely to adversely affect** (NLAA) the following marine mammal species: blue whales (*Balaenoptera musculus*), fin whales (*B. physalus*), humpback whales (*Megaptera novaeangliae*), sperm whales (*Physeter macrocephalus*), killer whales (*Orcinus orca*) and sei whales (*B. borealis*). Previously, for interim repairs on the South Jetty, the Corps obtained an IHA permit as it was believed that sea lions would be disturbed during construction (Corps 2007). The Corps has determined that the proposed action is **likely to adversely affect** Stellar sea lions (*Eumotopias jubatus*) and will again obtain an IHA permit from NMFS for incidental harassment of Steller sea lions during construction, as well as non-federally listed California sea lions and harbor seals. Through this Biological Analysis the Corps has further determined that the proposed action may affect and is **likely to adversely affect** eulachon (*Thaleichthys pacificus*). The Corps has also determined that the proposed action is **likely to adversely affect** green sturgeon (*Acipenser medirosris*). Finally, the Corps has determined that the proposed action may affect and is **likely to adversely** affect all runs of listed salmonids and steelhead discussed further in this BA.

BACKGROUND

The MCR project consists of a 0.5-mile wide navigation channel extending for about 6 miles (3 miles seaward and shoreward of the tip of the North Jetty) through a jettied entrance between the Columbia River and the Pacific Ocean on the border between Washington and Oregon. Figure 1 shows the navigation project and the three primary navigation structures, the North Jetty, South Jetty, and Jetty A. Those structures are shown in more detail in Figure 2. The North Jetty and Jetty A are located in Pacific County, Washington, near Ilwaco and Long Beach on the Long

Beach Peninsula. The South Jetty is located in Clatsop County, Oregon near Warrenton/Hammond and Astoria.

Figure 2. Rubble-mound Jetties at the MCR

Top left photo shows the South Jetty looking east. The remnant feature shown disconnected from the primary structure is the concrete monolith that was constructed in 1941. The top right photo shows Jetty A. The bottom photo illustrates the North Jetty and the shoreline north of the MCR.

South Jetty

Jetty A

North Jetty

From 1885 to 1939, three rubble-mound jetties with a total length of 9.7 miles were constructed at the MCR on massive tidal shoals. The jetties were constructed to accelerate the flow of the river, which helps maintain the depth and orientation of the navigation channel, and to provide protection for ships of all sizes (both commercial and recreational) entering and leaving the Columbia River. The intention was to secure a consistent navigation channel through the coastal inlet, though morphology of the inlet currently remains in a dynamic, high-energy state. Under such conditions, the jetties have experienced significant deterioration since construction, mainly due to extreme wave attack and foundation instability associated with erosion of the tidal shoals on which the jetties were built.

The initial 4.5-mile section of the South Jetty was completed in 1895-1896. The Rivers and Harbor Act of 3 March 1905 authorized the extension of the South Jetty to 6.6 miles, with the 2.4-mile extension completed in 1913. Historical records show that six spur groins were constructed along the channel side of the South Jetty. Four of the groins were subsequently buried by accreted shoreline or sand shoal. Nine repairs to the South Jetty have been completed with the latest one in 2007. To date, jetty rock placement at the South Jetty totals approximately 8.8 million tons. In spite of these repairs and structural features, over 6,100 feet of head loss has occurred at the South Jetty.

The North Jetty was completed in 1917. Three repairs to the North Jetty have been made with the last one completed in 2005. To date, jetty rock placement totals approximately 3.4 million tons. Since initial construction, about 0.4 miles of the North Jetty head has eroded and is no longer functional.

Jetty A was constructed in 1939 to 1.1 miles in length in connection with rehabilitation of the North Jetty for the purpose of channel stabilization. Its purpose was to assist in controlling the location and direction of the ebb tidal flow through the navigation entrance. Improvements made from 1930 to 1942 (including addition of Jetty A and Sand Island pile dikes) produced the present entrance configuration.

The construction and repair history of the MCR jetties is summarized in Table 1.

The Corps' dredging and in-water disposal of dredged sediments to maintain the above referenced authorized navigation channel is conducted under the provisions of sections 102 and 103 of the Marine Protection Reserve and Sanctuaries Act of 1972, sections 401 and 404 of the Clean Water Act of 1977, and in accordance with Regulations 33 CFR parts 335-338.

Table 1. Construction and Repair History for the MCR Jetties

1881: Proposed project to build a strong pile-dike, 3 feet high about at low tide, 8,000 feet long and 20 feet wide along a line previously established on the south side. The structure to start near the northeast corner of Fort Stevens, following the 12-foot curve, dike will be directed a little westward of the outer part of headland of Cape Hancock. It was stated that work commence soon (during summer and autumn) because channel maintenance is dependent upon building up Clatsop Spit.

1883: A jetty plan approved by the Board of Engineers from the south cape of the entrance on the spit. A survey was conducted in October-November of the south cape, Point Adams, to extreme low water. The jetty extends from Point Adams and makes the distance between the outer end of the jetty and Cape Disappointment the same as the distance between Chinook Point and Point Adams. The Board stated that any structures placed in-river should not harm the river and should keep the channel open using the tide; therefore, the jetty should not obstruct the entry of the flood tide. The jetty design called for a crest elevation at low water level. Estimated depths of various jetty sections from the landward end are: 5,000 feet - less than +6 feet; 7,500 feet – +6 to +11 feet; 4,000 feet – +11 to +16 feet; and 7,500 feet – +16 to +21 feet. Jetty crest elevation was designed to be at low water level because of wave violence that could harm a higher jetty. The logic was that a higher jetty could be built, if needed later, by placing more stone on the existing jetty. A jetty height to mid-tide level was suggested but not recommended because the lower jetty would be quite effective in directing the ebb tide and would interfere less with the flood tide. A higher jetty would result in higher maintenance costs due to the jetty being more exposed to wave action.

1884: The improvement plan for MCR was approved by the Rivers and Harbors Act of July 5, 1884 to maintain a channel 30 feet deep at mean low tide by constructing a low-tide jetty, about 4.5 miles long, from near Fort Stevens on the South Cape to a point about 3 miles south of Cape Disappointment.

1886-1896: Original construction South Jetty from Fort Stevens (station 25+80) across Trestle Bay and Clatsop Spit to station 250+20. Rock placed with a natural slope to an elevation from 4 to 12 feet, crest width roughly 10 feet. "The jetty, of a brush-mattress and stone ballast, was built for 1,020 feet from ordinary highest tide-line, and minor constructions added." Material has filled along the jetty's south side, moving the shoreline seaward. Highest tide-line is located at tramway station 30+50. A 115 feet long spur was built landward of the jetty for shore protection. A 510 feet long sand-catch, consisting of heavy beach drift and loose brush, was built on the south side of landward end of the jetty to continue filling the old outlet of a lagoon at extreme end of Point Adams. Jetty stone was originally dumped in ridges, but waves flattened and compacted the rocks to a width of 50 feet. The report indicated urgency to extend the jetty to prevent further deterioration of the bar channel.

1889: The South Jetty now under construction for 1.5 miles. Clatsop Spit has more material visible at low water and the river channel has a tendency towards a straight course out to sea. Tillamook Chute being closed. Sand building up south of the jetty adjacent to and in front of the mattresses as they are constructed.

1890: South Jetty construction is 3.25 miles underway. Jetty elevation at MLLW for about 3 miles. 1.25 miles of tramway to be constructed. Clatsop Spit building up, the outflowing waters being concentrated over the channel bar. Station 25+80 considered the beginning of the jetty. The jetty mattress has advanced from stations 99+04 to 194+08. The jetty elevation is at MLLW to station 170+00. From Station 170+00 to the end of mattress work, there is about 9 feet of rock on top of the mattress. At station 65+00, there were signs of sinking and a large amount of rock was dumped in place.

1903-1913: Extension of South Jetty. Crest elevation of jetty raised to 10 feet MLLW from stations 210+35 to 250+20, and rock placed from stations 250+20 to 375+52, elevation increasing in steps to 24 feet MLLW. Crest width is 25 feet and side slopes are natural slope of rock. Seaward bend in the jetty is added and called the "knuckle."

1913-1917: Original construction of North Jetty from stations 0+00 to 122+00. Side slopes are 1 vertical by 1.5 horizontal (1:1.5) and crest width is 25 feet. Crest elevation varies from 15 to 32 feet.

1931-1932: Repair South Jetty from stations 175+00 to 257+68.7 (shoreline to knuckle), side slopes 1:1.5, crest elevation 24 feet MLLW, and crest width 24 feet. This is first maintenance for South Jetty. The jetty had been flattened to about low water level. 2.2 million tons of stone placed in super-structure. The work completed in 1936. The end of jetty would unravel 300 feet or more, so a solid concrete terminal was constructed above low water level. The terminal was located 3,900 feet shoreward of the original jetty end that was completed in 1913.

1933-1934: Repair of South Jetty from stations 257+68.7 to 305+05 (knuckle to middle of outer segment). Two level cross section with crest elevations of 17 and 26 feet. Crest width of each level is 24 feet. Side slopes are 1:1.5 on channel side and vary from 1:1 to 1:1.75 to 1:2 on ocean side.

1935-1936: Repair South Jetty from stations 305+05 to 353+05 (middle of outer segment to existing end). Similar design to 1933-1934 repair.

Table 1 (continued). Construction and Repair History for the MCR Jetties

1936: Stone/asphalt cone-shaped terminal constructed on South Jetty from stations 340+30 to 344+30. Crest width of approximately 50 feet and elevation varied from 23 to 26 feet. Side slopes are 1:2.

1937-1939: Repair of North Jetty from stations 68+35 to 110+35. Crest elevation 26 feet and crest width 30 feet. Side slope 1:1.25 on ocean side and 1:1.5 on channel side.

1939: Original construction of Jetty A from stations 40+93.89 to 96+83. Crest width is 10 feet from beginning to station 53+00, 30 feet in width, and elevation at 20 feet from this point on. Four pile dikes completed at Sand Island.

1940: Repair of South Jetty with replacement rock in locations as needed.

1940-1942: South Jetty repair from stations 332+00 to 343+30. Concrete terminal/stone foundation added. Crest elevation from 8-20 feet and crest width from 50-75 feet, 10 inches. Side slopes determined by concrete terminal shape.

1945-1947: Repair Jetty A from stations 78+00 to 96+00. Crest elevation to 20 feet with crest width of 40 feet.

1948-1949: Repair 300 feet of Jetty A from stations 92+35 to 95+35 with a crest elevation of 20 feet, a crest width of 30 feet, and side slopes of 1:1.25.

1951: Repair Jetty A from stations 91+50 to 93+00 with a crest elevation of 20 feet MLLW, a crest width of 30 feet, and side slopes of 1:1.5.

1952: Repair of Jetty A from stations 90+00 to 94+00 with a crest elevation of 20 feet, a crest width of 30 feet, and side slopes of 1:1.5.

1958: Repair of Jetty A from Stations 41+00 to 79+00. Crest elevation raised to 20 feet and a crest width of 20 feet from Stations 41+00 to 56+00. Crest width is 30 feet from Stations 61+00 to 79+00.

1961-1962: Repair Jetty A from stations 50+00 to 90+50, with no repairs from Stations 68+00 to 76+50. Crest elevation built with a 10% grade from 20 feet to 24 feet from stations 50+00 to 68+00. The crest elevation was raised to 24 feet from stations 76+50 to 90+50.

1961: South Jetty repair from stations 194+00 to 249+00 (before knuckle, current stationing). Crest elevation varies from 24 to 28 feet and crest width is 30 feet. Channel side slope 1:1.25 and ocean side slope 1:1.5. Repairs from stations 38+00 to 93+00 (old stationing). Elevation at station 38+00 is +24 feet and then increased with a 0.5% grade up to +28 feet for the remainder of repair section. The repair centerline is located 13 feet north of the centerline of the original jetty design. The design crest width is 30 feet. North slope is 1:1.25 and south slope is 1:1.5.

1962-1965: South Jetty repair from stations 249+00 to 314+05 (beyond knuckle). Crest elevation begins at 28 feet and transitions to 25 feet for most of section. Side slopes vary from 1:1.5 to 1:2 and crest width is 40 feet (this appears to be the furthest seaward intact portion of current jetty). Repairs made from stations 93+00 to 157+50 (old stationing). The crest elevation is +28 feet at station 93+00, then decreases to +25 feet at station 95+00, and then continues with this elevation to end of the repairs. The crest width is 40 feet and has a slope of 1:1.5 from stations 93+00 to 152+00. Slope then transitions to 1:2 from stations 152+00 to 154+00. The centerline of the repair is 15 feet south of the trestle centerline.

1965: Repair North Jetty from stations 89+47 to 109+67 with a crest elevation of 24 feet and crest width is 30 feet. Side slopes vary from 1:1.5 to 1:2.

1982: Repair South Jetty from stations 194+00 to 249+00 (segment before knuckle). Crest elevation varies from 22 to 25 feet MLLW. Crest width varies from 25-30 feet and side slopes 1:1.5. Crest elevation varies from +22 feet at station 38+00 to +25 feet at station 80+35 (old stationing). From stations 44+50 to 80+35, crest width is 30 feet and slope is 1:1.5. Centerline of repairs has 10 feet maximum variance to the north for the South Jetty control line. From stations 80+35 to 93+00, centerline of repairs is the same as South Jetty control. Crest elevation +25 feet, width varies from 25-30 feet, side slope is 1:1.5.

2005: Interim repair of North Jetty (stations 55+00 to 86+00). Crest elevation +25 feet with side slope of 1:1.5.

2006: Interim repair of South Jetty (stations 223+00 to 245+00). Crest elevation +25 feet with side slope of 1:2.

2007: Interim repair of South Jetty (stations 255+00 to 285+00). Crest elevation +25 feet with side slope of 1:2.

DESCRIPTION OF THE PROPOSED ACTION

OVERVIEW

The Corps proposes to perform modifications and repairs to the North and South Jetties and Jetty A at the MCR that would strengthen the jetty structures, extend their functional life, and maintain deep-draft navigation.

Proposed actions are generally comprised of four categories applicable to each jetty: (1) engineered designs elements and features of the physical structures; (2) construction measures and implementation activities; (3) proposed 7(a)(1) habitat improvement measures and wetland mitigation actions to improve habitat for the benefit of listed species and to offset wetland fill, and (4) proposed establishment of and coordination with an Adaptive Management Team (AMT) comprised of Corps' staff and representatives from appropriate Federal and State agencies.

It is notable that the duration of the construction schedules is 20 years, with a 50-year operational lifetime for the MCR jetty system. Therefore, an inherent level of uncertainty exists regarding dynamic environmental conditions and actual conditions of and at each of the jetties. For this reason, in all cases where areas, weights, and volumes (tons, acres, cubic yards, etc.) or other metrics are indicated, these are best professional estimates and may vary by greater or lesser amounts within a 20% range when final designs are completed. These amounts represent Corps' and staff's best professional judgments of what the range of variability could entail as the design is further developed and as on-the-ground conditions evolve over the 20-year construction schedule. The Corps maintains an active jetty monitoring and surveying program that will further inform the timing and design of the proposed action in order to facilitate efficient completion of the project and whenever possible to avoid emergency repair scenarios.

(1) Design elements and structural features specific to each jetty include the following:

- North Jetty – Scheduled repairs addressing the existing loss of cross section and the addition of engineering features designed to minimize future cross section instability are planned. The cross section repairs are primarily above MLLW, with a majority of stone placement not likely to extend beyond -5 ft below MLLW. In order to address the structural instability of the jetty cross-section, four spur groins will be added and the jetty head (western-most section) will be capped with large stone. Groins will be constructed primarily on existing relic stone and the head capping will be placed on relic as well as jetty stone that is above MLLW. The shore-side improvements that have been identified are culvert replacement and lagoon fill. These actions are designed to stop the current ongoing erosion of the jetty root.

- South Jetty – Scheduled repairs addressing the existing loss of cross section and the addition of engineering features designed to minimize future cross section instability are planned. The cross section repairs are primarily above MLLW, with a majority of stone placement not likely to extend beyond -5 ft below MLLW. In order to address the structural instability of the jetty cross-section, five spur groins will be added and the jetty head (western-most section) will be capped with large stone. Groins will be constructed primarily on existing relic stone and the head capping will be placed on relic as well as jetty stone that is above MLLW. Augmentation of the dune at the western shoreline extending south from the jetty root has been included in the repair plan. This action is intended to prevent the degradation of the jetty root and prevent the potential breaching of the fore dune.

- Jetty A – Scheduled rehabilitation addressing the existing loss of cross section and the addition of engineering features designed to minimize future cross section instability are planned for Jetty A. The cross section repairs are primarily above MLLW, with a majority of stone placement not likely to extend beyond -5 ft below MLLW. In order to address the structural instability of the jetty cross-section, two spur groins will be added and the jetty head (southern most section) will be capped with large stone. The groins will be constructed primarily on existing relic stone and the head capping will be placed on relic as well as jetty stone that is above MLLW. Immediate rehabilitation with small cross section, two spur groins, and head capping.

(2.) Construction measures and implementation activities for all three jetties include the following:

- Storage and staging areas for rock stockpiles and all associated construction and placement activities such as: roadways, parking areas, turn-outs, haul roads, weigh stations, yard area for sorting and staging actions, etc.
- Stone delivery from identified quarries either by barge or by truck. Possible transit routes have been identified. This also includes the construction and use of permanent barge offloading facilities and causeways with installation and removal of associated piles and dolphins.
- Stone placement either from land or water, which includes the construction, repair, and maintenance of a haul road on the jetty itself, crane set-up pads, and turnouts on jetty road. Placement by water could occur via the use of a jack-up barge on South Jetty, but will not occur by other means or on North Jetty to avoid impacts to crab and juvenile salmon migration.
- Regular dredging and disposal of infill at offloading facilities with frequency dependent on a combination of the evolving conditions at the site and expected construction scheduling and delivery. Disposal will occur at existing approved in-water sites.

(3.) A suite of potential projects to provide 7(a) (1) habitat improvement and wetland mitigation actions have been identified as beneficial to listed species. Depending on further development of alternatives within this list, a specific project or combination of projects will be selected and constructed concurrently to provide environmental benefits as portions of the proposed action are completed over time. Estimates for wetland impacts are preliminary and may be reduced when final delineations are completed; therefore wetland restoration may be less than approximations noted, but will be commensurate with impacts from construction activities. These restoration and habitat improvement measures will therefore require additional consultations, and it is anticipated that the proposed AMT will be of assistance in this process. It is anticipated that a programmatic opinion similar to SLOPES Restoration or Limit 8 may be useful to fulfill clearance requirements. Possible restoration measures could include an individual project or a combination of projects and actions such as:

- Excavation and creation of wetlands to restore and improve wetland functions including water quality, flood storage, and salmonid refugia.
- Culvert and tide gate replacements or retrofits to restore or improve fish passage and access to significant spawning, rearing, and resting habitat.
- Dike breaches to restore estuarine brackish intertidal shallow-water habitat for fish benefits.
- Beneficial uses of dredged material from MCR hopper dredge to replenish littoral cells.
- Invasive species removal and control and revegetation of native plants to restore ecological and food web functions that benefit fisheries.

(4.) Due to the long duration of the MCR Jetty Rehabilitation schedule, the Corps proposes formation of a modified Adaptive Management Team (AMT). The Corps suggests annual meetings to discuss relevant design and construction challenges and modifications, technical data, and adaptive management practices as needed. The primary purpose of the proposed AMT and its implementation is to ensure construction, operation, and maintenance actions have no greater impacts than those described in the Biological Assessment, and that terms and conditions of the Biological Opinion are being met. This will also allow confirmation that any necessary construction or design refinements remain within the range and scope of effects described during Consultations. This forum will facilitate continued coordination and updating and allow the Corps to inform agency partners when unforeseen changes arise. Results regarding marine mammal and fish monitoring, wetland mitigation and habitat improvement monitoring, as well as water quality monitoring will also be made available to the AMT in order to fulfill reporting requirements and to address any unexpected field observations. Results of jetty monitoring surveys will also inform the AMT of the repair schedule and design refinements that become necessary as the system evolves over time. This venue will also provide greater transparency and allow opportunities for additional agency input. Final selection and design of the habitat improvement and wetland mitigation proposal will also be vetted through this forum to facilitate obtaining final environmental clearance documents for this component of the MCR proposed action. Potential principal partners include federal (National Marine Fisheries Service, U.S. Fish and Wildlife Service) and State (Washington, Oregon) resource management agencies. The strategy is designed to be consistent with the guidance provided in 65 Federal Register (FR) 35242.

GENERAL TERMS AND FEATURES

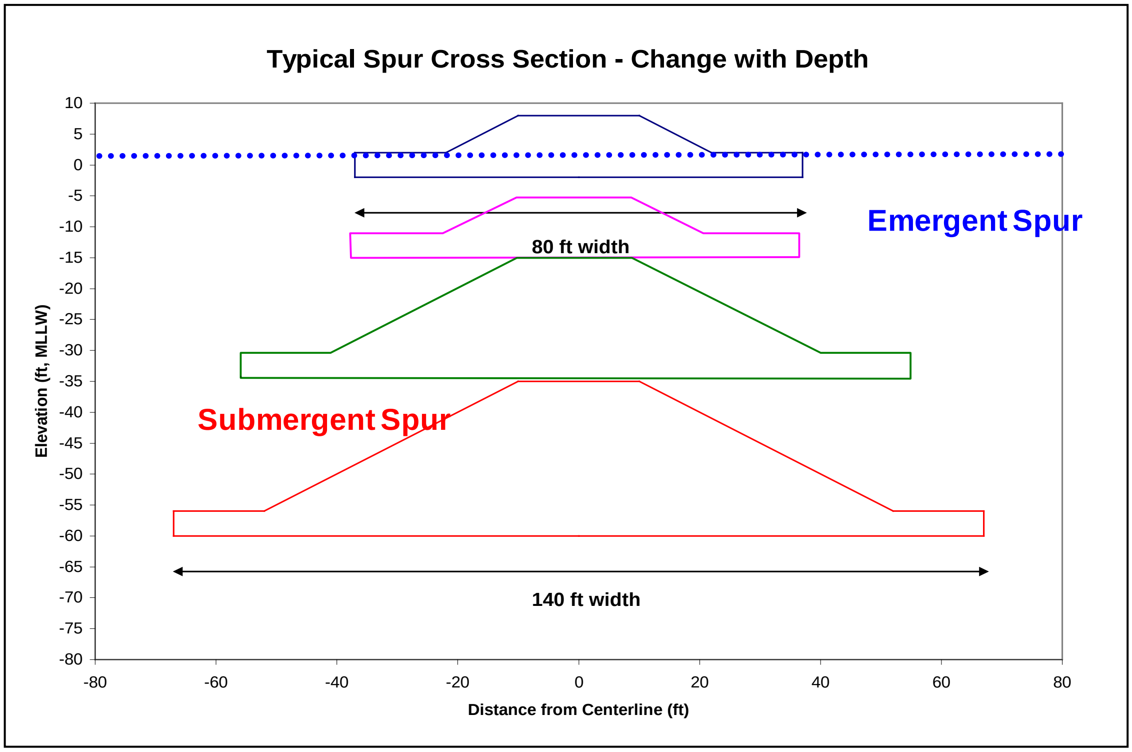
Previously during earlier design phases of the proposed action, the U.S. Geological Survey (USGS) in Menlo Park, California assisted the Corps with evaluating potential improvements and impacts of rebuilding and repairing the lengths of the MCR jetties. The USGS efforts focused on using the Delft-3D model of the Columbia River estuary and adjacent coast (Delft3D 2006) to identify potential changes in circulation, salinity and sediment transport that could result from the offshore re-build of the three jetties. Increased jetty lengths were investigated to determine if they could provide a more sustainable jetty system over the long term. Although rebuild of the jetties is no longer proposed, Corps' engineering staff has also indicated modeling results remain relevant and valid for evaluating jetty performance in the current proposed action, which caps jetty lengths in their current locations (Moritz 2010).

The Corps' Engineering Research and Development Center (ERDC) in Vicksburg, Mississippi was also contracted to conduct a physical model of the jetty cross-section design. The range of structural repair types addressed in the model included crest elevation and crest widths variations, side-slope variations, underwater berms, armor stone, and concrete armor unit options. Both the North Jetty and South Jetty were tested under low and high water conditions. Physical modeling results showed that the primary failure modes for the North and South jetties were high water wave attack and overtopping. These results were used to determine cross-section design options for the jetties that achieve varying levels of structure reliability. The following design components are a result of a combination of these models and other modeling and engineering staff efforts (Moritz and Moritz 2010).

Each MCR jetty consists of three parts. The head is the seaward terminus and is exposed to the most severe wave action. Jetty head design is much more substantial than a typical jetty trunk section due to its increased exposure to wave attack and its critical protective function for the rest of the structure. The trunk forms the connection from jetty head to shore, retains sub-tidal shoals, and confines circulation in the navigation inlet. The root forms the connection from the jetty trunk to shore and prevents accreted landforms from migrating into the navigation channel.

A spur groin is a relatively short structure (in comparison to jetty length) usually extending perpendicular from the main axis of a jetty. Spur groins are constructed: (1) on the ocean or beach side of a jetty to deflect the long-shore (rip) current and related littoral sediment away from the jetty and prevent littoral sediment from entering the navigation channel; and (2) on the channel side of a jetty to divert the tidal or river current away from the channel side toe of the jetty. Spur groins also act to reduce the scour affecting the foundation while increasing the current in the navigation channel, thus reducing the deposition in the channel. In areas where foundation scour threatens the overall stability of the MCR jetties, spur groins constructed perpendicular to the structure facilitate stabilization by the accumulation of sediment along the jetty's foundation. Each spur groin will have a crest width of about 20 feet, and will be constructed using a bedding layer (mixture of gravel and rock) that will be covered with large stone sized for the location and exposure. Submergent spur groins that located at greater depths also typically have wider bases than shallower, emergent groins (Figure 3).

Figure 3. Typical Spur Cross Section - Change with Depth



The ERDC analyzed the hydrodynamics and circulation patterns in the MCR entrance, as well as the potential impacts and effectiveness of placing spur groins on the jetties. This analysis was conducted with the coastal modeling system and other models to select the type, depth, and length of spur groins necessary to protect the each jetty from the processes causing increased scour (e.g., rip currents, eddies). Although the models were also evaluating a potential restoration of the jetties' former lengths, proposed construction of spur groins at each jetty has not changed since modeling was completed. Therefore, Corps' engineering staff has indicated that modeling results remain relevant and valid in their assessment of spur groin performance.

Two potential construction methods could be used for spur groins, either land-based or marine-based depending on location. Barges or similar equipment could be used to dump the bedding layer rock into place and a clamshell would be used to place larger stone on top of the bedding rock layer in locations with sufficient water depth. This type of marine placement activity will not require installation of additional piles or dolphins. Material could also be placed using land-based equipment from on top of the jetty. Land-based construction may require a wide turnout crane placement with over-excavation down to grade as the crane walks back onto the main jetty axis. In addition, the emergent spur groins may be used as turnouts for construction equipment. The land-based construction method could be used for all but the deepest spur groins.

Head capping involves placing much larger armor stone at the terminus of the jetty where the highest degree of enforcement is necessary to withstand conditions. Enforcement could also include the use of concrete armor units (CAU). These will be fabricated off-site and then transported to the head via truck or barge. The armor stone at the head helps avoid recession and loss of length and by protecting the rest of the jetty from unraveling back towards the root.

Repair and rehabilitation are two proposed approaches that specifically describe construction and stone placement actions for the cross-sections and engineered features along the trunks and roots of the jetties. The economics and design model used to select Schedule Repair as the proposed action at the North and South jetties predicts a certain number of repair actions that will be needed to avoid a breaching scenario during the 20-year construction schedule and 50-year operational lifetime of the jetties.

Along certain sections of each jetty, wave cast and erosional forces have in some cases flattened the jetty prism and left a bedding of relic stone with little or only a partially complete jetty prism remaining. The Scheduled Repair approach prioritizes work on specific portions of the jetty so that sections in a greater degree of deterioration will be repaired with rock according to a programmed sequence developed as a result of regular jetty monitoring and inspections. Proposed repair alternatives involve adding limited amounts of stone to trunk, head, and root features in order to restore the damaged cross-sections back to a standard repair template. A repair action is generally triggered when the upper cross-sectional area falls below 30%-40% of its standard jetty template profile (only 30% or 40% of the current jetty structure remains; 60%-70% of the previously existing prism is gone). Then a standard repair template is implemented. For each repair action, a majority of stone placement will occur above MLLW. However, depending on conditions at specific jetty cross-sections, stone could extend deeper than -5 ft below MLLW in order to restore the reach back to the standard repair template. Therefore, repair actions could be slightly greater or smaller depending on the condition of the cross-section being repaired. Stone placement will remain mostly within the prism of the existing jetty and relic stone structures; though it is possible that wave actions and slope angles could result in a small percentage of further rock slipping off the relic slope.

Proposed rehabilitation alternatives generally incorporate engineering components and rock placement along the cross-section of the entire root and trunk. The construction and placement sequence for Immediate Rehabilitation at Jetty A means stone placement activities are initiated at one end of the jetty and are completed continuously in succession without prioritization based on conditions at any particular jetty section. The proposed rehabilitation action on Jetty A is more robust than a repair action and includes a small cross section along the entire length of the jetty. Sections in a greater state of deterioration may receive a relatively larger amount of rock compared to sections with less damage. The rehabilitation cross-section template is expanded slightly beyond the existing prism template. This generally involves stone placement that primarily fits within the existing footprint of the jetty structure or relic stone, but may extend slightly beyond the existing prism. It also generally involves the bulk of the rock placement above MLLW, though it could extend below in some sections, again depending conditions in each reach.

The following discussions also mention station numbers on each jetty. These stations indicate lineal distance along the jetty relative to a fixed reference point (0+00) located at the landward-most point on the jetty root. Numbering begins at the reference point (0+00) and increases seaward such that each station number represents that distance in feet, multiplied by 100, plus the additional number of feet indicated after the station number. For instance, station 100+17 would be 10,017 feet seaward from the reference point. A summary of design parameters for the preferred plan at each jetty is shown in Table 2.

Table 2. Preferred Plan Design Metrics Summary for MCR Jetties

Note: volumes, lengths and areas may vary by ± 20% upon final design.

North Jetty Scheduled Repair with Engineering Features

Jetty Crest Elevation	Estimated Stone Density	Total Repair Length	Jetty Crest Width	Jetty Sideslope		Jetty Head Station	Head Length	Spur Groin Sta.	Spur Groin Tons
				Channel	Ocean				
25' above MLLW	167 #/ft3	8,100'	30'	1v:1.5h	1v:1.5h	99+00 to 101+00	200'	Sta 50-C Sta 70-C Sta 80-O Sta 90-C	3,895 12,870 2,340 33,960

South Jetty Scheduled Repair with Engineering Features

Jetty Crest Elevation	Estimated Stone Density	Total Repair Length	Jetty Crest Width	Jetty Sideslope		Jetty Head Station	Head Length	Spur Groin Sta.	Spur Groin Tons
				Channel	Ocean				
25' above MLLW	167 #/ft3	15,800'	30'	1v:1.5h	1v:2h	311+00 to 313+00	200'	Sta 165-O Sta 210-C Sta 230-C Sta 265-C Sta 305-O	1,496 2,095 2,095 2,841 16,747

Jetty A Rehab with Engineering Features

Jetty Crest Elevation	Estimated Stone Density	Total Repair Length	Jetty Crest Width	Jetty Sideslope		Jetty Head Station	Head Length	Spur Groin Sta.	Spur Groin Tons
				Estuary	Ocean				
20' above MLLW	167 #/ft3	5,300'	40'	1v:2h	1v:2h	91+00 to 93+00	200'	Sta 84-O Sta 90-E	12,272 12,272

DESIGN ELEMENTS AND STRUCTURAL FEATURES OF PROPOSED ACTION

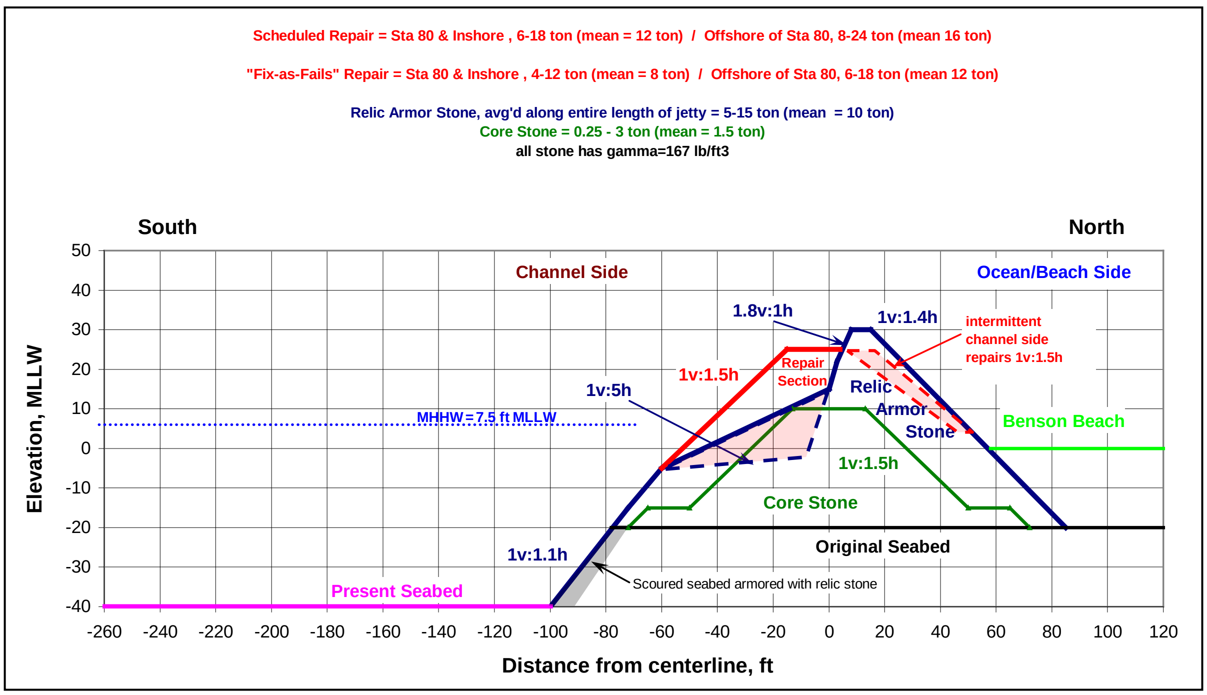
MCR North Jetty

The proposed action for the North Jetty is Scheduled Repair and construction of engineered features including four spur groins and head capping, culvert replacement, and lagoon fill to stop erosion of the jetty root (Figures 4 and 5). The jetty head and foundation at the most exposed portion of jetty will be stabilized.

North Jetty Trunk and Root

The cross-section design from stations 20+00 to 99+00 will have a crest width of approximately 30 feet and will lie essentially within the existing jetty footprint based on the configuration of the original cross section, previous repair cross sections, and redistribution of jetty rock by wave action. About 460,000 tons (~287,500 cy) of new rock will be placed on relic armor stone, with the majority of stone placement above MLLW. About four repair events were predicted over the next 20 years. Each repair action is expected to cover a length range of up to 1,700 feet and include stone volumes in the range of 45,000 to 100,000 tons (~28,125-62,500 cy) per season.

Figure 4. North Jetty Cross Section for Existing Condition and Scheduled Repair Template



At the time of repair, it is expected that 60%-70% of the standard jetty template cross-section has been displaced. Therefore, each repair event will increase the degraded cross-section from 30%-40% back to 100% of the desired standard cross-section template. This means the overall added rock will essentially triple what exists immediately prior to the time of repair. This could be described as a ~300% increase in rock relative to the existing jetty rock volume. However, this will not increase the jetty prism or footprint beyond the scope and size of the historic structure, and does not include any modification that changes the character, scope, or size of the original structure design.

With placement divided into elevation zones per representative repair event, about 21,550 cy of rock will be placed above mean higher high water (MHHW). This represents 58% of the overall stone placement on these portions of the jetty and 376% change from the existing jetty prism. This means that currently only a small portion of the original profile remains in this zone and over three times as much stone must be placed compared to what presently remains. As described, above, this same concept applies characterizations about the rest of the zones. About 9,230 cy of rock will be placed between MHHW and MLLW. This represents 25% of the overall stone placement on these portions of the jetty and a 192% change from the existing jetty prism. About 6,675 cy of rock will be placed below MLLW. This represents 18% of the overall stone placement on these portions of the jetty and a 150% change from the existing jetty prism. The footprint of the trunk and root of the North Jetty will remain on relic stone and within its current jetty dimensions.

North Jetty Spur Groins

Three submergent spur groins will be placed on the channel side and one emergent spur groin will be placed on the ocean side of the North Jetty to stabilize the foundation (Figures 6 to 9). The approximate dimensions and other features of the spur groins are shown in Table 3. If possible, in order to avoid and minimize impacts to species and habitats, either one of the spur groins located around stations 50 or 70 may also serve a dual purpose as an offloading facility for stone delivery. This will occur at the contractor’s discretion depending on channel current and wave conditions. Otherwise, a separate offloading facility will be constructed in the vicinity between these stations to take advantage of calmer waters. There is a dredge material disposal site along the North Jetty and adjacent disposal cells closest to the jetty and spur groins will be precluded from use to avoid interference with jetty construction and to ensure barge safety during disposal. Barge offloading structures and dredge activities are discussed in more detail later in this assessment.

Representing rock volume estimated totals divided into elevation zones for all newly constructed spurs on the North Jetty, about 25 cy of rock will be placed above MHHW. This represents 0.1% of the overall stone placement on these portions of the North Jetty spur groins and there is very little or no existing jetty stone expected to be present within this elevation range. About 1,146 cy of rock will be placed between MHHW and MLLW. This represents 4% of the overall stone placement on these portions of the North Jetty spur groins and there is very little or no existing jetty stone expected to be present within this elevation range. About 27,760 cy of rock will be placed below MLLW. This represents 95.9% of the overall stone placement on these portions of the North Jetty spur groins and there is very little or no existing jetty stone expected to be present within this elevation range. The footprint of the North Jetty spurs will increase from 0 acres to 1.55 acres. In the relevant figures, note that the difference in the vertical and horizontal scales causes a slight representational distortion along the axes.

Figure 5. Proposed Action for the MCR North Jetty

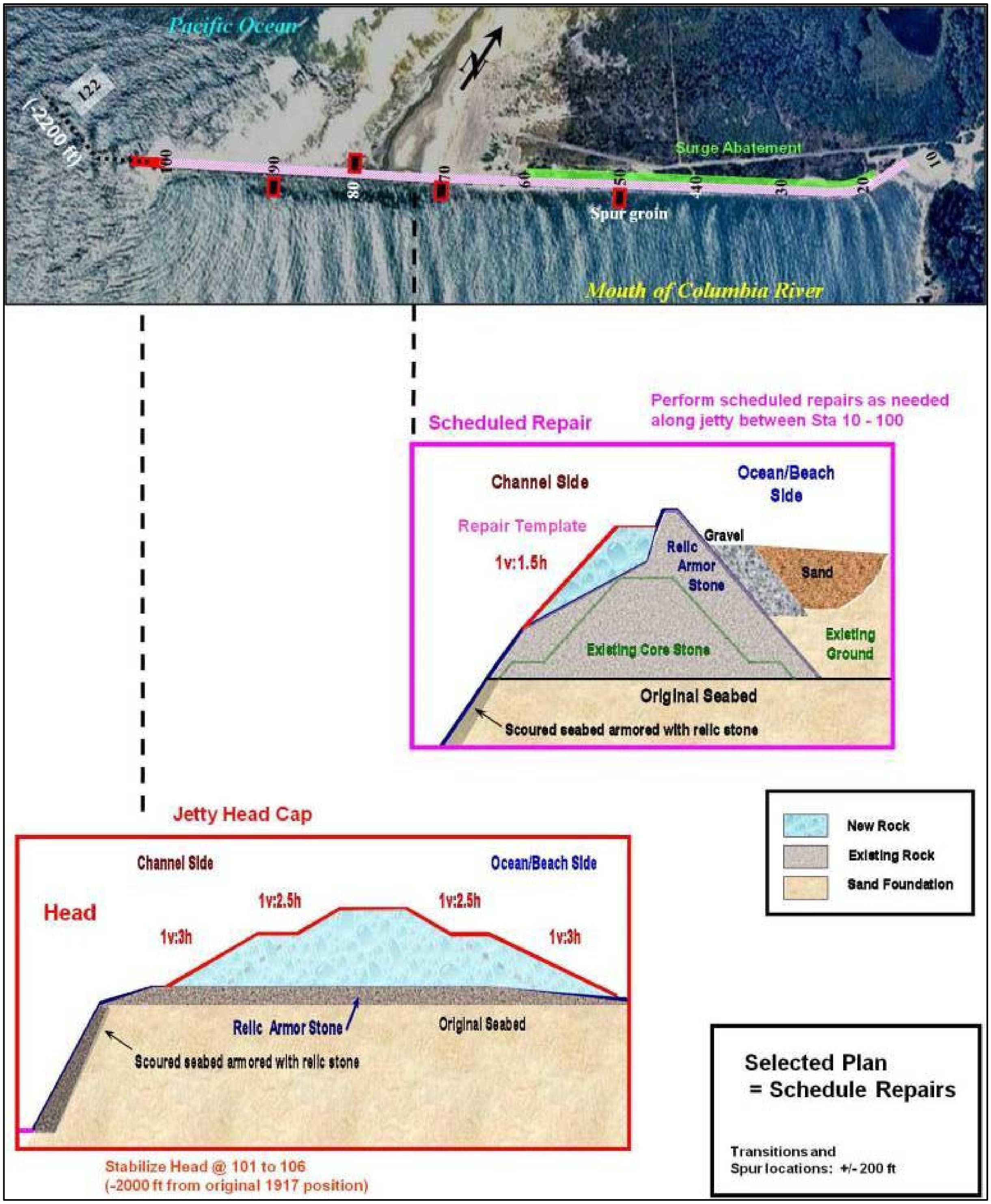
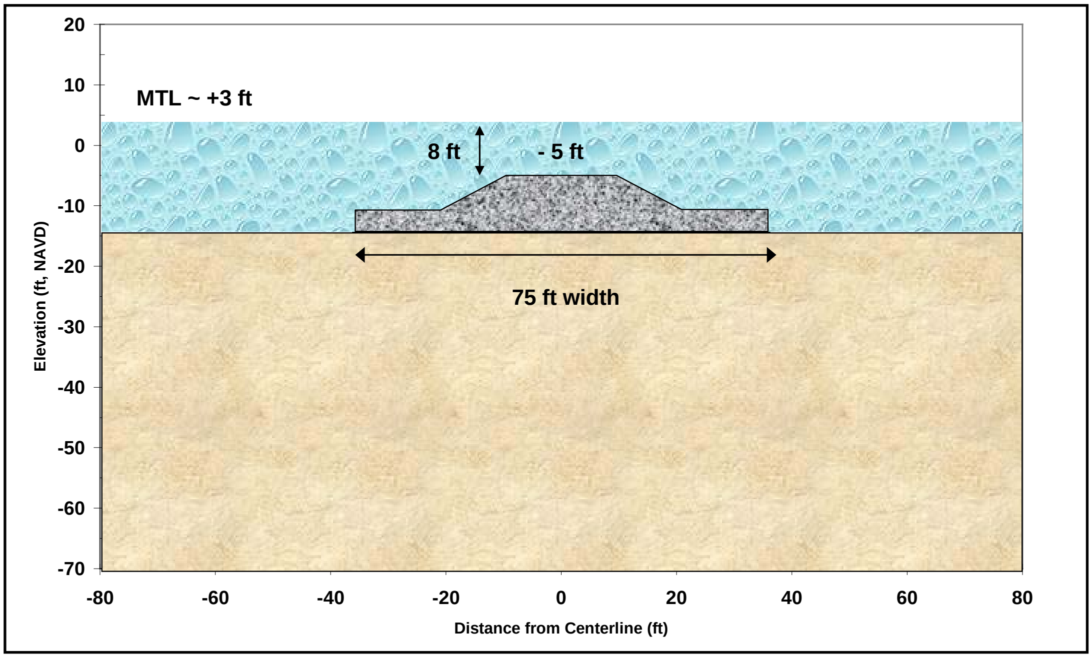


Table 3. North Jetty Spur Groin Features

Spur Groin Features	North Jetty
Number of spurs on channel side	3
Number of spurs on ocean side	1
Approximate total rock volume per spur (+/- 20%)	NJ1C: 3,350 tons (~2,094 cy) NJ2C: 11,090 tons (~6,931 cy) NJ3O: 2,010 tons (~1,256 cy) NJ4C: 29,250 tons (~18,281 cy)
Approximate total rock volume (all spurs) (+/- 20%)	53,000 tons (~33,125 cy)
Approximate area affected by each spur	NJ1C: 0.18 acres NJ2C: 0.45 acres NJ3O: 0.11 acres NJ4C: 0.80 acres
Approximate total area affected (all spurs)	1.55 acres
Approximate area of spurs above MLLW	NJ1C: 0% NJ2C: 0% NJ3O: 24% NJ4C: 0%
Approximate area of spurs below -20 MLLW	NJ1C: 0% NJ2C: 88% NJ3O: 0% NJ4C: 100%
Approximate dimension of spurs: length x width x height (feet)	NJ1C: 100 x 80 x 10 NJ2C: 170 x 115 x 19 NJ3O: 60 x 80 x 10 NJ4C: 170 x 115 x 19

Figure 6. North Jetty Spur Groin NJ1C

Note difference in scale between vertical and horizontal axes.



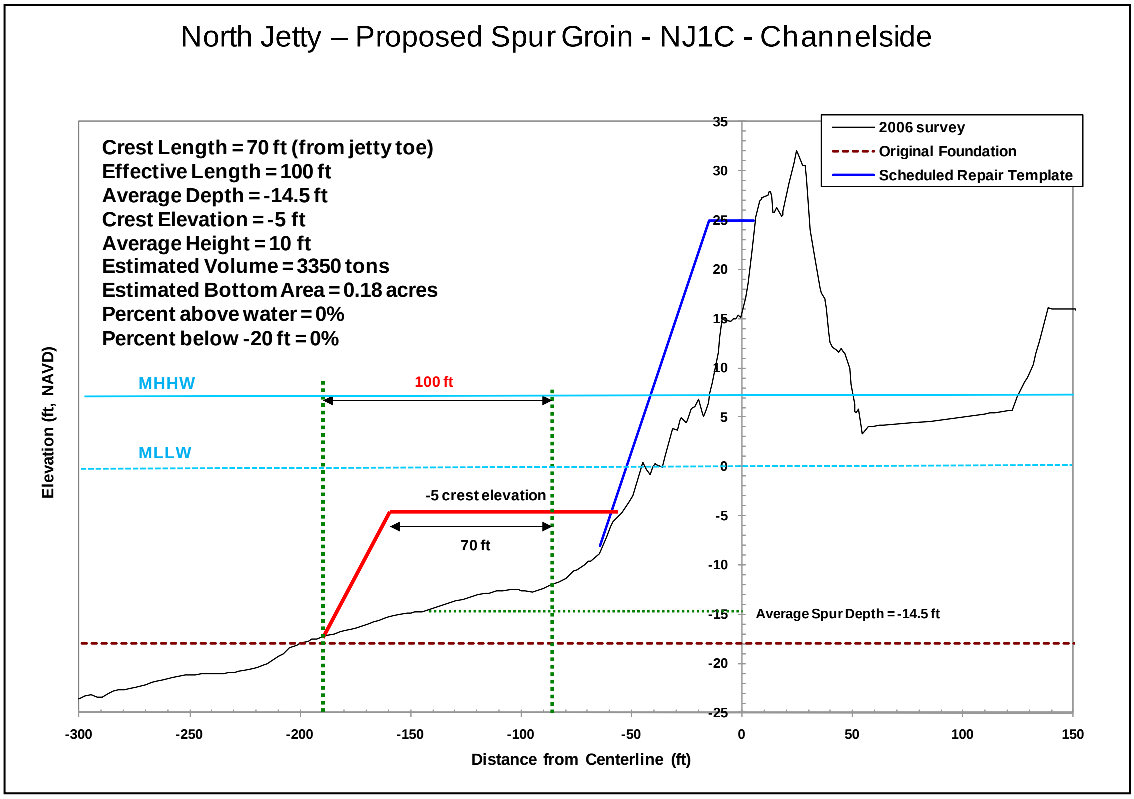
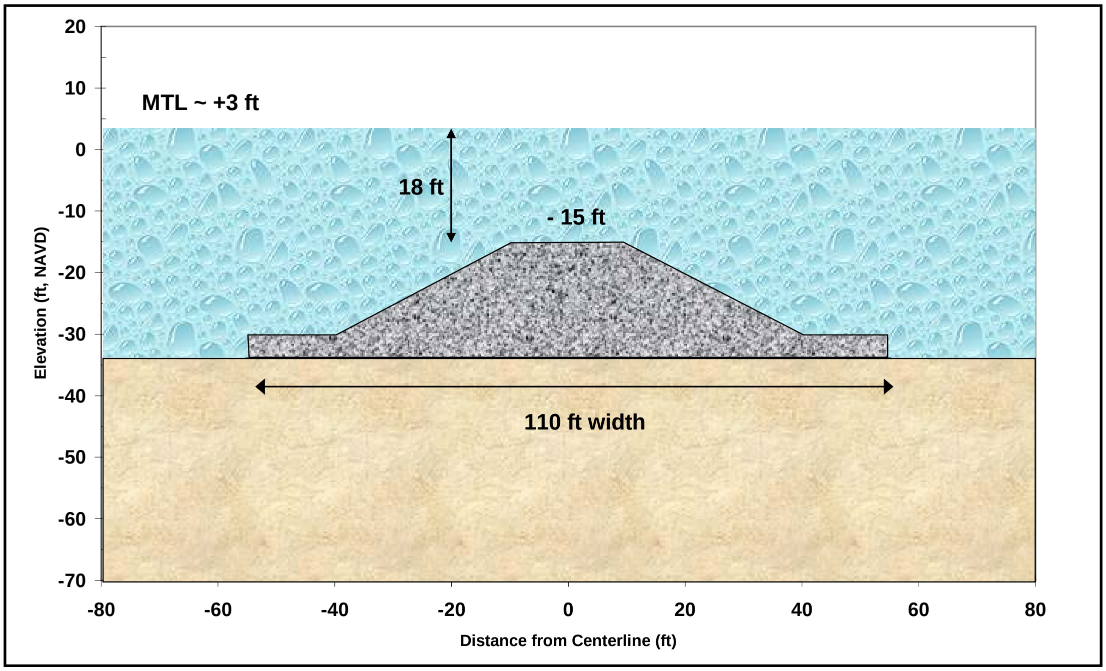


Figure 7. North Jetty Spur Groin NJ2C

Note difference in scale between vertical and horizontal axes.



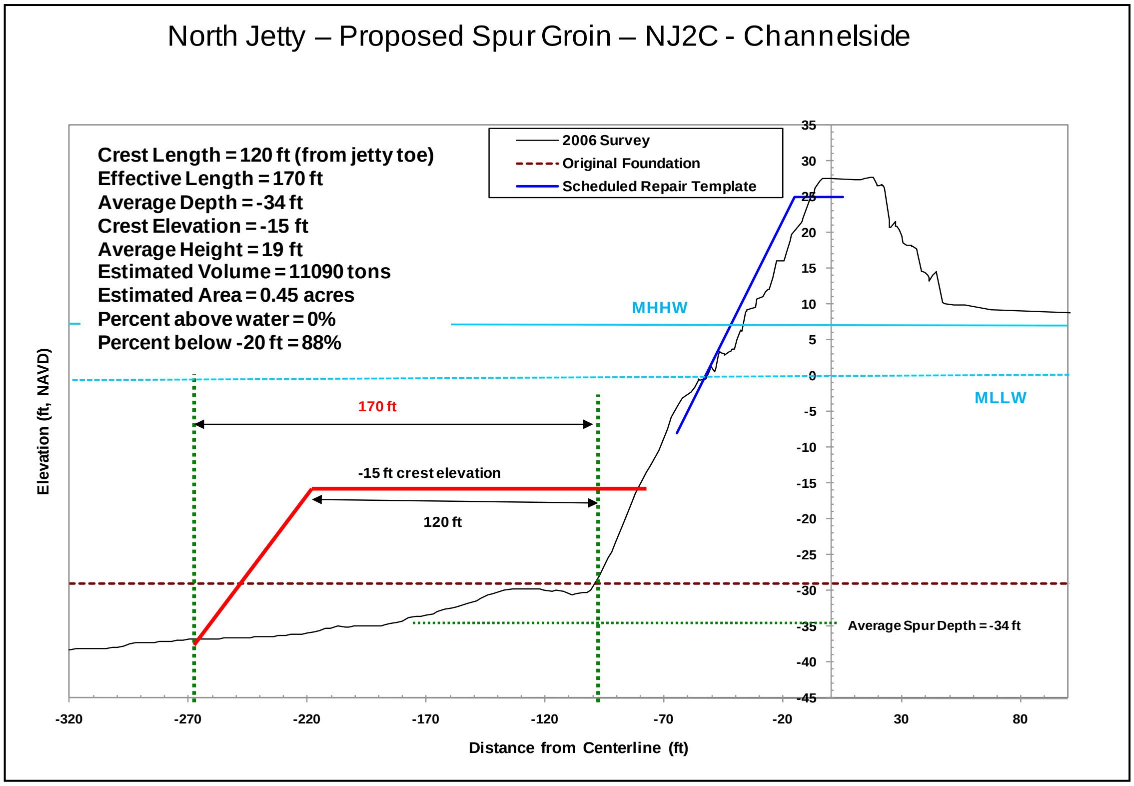
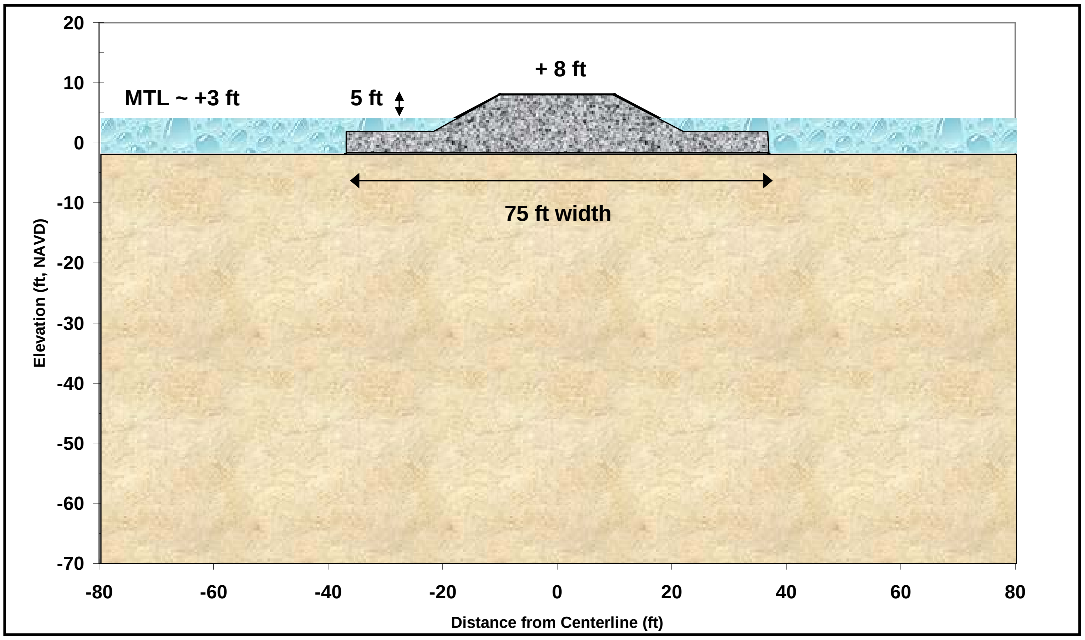


Figure 8. North Jetty Spur Groin NJ3O

Note difference in scale between vertical and horizontal axes.



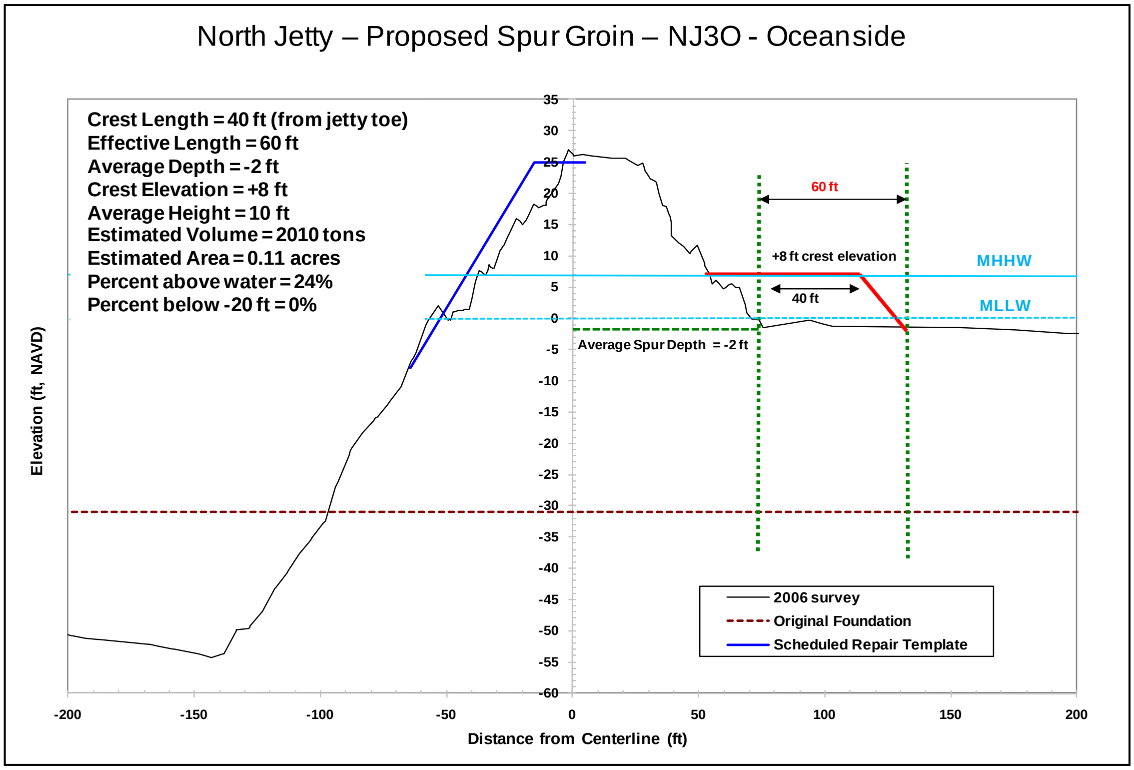
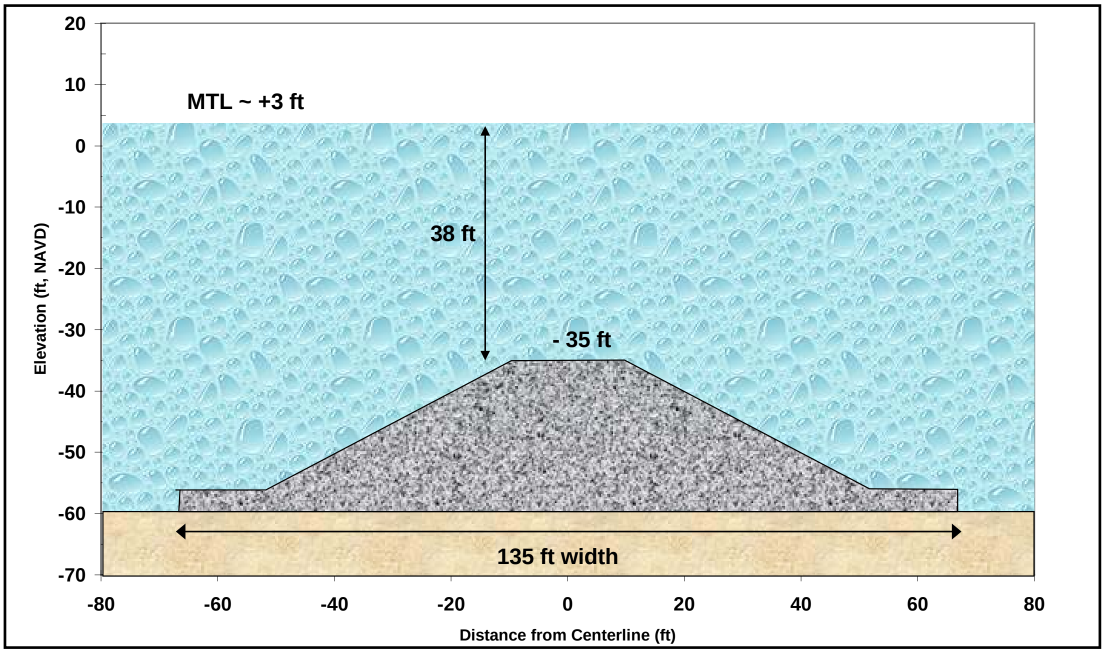
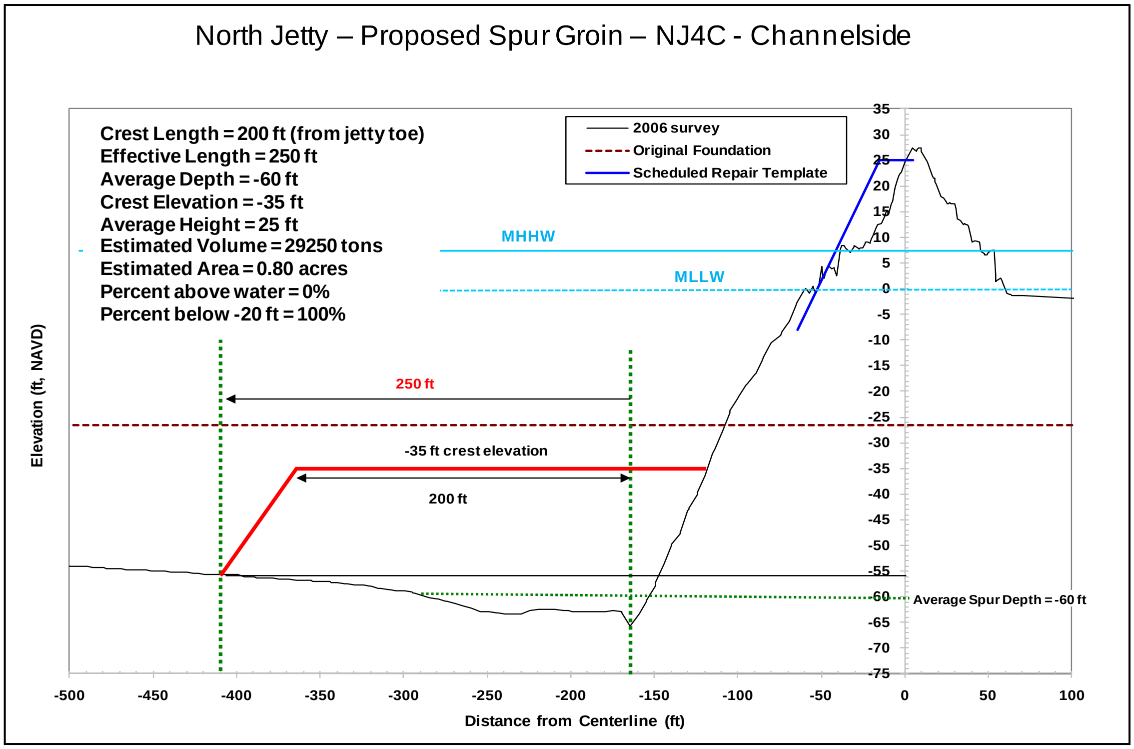


Figure 9. North Jetty Spur Groin NJ4C

Note difference in scale between vertical and horizontal axes.





North Jetty Head Capping

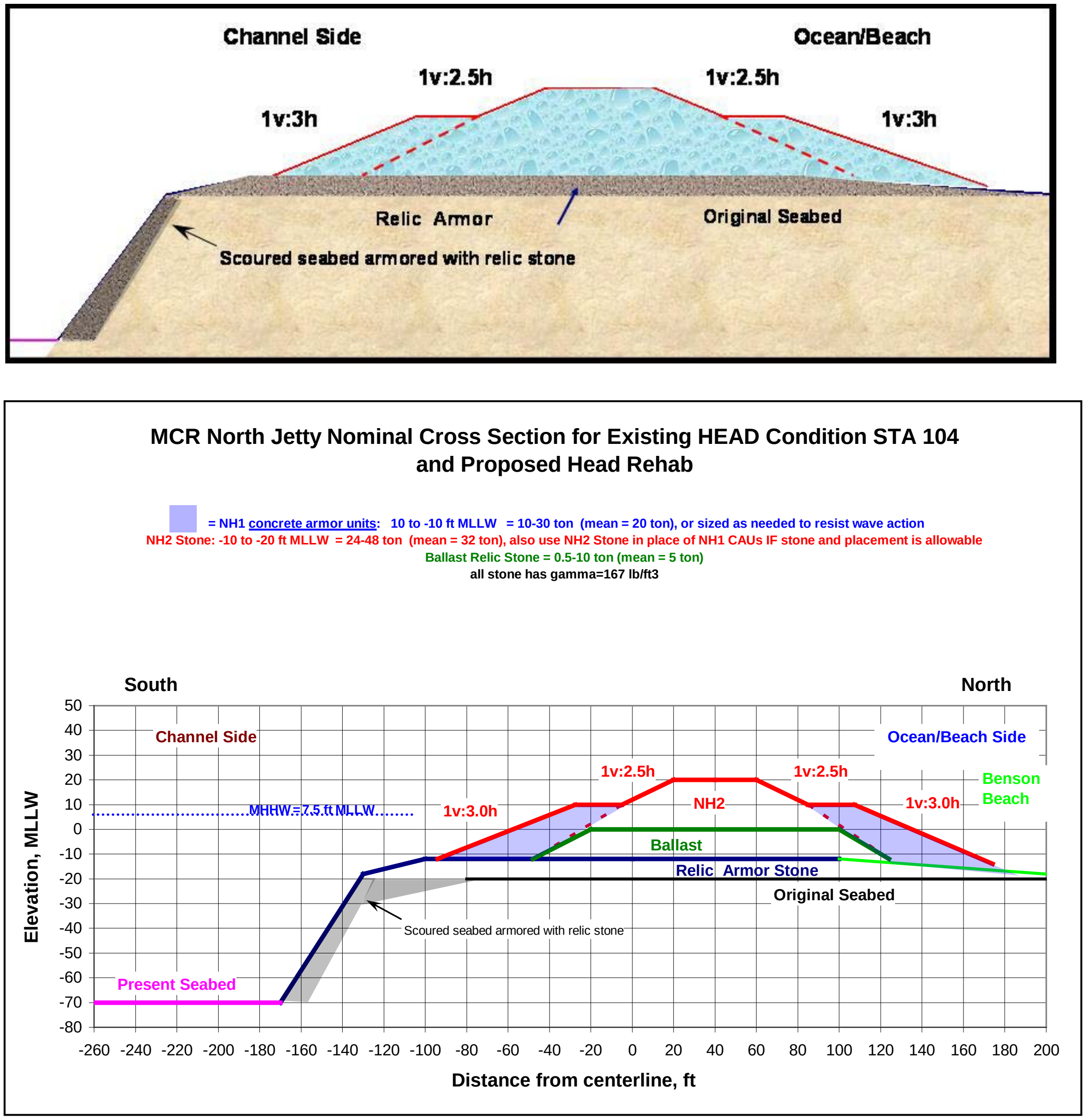
An armor stone cap or concrete armor units (CAU) will be placed on the head of the North Jetty to stop its deterioration (Table 4 and Figure 10). Approximately 38,000 tons (~23,750 cy) of stone or functionally equivalent CAUs will be placed on the relic stone to cap the jetty head. Future physical modeling will refine head capping features.

Table 4. North Jetty Head Cap Features

Head Cap Features	North Jetty
Location of cap	stations 99 to 101
Timing of construction	2015
Approximate dimensions of cap: length x width x height (feet)	350 x 270 x 45 (2.17 acres)
Stone size	30 to 50 tons
Area affected (outside relic stone)	None
% of cap constructed on relic stone	100%
Construction method	Cranes set on the jetty

For capping of the head, when stone placement is divided into elevation zones about 13,425 cy of rock will be placed above MHHW. This represents 49% of the overall stone placement on this portion of the jetty, and there is very little or no existing mounded jetty stone expected to be present within this elevation range. About 6,490 cy of rock will be placed between MHHW and MLLW. This represents 24% of the overall stone placement on this portion of the North Jetty, and there is very little or no existing jetty stone expected to be present within this elevation range. About 7,280 cy of rock will be placed below MLLW. This represents 27% of the overall stone placement on this portion of the North Jetty head, and a 2684% change from the existing jetty prism on this portion, as there is very little or no existing mounded jetty stone expected to be present within this elevation range. In all zones, all proposed stone placement will occur on existing base relic stone that formed the original jetty cross-section and was displaced and flattened by wave action, and does not include any modification that changes the character or increases the scope, or size of the original structure design. The terminus of the head is simply closer to shore on a shorter jetty structure. The footprint of the existing jetty mound on the flattened relic stone is approximately 1.37 acres, and the additional capping on the relic stone increases the width of the prism approximately 0.80 acres, for a total footprint of 2.17 acres, all of which will remain on the existing relic stone.

Figure 10. North Jetty Head Cap



North Jetty Lagoon and Wetland Fill and Culvert Replacement

Approximately 109,000 tons (~68,125 cy) of gravel and sand will be added to the jetty's beach side as lagoon fill to eliminate the tidal flow through the jetty that is destabilizing the foundation. A recent berm repair action now precludes lagoon inundation by tidal waters. Scouring has taken place on the north side of the North Jetty resulting in formation of a backwater area (lagoon) that was previously inundated both by tidal waters that come through the jetty and by freshwater that drains from the O'Neil Lake-McKenzie Head Lagoon and wetland complex area through the accreted land to the north of the jetty and North Jetty Road. This area drains through a culvert under the road and provides some of the freshwater flow to the lagoon. The surrounding lagoon resembles a scoured-out tidal channel and is a non-vegetated (and non-wetland) area of bare sand comprising approximately 4.71 acres. These wetland and waters will be filled to protect and stabilize the foundation of the North Jetty and to serve as a location for rock stockpiles and construction staging activities. The features of this work are shown in Table 5.

Table 5. North Jetty Lagoon and Wetland Fill Features

Features	North Jetty
Timing of construction	2014
Material used for fill	Sand, gravel, quarry stone
Short-term and long-term use	Stockpile area, long-term stabilization of root
De-watering	Culvert feeding into area will be re-placed
Impact on wetlands	1.78 acres
Impact on Section 404 waters	4.71 acres

After further hydraulic and hydrologic design, the aging culvert draining south from the wetland complex north of the roadway will be replaced, as it provides required drainage under the roadway. The design of the inlet, elevation, and culvert size will be determined so that hydrologic function in the adjacent wetland system is not negatively impacted. The outlet channel downstream of the culvert will not be filled. This area may provide an opportunity for minor stream and bank enhancement which will be evaluated when the culvert design is finalized, but this is uncertain until possible benefits can be further assessed. Under the proposed action, the existing channel will outlet to an engineered sump area comprised of newly placed lagoon fill material. In addition to infiltration through the jetty structure, this small portion of the creek currently connects the wetland to the lagoon and likely also receives some backwater flow from jetty infiltration. The current culvert is perched, and the regularly disconnected nature of the lagoon system does not appear to support anadromous fish use. Fish surveys were not completed for the stream inlet leading into this wetland complex and creek. The Corps proposes to conduct an initial sampling survey during peak juvenile salmon outmigration to determine whether or not fish salvage and fish exclusion efforts for listed species is warranted. The Corps will coordinate with NMFS if listed species are identified. Redesign of this system may provide an opportunity to accommodate improved hydrology to newly created wetlands excavated adjacent to the existing wetland complex. This will be further investigated during the hydraulic/hydrologic design analysis.

MCR South Jetty

The proposed action for the South Jetty includes scheduled repairs addressing mostly above MLLW water structural instability, five spur groins, head capping, and improving the jetty shoreline near the root (Figure 11). Seven Scheduled Repair events over the next 20 years were predicted at the South Jetty.

South Jetty Trunk and Root

The cross-section design from stations 155+00 to 311+00 will have a crest width of approximately 30 feet and will lie essentially within the existing jetty footprint based on the configuration of the original cross section, previous repair cross sections, and redistribution of jetty rock by wave action (Figure 12). The majority of the stone placement will be conducted above the MLLW. Each repair action is expected to cover a length up to 2,100 feet and include stone volumes in the range of 30,000 to 118,000 tons per season (18,750 - 73,750 cy).

As with the North Jetty repair action, it is expected that 60%-70% of the South Jetty's overall standard jetty template cross section has been displaced. Therefore, each repair event will increase the existing degraded cross section from 30%-40% back to 100% of the desired standard cross-section template. This means overall, the added rock will essentially triple what exists immediately prior to the time of repair. This could be described as a ~300% increase in rock relative to the existing jetty rock volume. However, this will not result in an increase the jetty prism or footprint beyond the scope and size of the historic structure, and does not include any modification that changes the character, scope, or size of the original structure design.

Per repair event, when divided into elevation zones, about 37,640 cy of rock will be placed above MHHW. This represents 68% of the overall stone placement on these portions of the South Jetty and a 1023% change from the existing jetty prism, as very little stone currently remains in the zone and a larger amount of stone must be placed compared to what presently remains. As described, above, this same concept applies characterizations about the rest of the zones. About 10,420 cy of rock will be placed between MHHW and MLLW. This represents 19% of the overall stone placement on these portions of the South Jetty and a 225% change from the existing jetty prism. About 6,940 cy of rock will be placed below MLLW. This represents 13% of the overall stone placement on these portions of the South Jetty and a 150% change from the existing jetty cross section. However, in all zones, all proposed stone placement will occur on existing base relic stone that formed the original jetty cross section. The footprint of the trunk and root of the South Jetty will remain within its current jetty dimensions and on relic stone.

Figure 11. Proposed Action for the MCR South Jetty

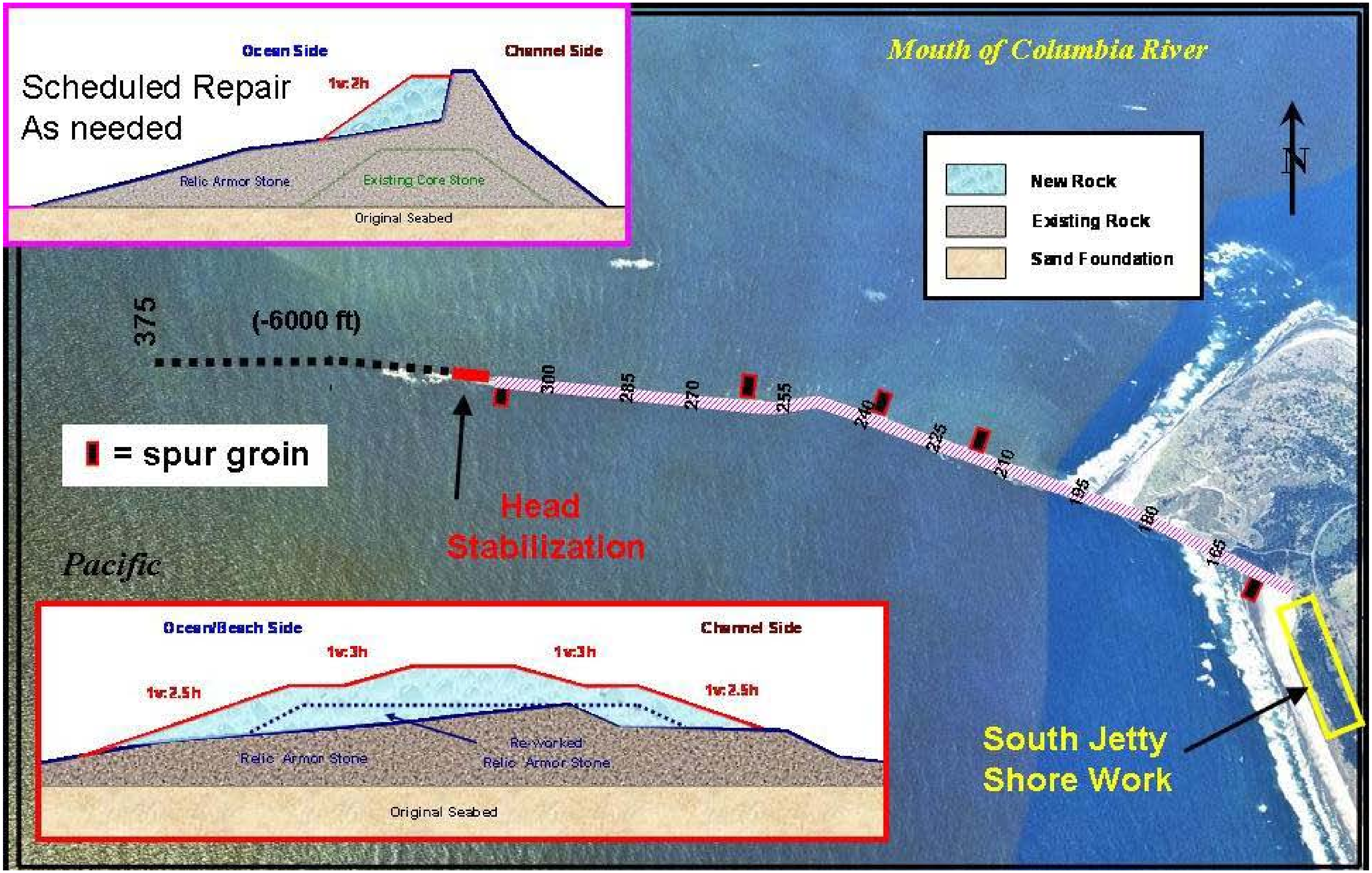
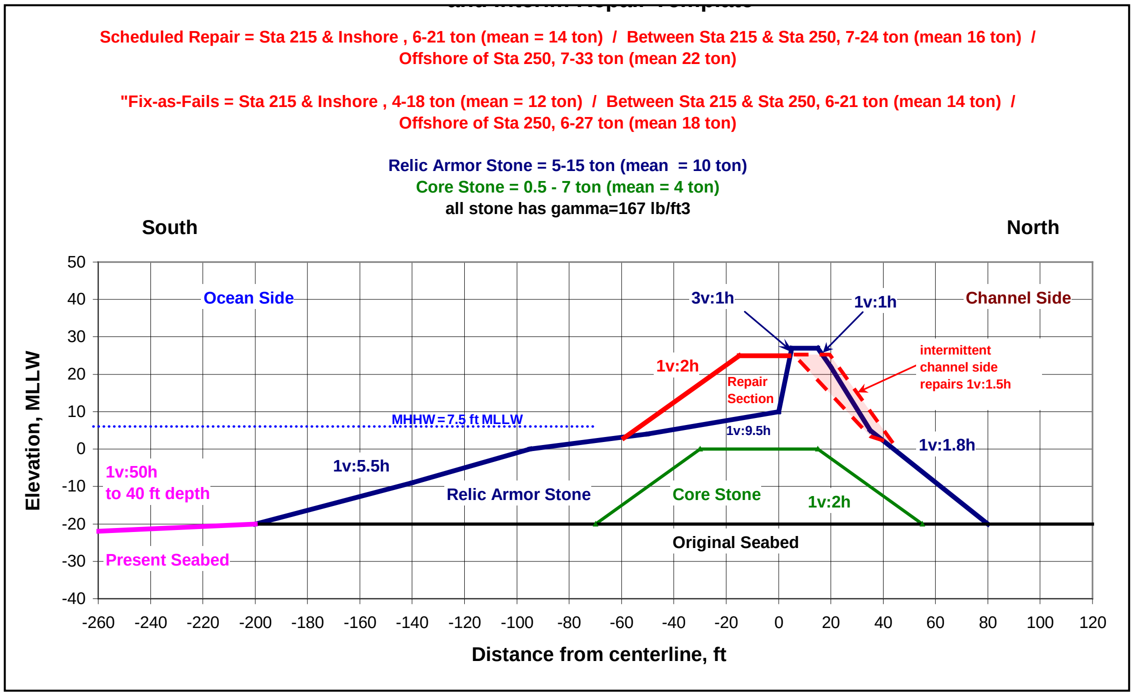


Figure 12. South Jetty Cross Section for Existing Condition and Scheduled Repair



South Jetty Spur Groins

Three emergent and two submergent spur groins will be constructed to stabilize the jetty's foundation (Figures 13 to 17). The dimensions and other features of the spur groins are shown in Table 6.

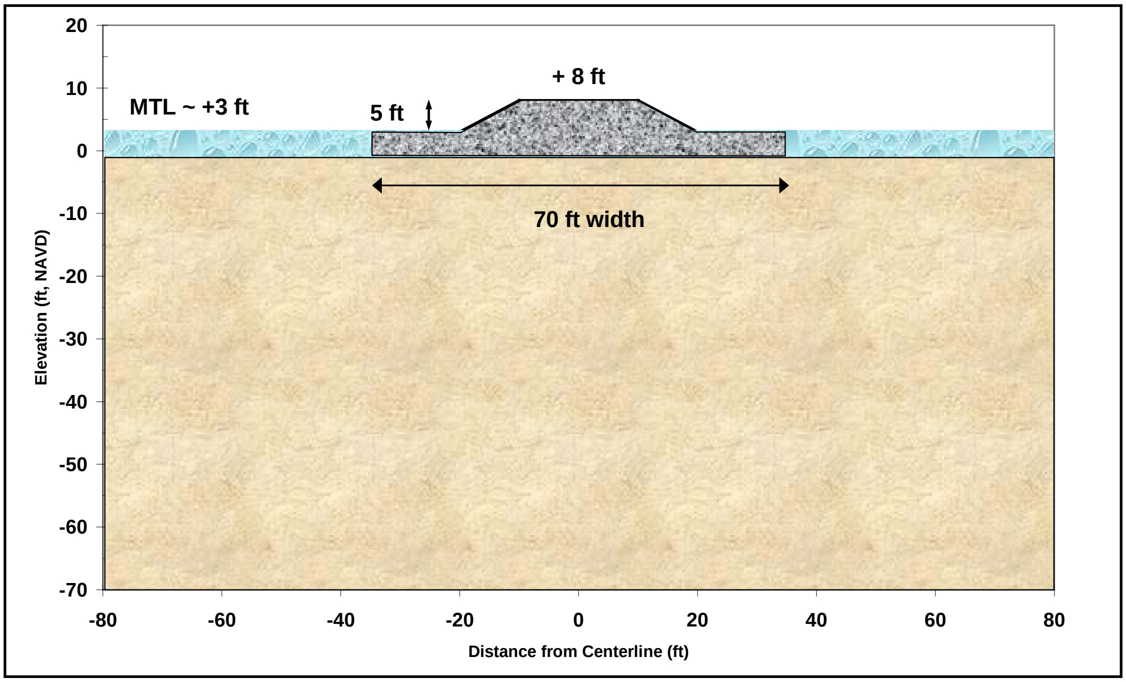
Representing estimated rock volume totals divided into elevation zones for all spurs on the South Jetty, about 21 cy of rock will be placed above MHHW. This represents 0.1% % of the overall stone placement on these portions of the South Jetty, and there is very little or no existing jetty stone expected to be present within this elevation range. About 2,190 cy of rock will be placed between MHHW and MLLW. This represents 12.3% of the overall stone placement on these portions of the South Jetty, and there is very little or no existing jetty stone expected to be present within this elevation range. About 15,700 cy of rock will be placed below MLLW. This represents 87.6% of the overall stone placement on these portions of the South Jetty, and there is very little or no existing jetty stone expected to be present within this elevation range. The footprint of the spurs on the South Jetty will increase from 0 acres to 1.10 acres. In the relevant figures, note that the difference in the vertical and horizontal scales causes a slight representational distortion.

Table 6. South Jetty Spur Groin Features

Spur Groin Feature	South Jetty
Number of spurs on channel side or downstream	3
Number of spurs on ocean side or upstream	2
Approximate total rock volume per spur (+/- 20%)	SJ1O: 1,680 tons (~1,050 cy) SJ2C: 2,350 tons (~1,469 cy) SJ3C: 2,350 tons (~1,469 cy) SJ4C: 3,180 tons (~1,988 cy) SJ5O: 18,750 tons (~11,719 cy)
Approximate total rock volume (all spurs) (+/- 20%)	25,000 tons (~15,625 cy)
Approximate area affected by each spur	SJ1O: 0.11 acres SJ2C: 0.13 acres SJ3C: 0.13 acres SJ4C: 0.19 acres SJ5O: 0.55 acres
Approximate total area affected (all spurs)	1.10 acres
Approximate area of spurs above water	SJ1O: 29% SJ2C: 7% SJ3C: 7% SJ4C: 0% SJ5O: 0%
Approximate area of spurs below -20 MLLW	SJ1O: 0% SJ2C: 0% SJ3C: 0% SJ4C: 0% SJ5O: 92%
Approximate dimension of spurs: length x width x height (feet)	SJ1O: 60 x 80 x 9 SJ2C: 70 x 80 x 10 SJ3C: 70 x 80 x 10 SJ4C: 90 x 90 x 12 SJ5O: 190 x 125 x 22

Figure 13. South Jetty Spur Groin SJ1O

Note difference in scale between vertical and horizontal axes.



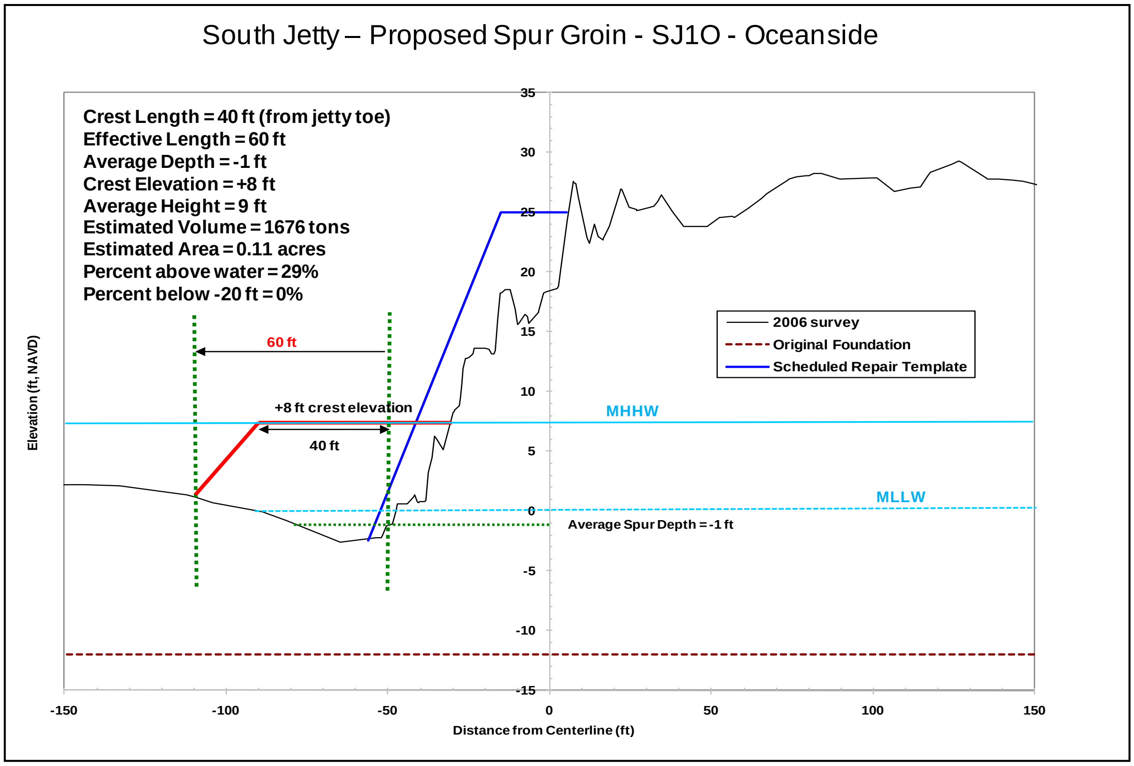
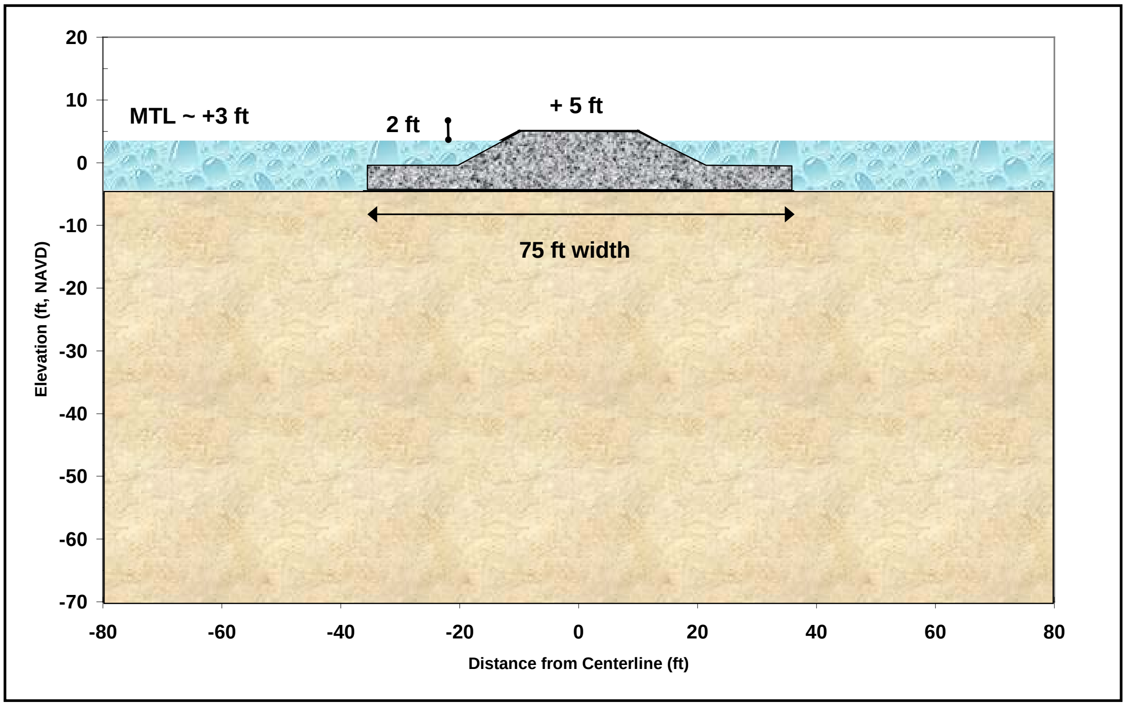


Figure 14. South Jetty Spur Groin SJ2C

Note difference in scale between vertical and horizontal axes.



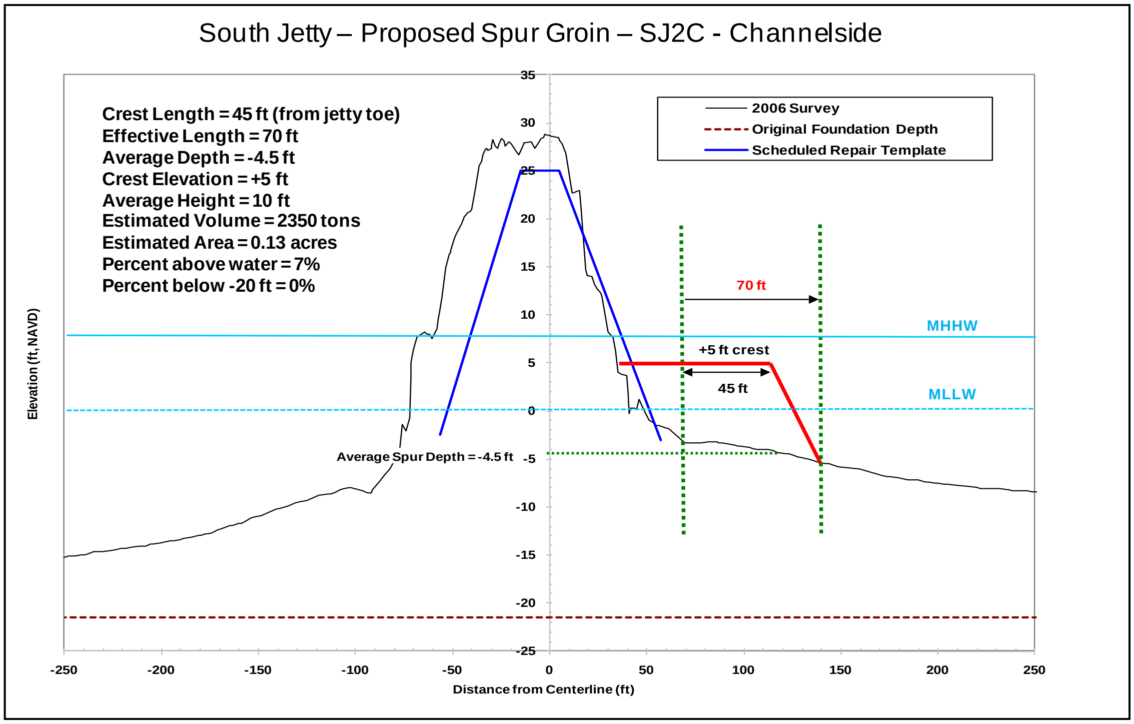
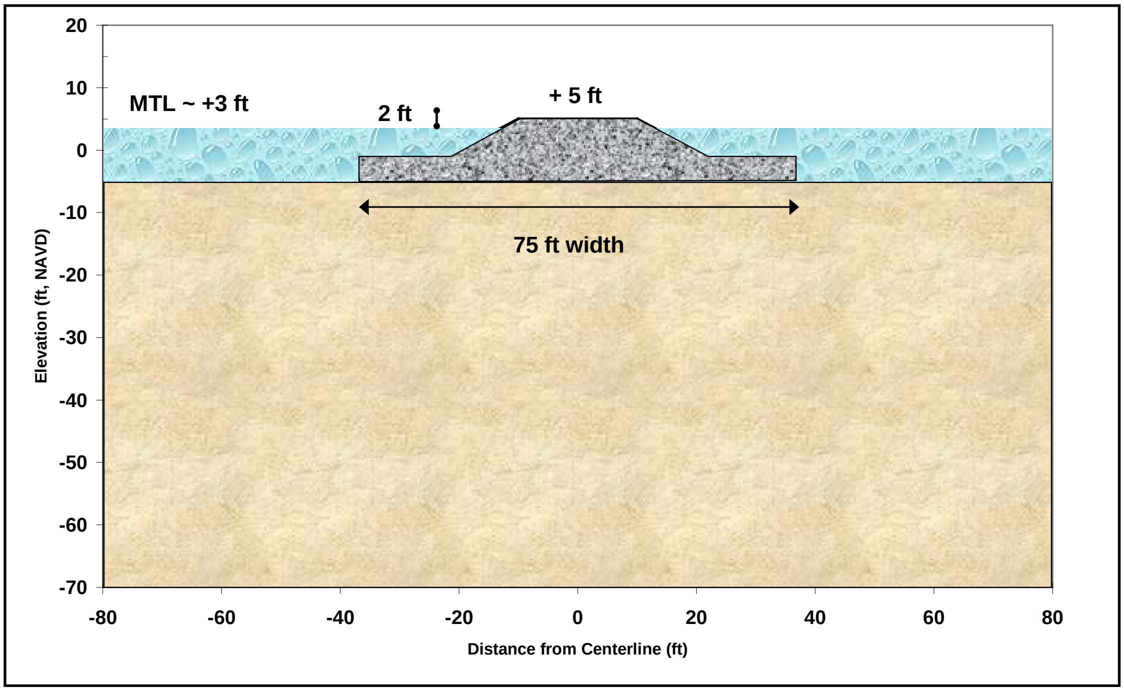


Figure 15. South Jetty Spur Groin SJ3C

Note difference in scale between vertical and horizontal axes.



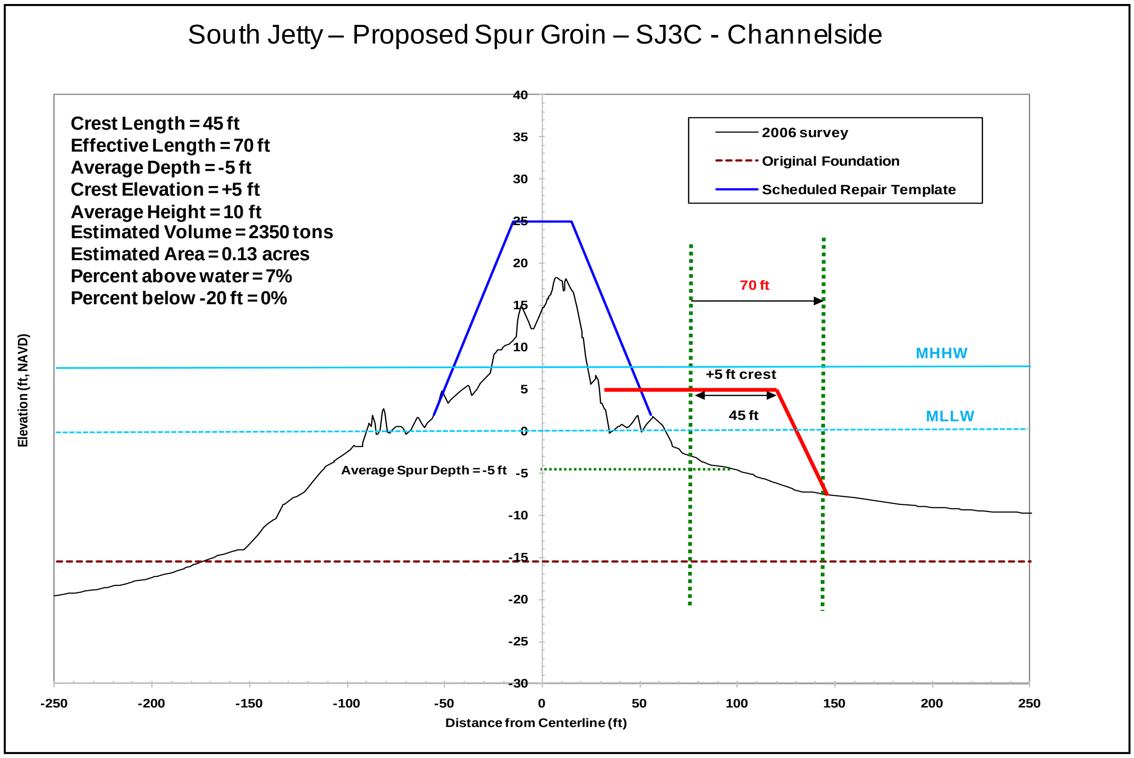
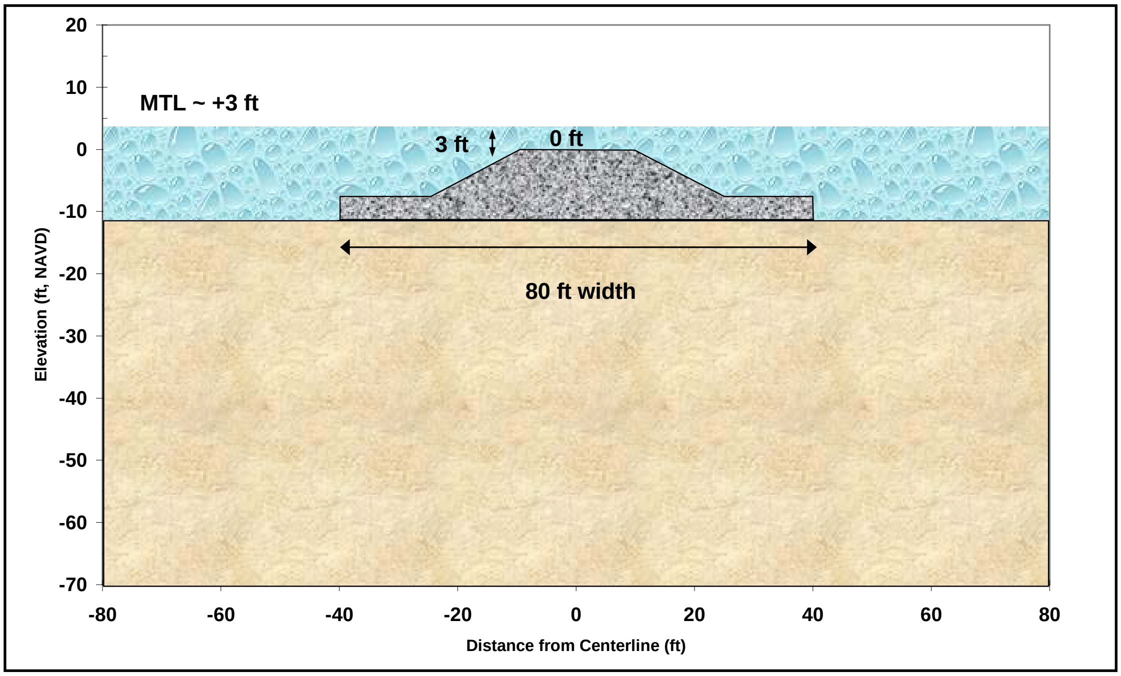


Figure 16. South Jetty Spur Groin SJ4C

Note difference in scale between vertical and horizontal axes.



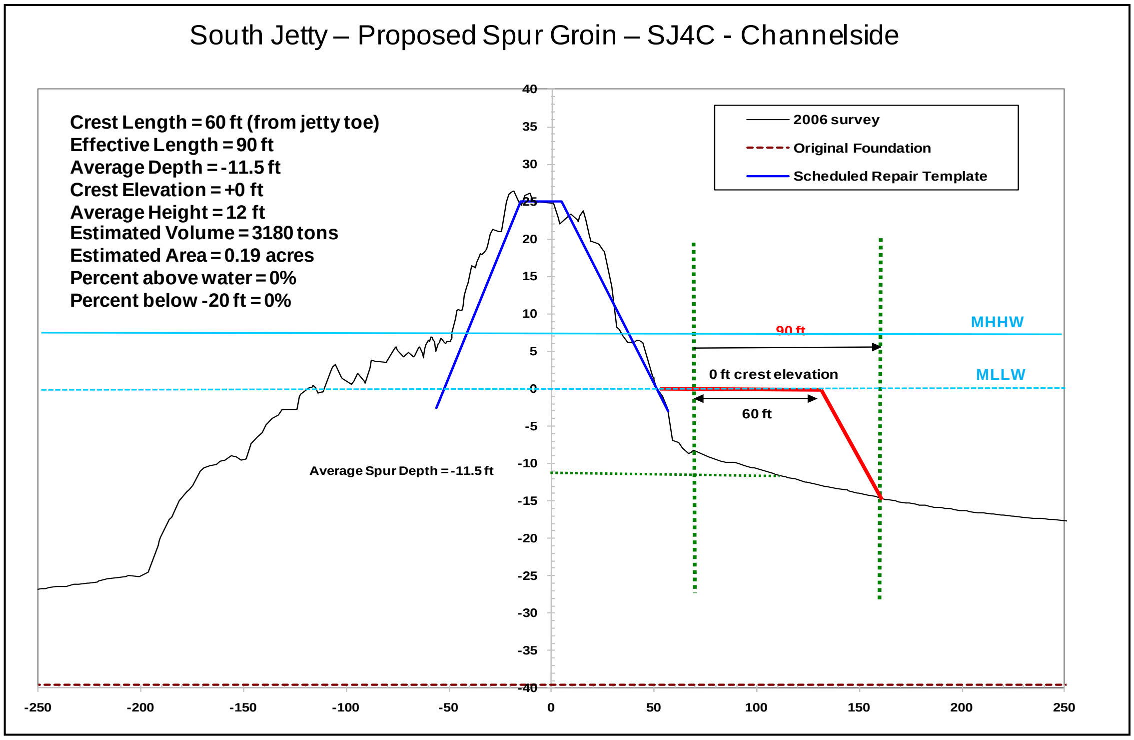
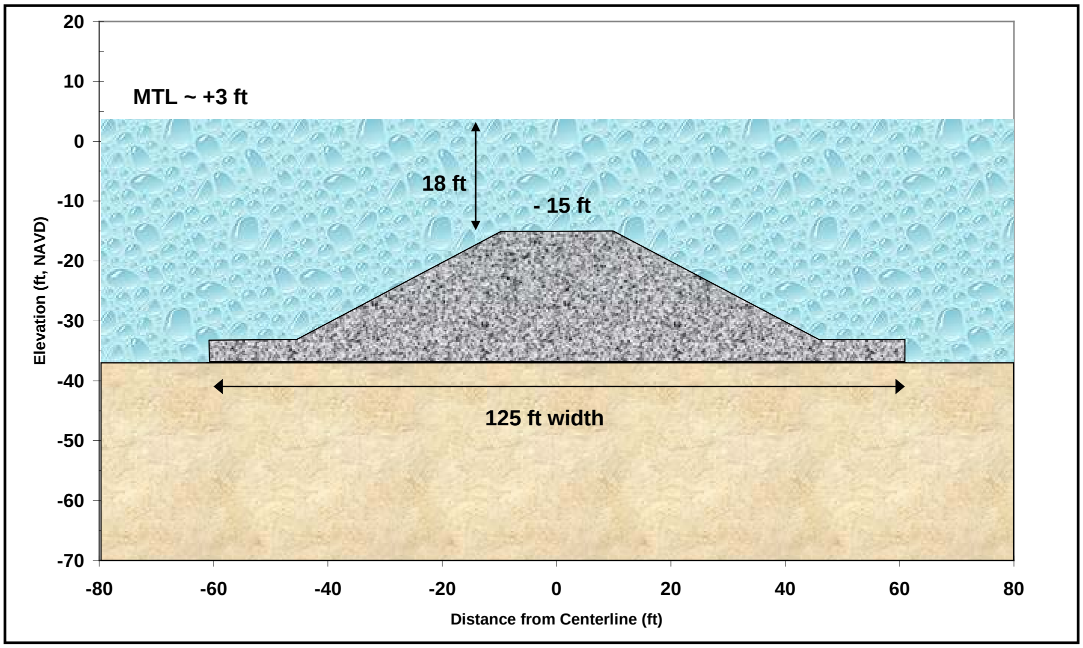
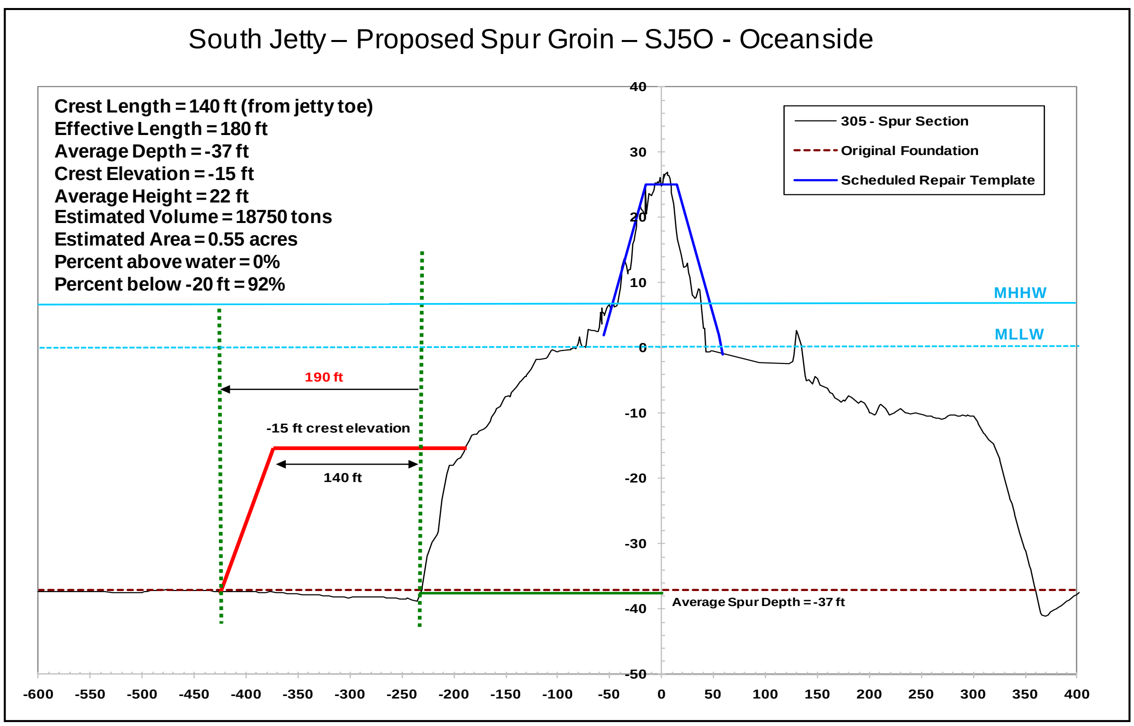


Figure 17. South Jetty Spur Groin SJ5O

Note difference in scale between vertical and horizontal axes.





South Jetty Head Capping

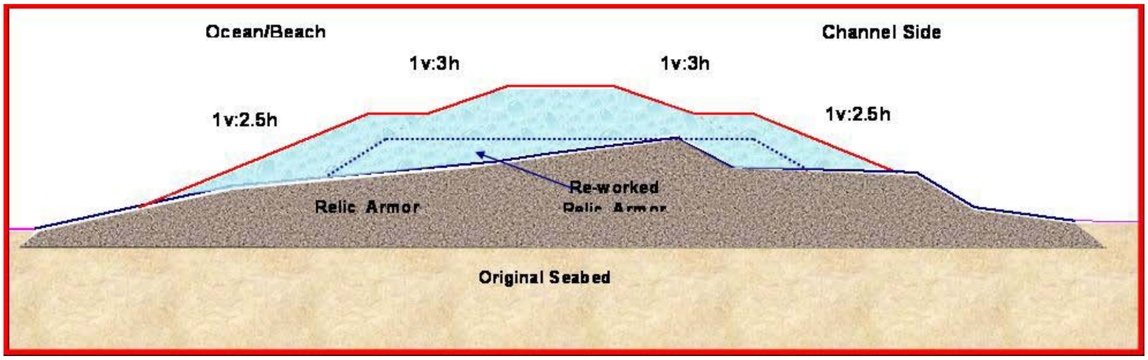
An armor stone cap with approximately 40,000 to 74,000 tons (~25,000 - 46,250 cy) of stone or equivalent concrete armor units will be placed on the head of the South Jetty to stop its deterioration (Figure 18). The features of this work are shown in Table 7.

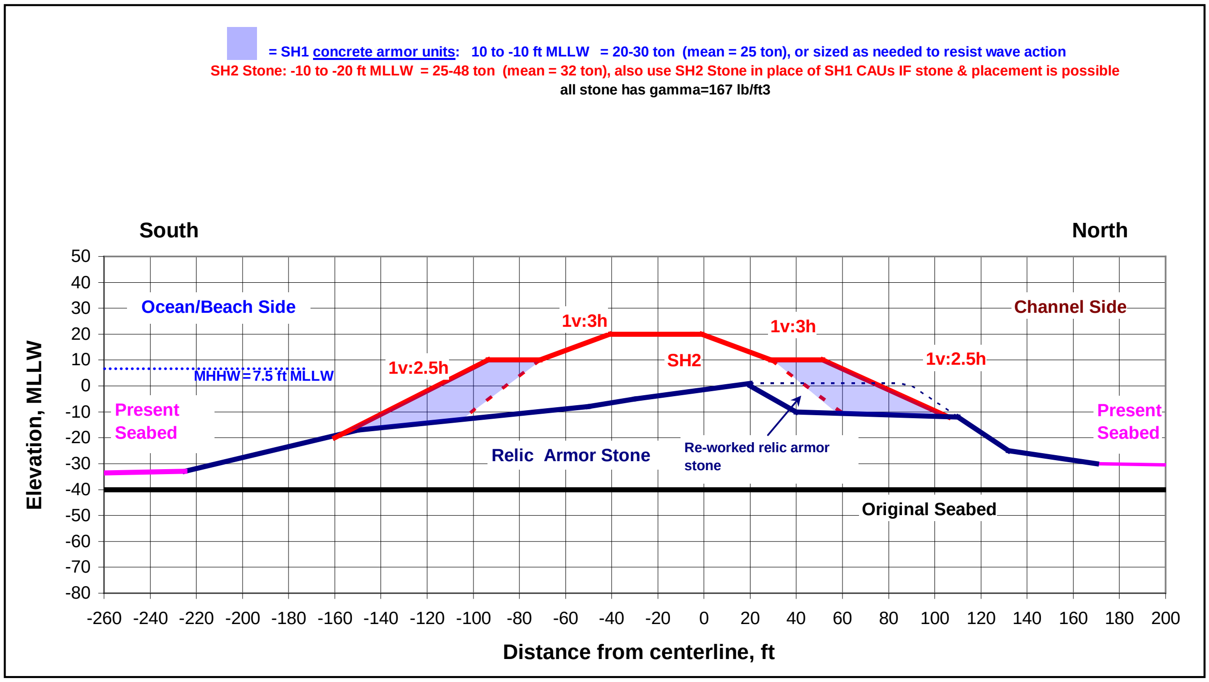
For capping of the head, divided into elevation zones about 13,425 cy of rock will be placed above MHHW. This represents 52% of the overall stone placement on this portion of the South Jetty and there is very little or no existing jetty stone expected to be present within this elevation range. About 6,490 cy of rock will be placed between MHHW and MLLW. This represents 25% of the overall stone placement on this portion of the South Jetty and there is very little or no existing jetty stone expected to be present within this elevation range. About 6,050 cy of rock will be placed below MLLW. This represents 23% of the overall stone placement on this portion of the South Jetty and 1150% change from the existing base condition as there is very little or no existing mounded jetty stone expected to be present within this elevation range. In all zones, all proposed stone placement will occur on existing base relic stone that formed the original jetty cross section and was displaced and flattened by wave action, and does not include any modification that changes the character or increases the scope or size of the original structure design. The terminus of the head is simply closer to shore on a shorter jetty structure. The footprint of the existing jetty mound on the flattened relic stone is approximately 1.69 acres, and the additional capping on the relic stone increases the width of the prism approximately 0.64 acres, for a total footprint of 2.33 acres, all of which will occur on existing relic stone.

Table 7. South Jetty Head Capping Features

Capping Feature	South Jetty
Location of cap	stations 311 to 313
Timing of construction	2019-2020
Dimensions of cap: length x width x height (feet)	350 x 290 x 45 (2.33 acres)
Stone size	30 to 50 tons
Area affected (outside relic stone)	None
% of cap constructed on relic stone	100%
Construction method	Land-based cranes or jack-up barge

Figure 18. South Jetty Head Cap

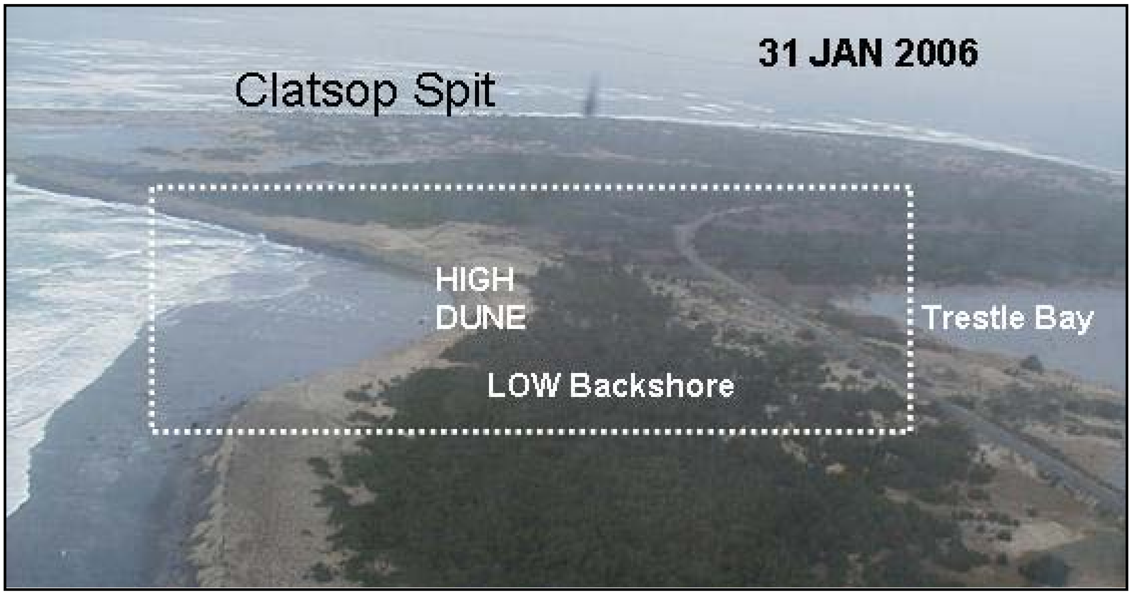




South Jetty Root Erosion and Dune Augmentation

Currently, the coastal shore interface along the South Jetty is in a condition of advanced deterioration (Figure 19). The foredune separating the ocean from the backshore is almost breached. The backshore is a narrow strip of a low-elevation, accretion area that separates Trestle Bay from the ocean by hundreds of yards. The offshore area along the South Jetty (and to the south) continues to erode, promoting larger wave action to affect the shoreline along the South Jetty root. The back dune of Trestle Bay has continued to advance westward due to increased circulation in the bay, seasonal wave chop, and hydraulic surcharging. Under existing conditions, the shoreline at the root of the South Jetty will continue to erode and recede, resulting in a possible shoreline breach into Trestle Bay in about 8-16 years. If this sand spit breach occurs, the result would be catastrophic. The MCR inlet would establish a secondary flow way from the estuary to the ocean along this area (south of South Jetty). This condition would profoundly disrupt navigation at the MCR and bring lasting changes to the physical nature of the inlet.

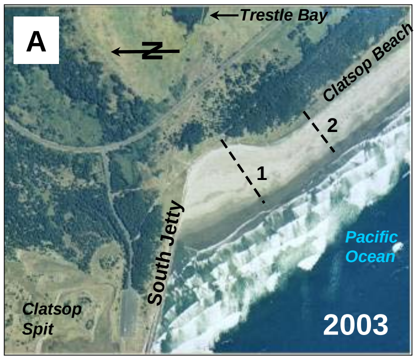
Figure 19. Clatsop Spit and South Jetty Root Erosion



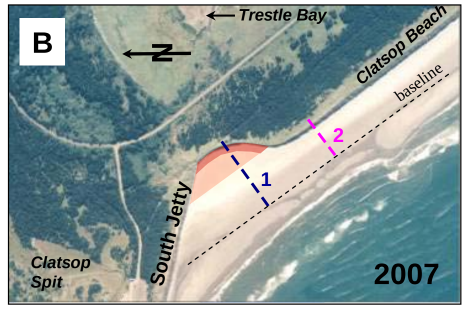
About 40,000 to 70,000 cy of cobble in the shape of angular or rounded graded stone is proposed at the South Jetty root in order to fortify the toe of the foredune and to improve the foreshore fronting to resist wave-induced erosion/recession (Figure 20). Maximum crest width of the template is estimated to extend 70 feet seaward from the seaward base of the present foredune. Construction of the berm augmentation would require 2 to 6 weeks. To adequately protect the foredune during storm conditions, this requires that the top of the stone berm (crest) extend vertically to approximately 25 feet NAVD and have an alongshore application length of approximately 1,100 feet, extending southward from the South Jetty root. This is equivalent to about 3 acres. The constructed template crest would be 10 to 15 feet above the current beach grade and have a 1 vertical to 10 horizontal slope aspects from crest to existing grade. Cobble is not expected to extend below MHHW. An additional layer of sand may be placed over this berm, or natural accretion may facilitate sand recruitment after construction of the adjacent spur groin.

Cobble material would be procured from upland sources and placed using haul trucks and dozers. The material would be transported on existing surface roads and through Fort Stevens State Park to a beach access point at the project site. There is an existing relic access road along the jetty root that will be refurbished and used to transport stone to the dune augmentation area. Though there is an existing razor clam bed adjacent to the vicinity of the proposed dune augmentation, species impacts are not expected because all of the stone placement will occur above MHHW, and haul traffic will be precluded using Parking Lot B and from driving on the beach during material delivery. Excavator and bulldozer work will be mostly confined to the dry sand areas to further avoid negative species effects.

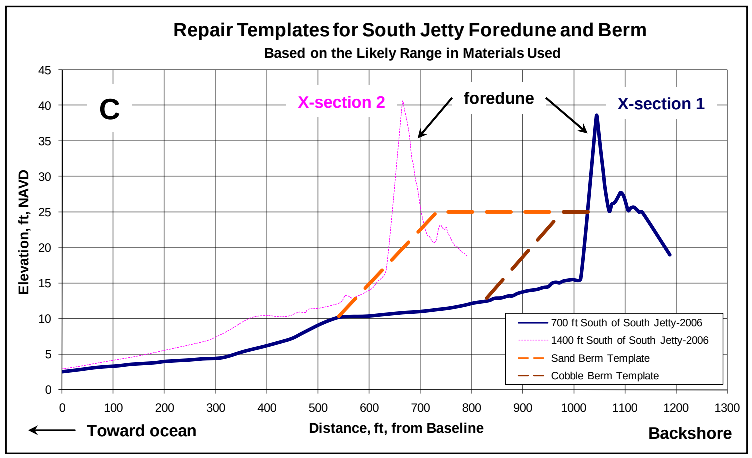
Figure 20. South Jetty Root Shoreline Area



MCR South Jetty root, south side where Clatsop Spit joins with Clatsop Plains/Beach. Panels A and B show the erosion embayment along the south jetty root for 2003 (hIgh tide) and 2007 (low tide). The embayment & adjacent shore have receded 40 ft landward during 2003-2007, reducing the protective foredune along the embayment.



Panel C shows cross-sections 1 and 2 for 2007(shown in panels A & B). Severe erosion in this area had threatened the inlet stability during early 1930s, when jetty rehabilitation and sand augmentation measures were implemented. Erosion has again become chronic since the late 1970s. The foredune protects the backshore (elevation 15-18 ft NAVD) from wave surge action during storms. If the foredune is breached, the backshore will be rapidly eroded. Without erosion abatement, it is estimated that that the Pacific Ocean will establish hydraulic connectivity with Trestle Bay in 10-15 years from 2009, and again threaten inlet stability. Panel C shows two options for protecting the foredune within the erosion embayment: A SAND berm template requires ~225,000 cy of sand placement, and a COBBLE berm template requires ~60,000 cy of cobble placement.



The dune augmentation may require maintenance every 4-10 years (assume 40% replacement volume). Consideration will be given to development of revegetation plans which incorporate native dune grasses to supplement foredune stabilization in the augmentation area. This bioengineering component could help restore habitat and take advantage of natural plant rooting functions that provide greater protection from erosive forces.

MCR Jetty A

The proposed action for Jetty A includes Immediate Rehabilitation with a small cross section, two spur groins, and head capping (Figure 21).

Jetty A Trunk and Root

The cross-section design from stations 40+00 to 91+00 will have a crest width of approximately 40 feet and will lie mostly within the existing jetty footprint based on the configuration of the original cross section, previous repair cross sections, and redistribution of jetty rock by wave action (Figure 22). About 55,000 tons (~34,375 cy) of new rock will be placed on the existing jetty cross section and relic armor stone on the estuary/channel side of the jetty and 75,000 tons (~46,875 cy) of new rock on the ocean side of the jetty. Though most of the work will occur above MLLW, there will also be some stone placement below this elevation. The small cross-section also has a higher likelihood of expanding beyond the relic base compared to repair actions.

About 63,700 cy of rock will be placed above MHHW. This represents 63% of the overall stone placement on these portions of Jetty A and a 2020% change from the existing jetty prism, as very little stone currently remains in the zone and a larger amount of stone must be placed compared to what presently remains. As described previously for North and South jetties, this same concept applies to characterizations about the rest of the zones. About 28,940 cy of rock will be placed between MHHW and MLLW. This represents 29% of the overall stone placement on these portions of Jetty A and a 280% change from the jetty prism. About 8,030 cy of rock will be placed below MLLW. This represents 8% of the overall rock on these portions of Jetty A and a 233% change from the existing jetty prism. In all zones, most of the proposed stone placement will occur on existing base relic stone that formed the original jetty cross-section. However, the footprint of the proposed prism could increase in width compared to the existing prism by up to 10 feet along the length of the jetty (though it would still be on the relic stone). This equals about 1.2 acres, but it is not expected to result in additional habitat conversion because it will be in a bottom location already comprised of jetty stone, and does not include any modification that changes the character, scope, or size of the original structure design.

Figure 21. Proposed Action for MCR Jetty A

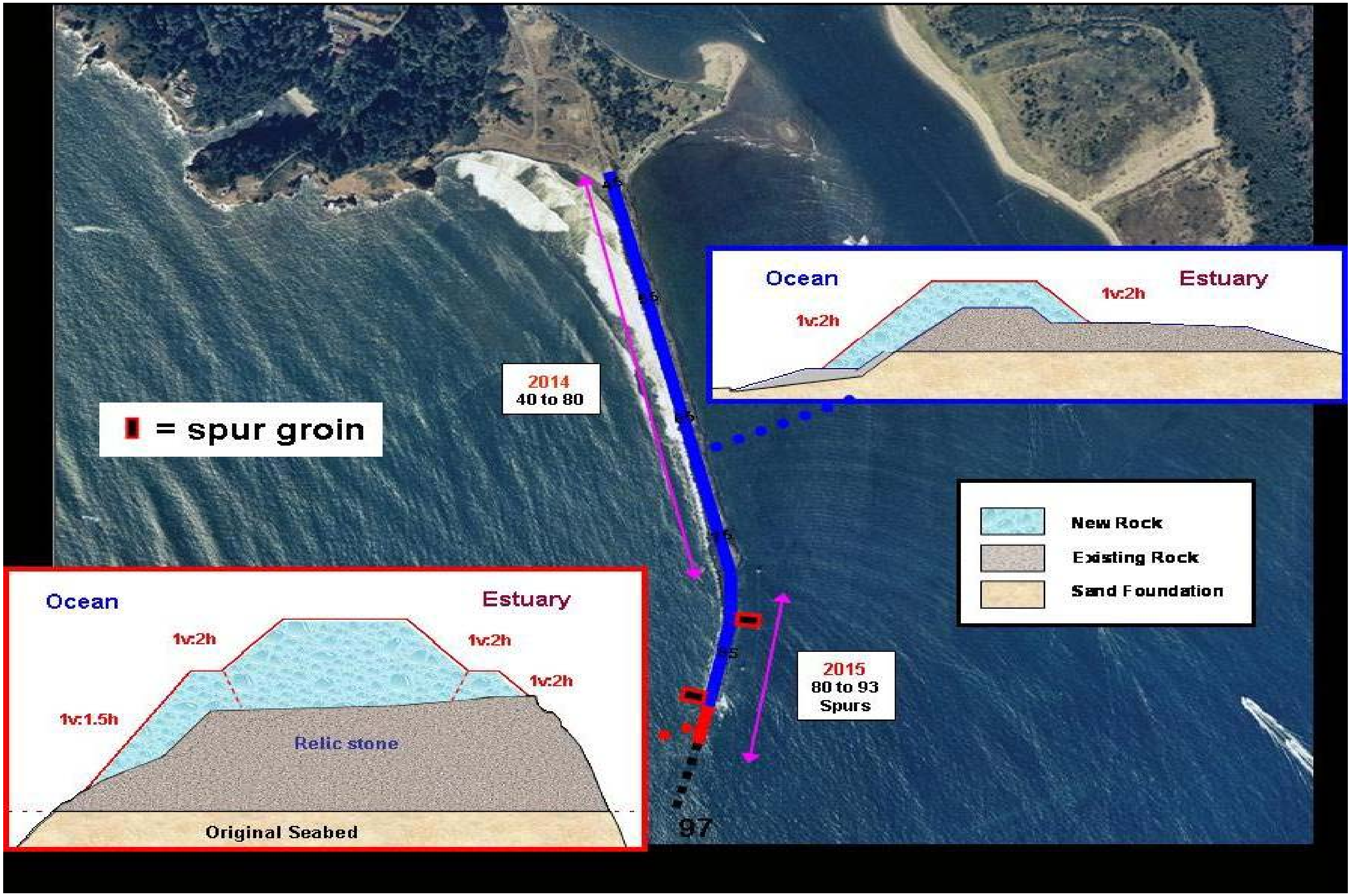
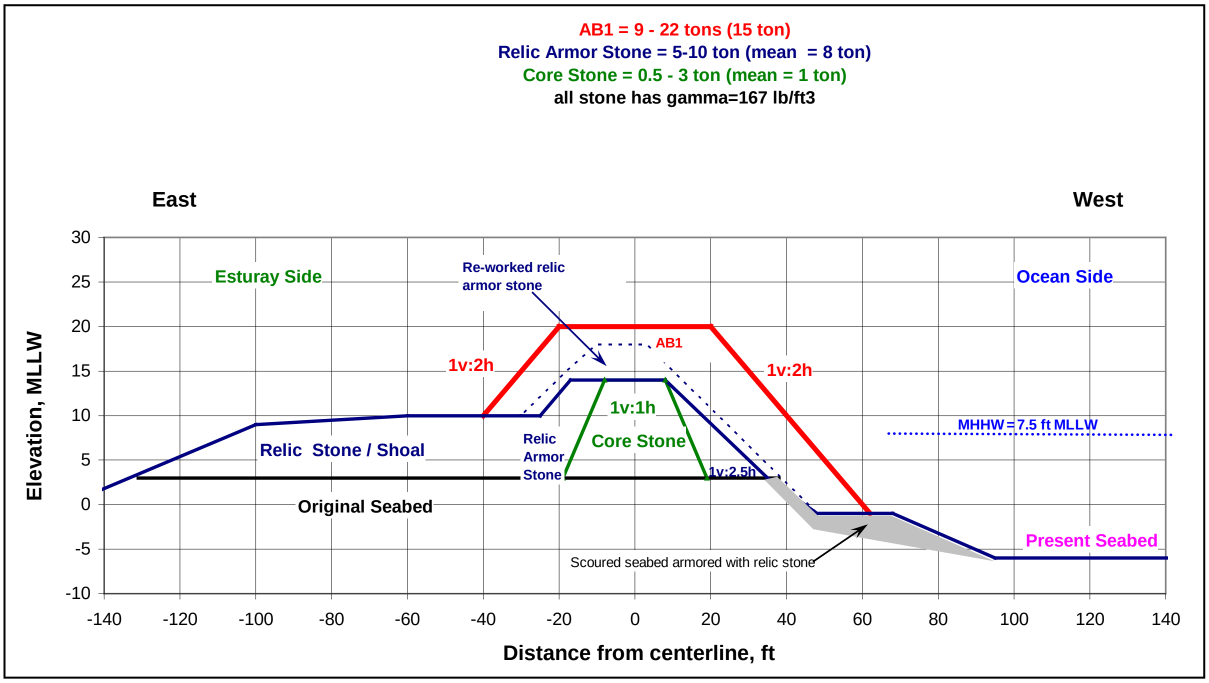


Figure 22. Jetty A Cross Section for Proposed Action



Jetty A Spur Groins

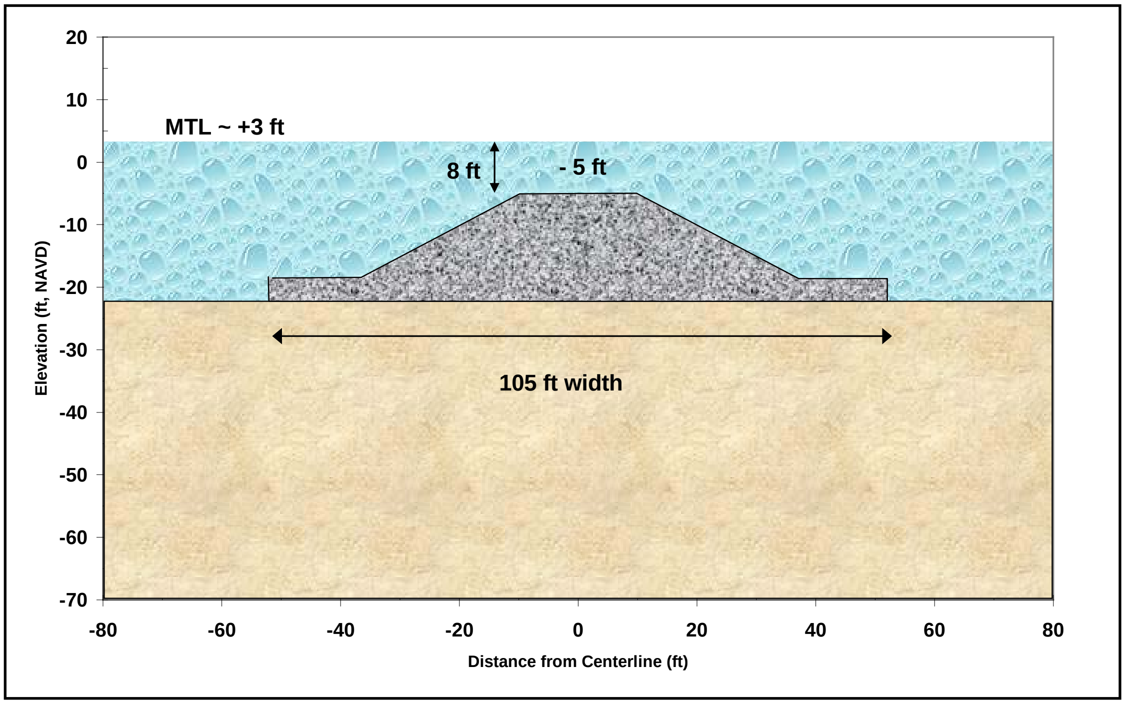
One submergent spur groin will be placed on the downstream (referred to as JA1C) side and one submergent spur groin will be placed on the upstream (referred to as JA2O) side to stabilize the jetty's foundation (Figures 23-24). The dimensions and other features of the spur groins are shown in Table 8. Representing estimated rock volume totals divided into elevation zones for all spurs on Jetty A, no stone will be placed above MLLW, and there is very little to no existing jetty stone expected to be present within either of these elevation ranges. About 10,800 cy of rock will be placed below MLLW and represents 100% of the overall stone placement on these portions of Jetty A. The footprint of the Jetty A spurs will increase from 0 acres to ~ 0.61 acres beyond existing relic stone. In the relevant figures, note that the difference in the vertical and horizontal scales causes a slight representational distortion.

Table 8. Jetty A Spur Groin Feature

Spur Groin Feature	Jetty A
Number of spurs on channel side or downstream for Jetty A	1
Number of spurs on ocean side or upstream for Jetty A	1
Approximate total rock volume per spur (+/- 20%)	JA1C: 9,650 tons (~ 6,031 cy) JA2O: 7,330 tons (~ 4,581 cy)
Approximate total rock volume (all spurs) (+/- 20%)	25,000 tons (~ 15,625 cy)
Approximate area affected by each spur	JA1C: 0.33 acres; JA2O: 0.29 acres
Approximate total area affected (all spurs)	0.61 acres
Approximate area of spurs above water	JA1C: 0%; JA2O: 0%
Approximate area of spurs below -20 MLLW	JA1C: 1%; JA2O: 0%
Approximate dimension of spurs: length x width x height (ft)	JA1C: 135 x 105 x 18 JA2O: 125 x 100 x 15

Figure 23. Jetty A Spur Groin JA1C

Note difference in scale between vertical and horizontal axes.



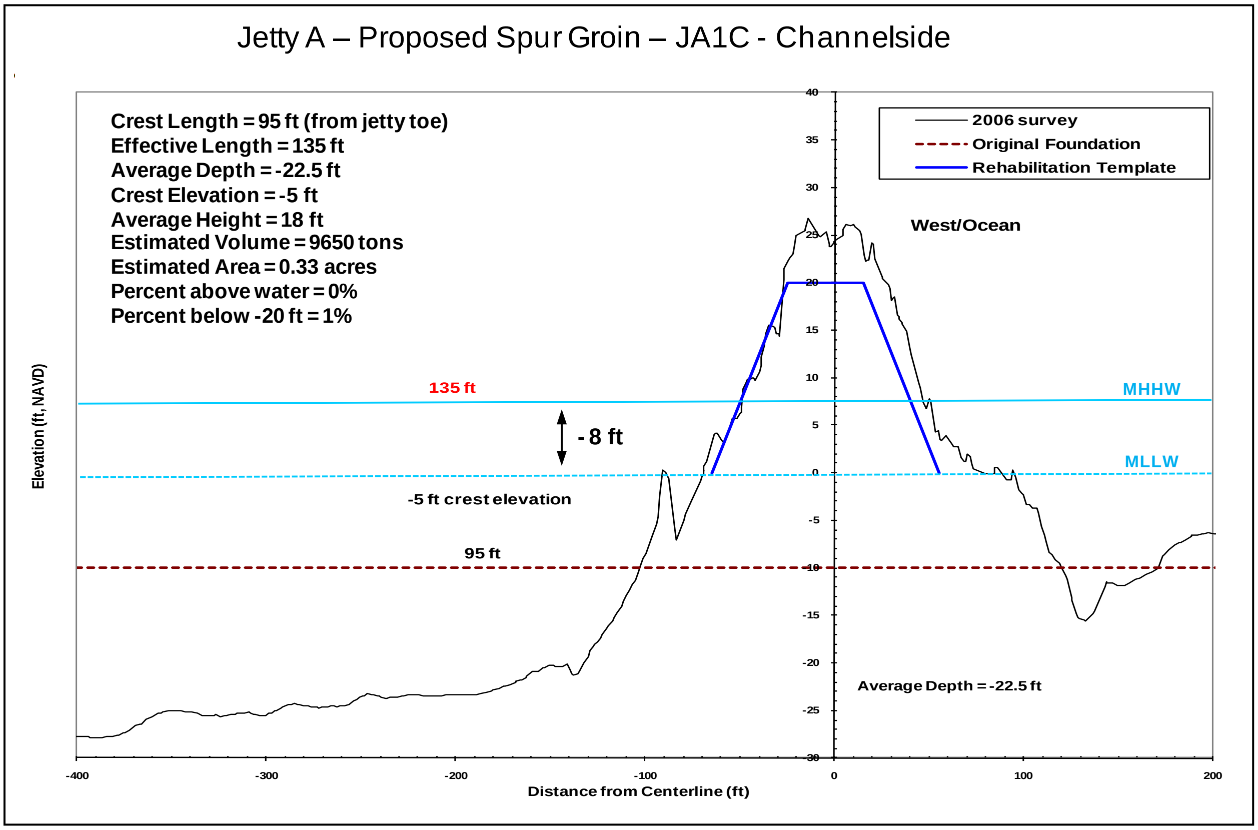
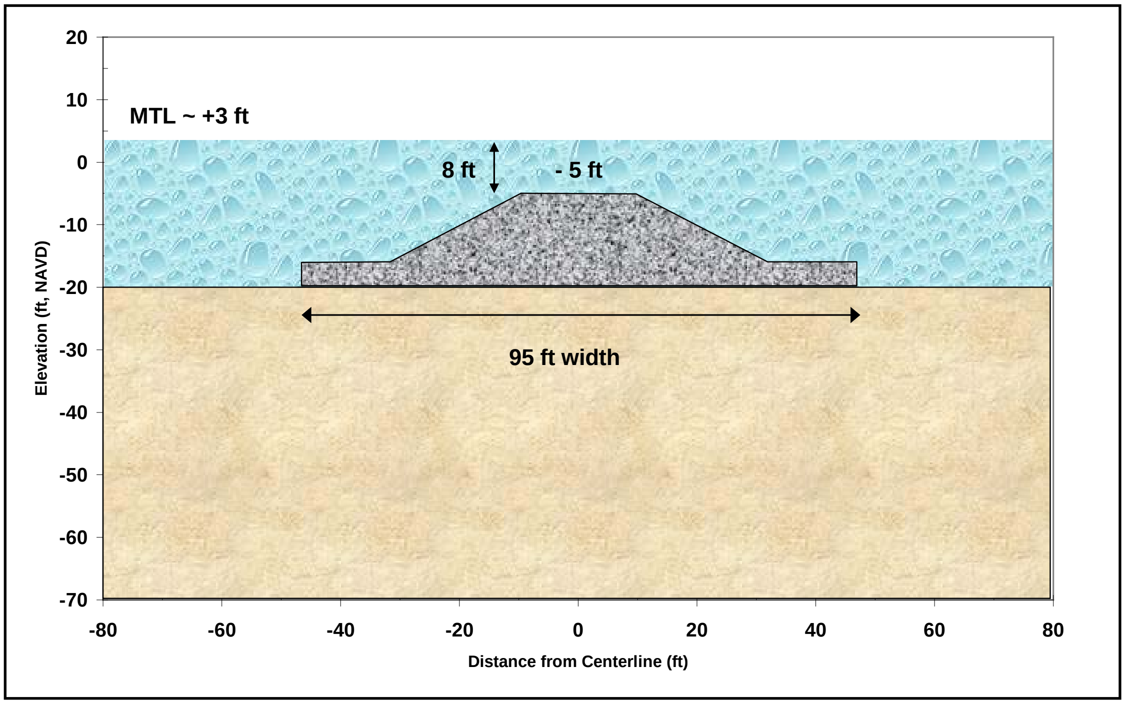
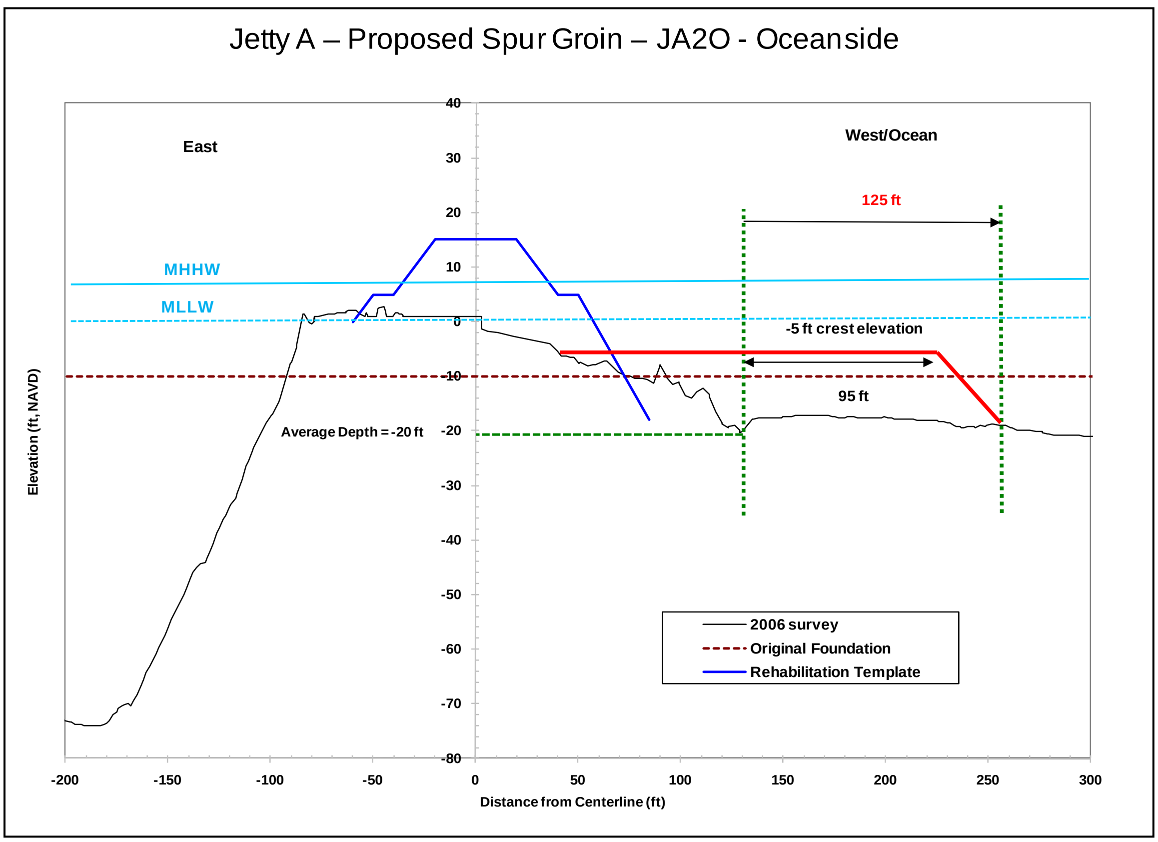


Figure 24. Jetty A Spur Groin JA2O

Note difference in scale between vertical and horizontal axes.





Jetty A Head Capping

An armor stone cap of approximately 24,000 tons (~ 15,000 cy) or equivalent concrete armor units will be placed on the head of the Jetty A to stop its deterioration (Figure 21). The features of this work are shown in Table 9.

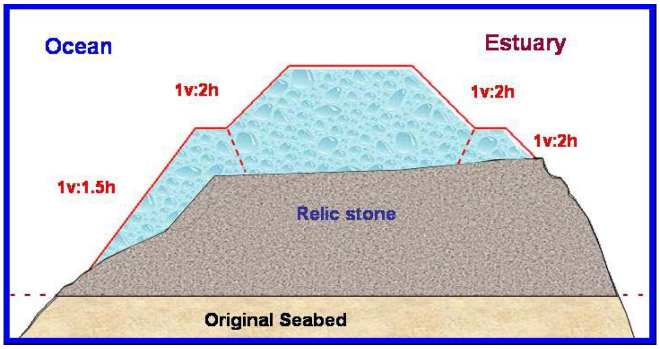
For capping of the head, divided into elevation zones about 7,920 cy of rock will be placed above MHHW. This represents 44% of the overall stone placement on this portion of Jetty A and there is very little or no existing jetty stone expected to be present within this elevation range. About 4,740 cy of rock will be placed between MHHW and MLLW. This represents a 26% of the overall stone placement on this portion of Jetty A and there is very little or no existing jetty stone expected to be present within this elevation range. About 5,420 cy of rock will be placed below MLLW. This represents 30% of the overall stone placement on this portion of Jetty A and a 1783% change from the existing jetty prism, as there is very little or no existing mounded jetty stone expected to be present within this elevation range.

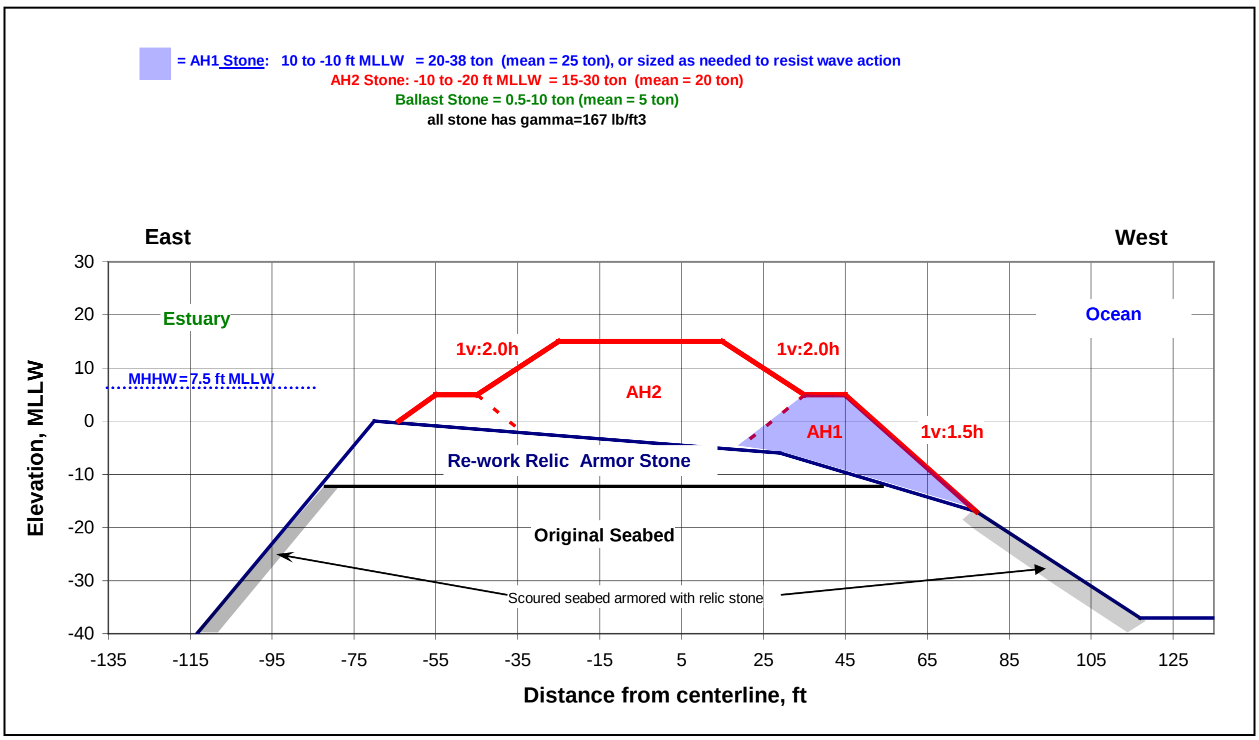
In all zones, all proposed stone placement will occur on existing base relic stone that formed the original jetty cross-section and was displaced and flattened by wave action, and does not include any modification that changes the character or increases the scope or size of the original structure design. The terminus of the head is simply closer to shore on a shorter jetty structure. . The footprint of the existing jetty mound on the flattened relic stone is approximately 0.64 acres, and the additional capping on the relic stone increases the width of the prism approximately 0.09 acres, for a total footprint of 0.73 acres on the existing relic stone.

Table 9. Jetty A Head Cap Feature

Features	Jetty A
Location of cap	stations 91 to 93
Timing of construction	2015
Dimensions of cap: length x width x height (feet)	200 x 160 x 40 (0.73 acres)
Stone size	30 to 40 tons
Area affected (outside relic stone)	None
% of cap constructed on relic stone	100%
Construction method	Land-based crane

Figure 25. Jetty A Head Cap





CONSTRUCTION MEASURES AND IMPLEMENTATION ACTIVITIES

Construction Schedule and Timing

The preferred in-water work window for the Columbia River estuary at the mouth is 1 November to 28 February. However, seasonal inclement weather and sea conditions preclude safe, in-water working conditions during this timeframe. Therefore, it is likely that most of in-water work for constructing spur groins, head capping, cross-section repairs, constructing off-loading facilities, etc. will occur outside this period during calmer seas, mostly between April and October.

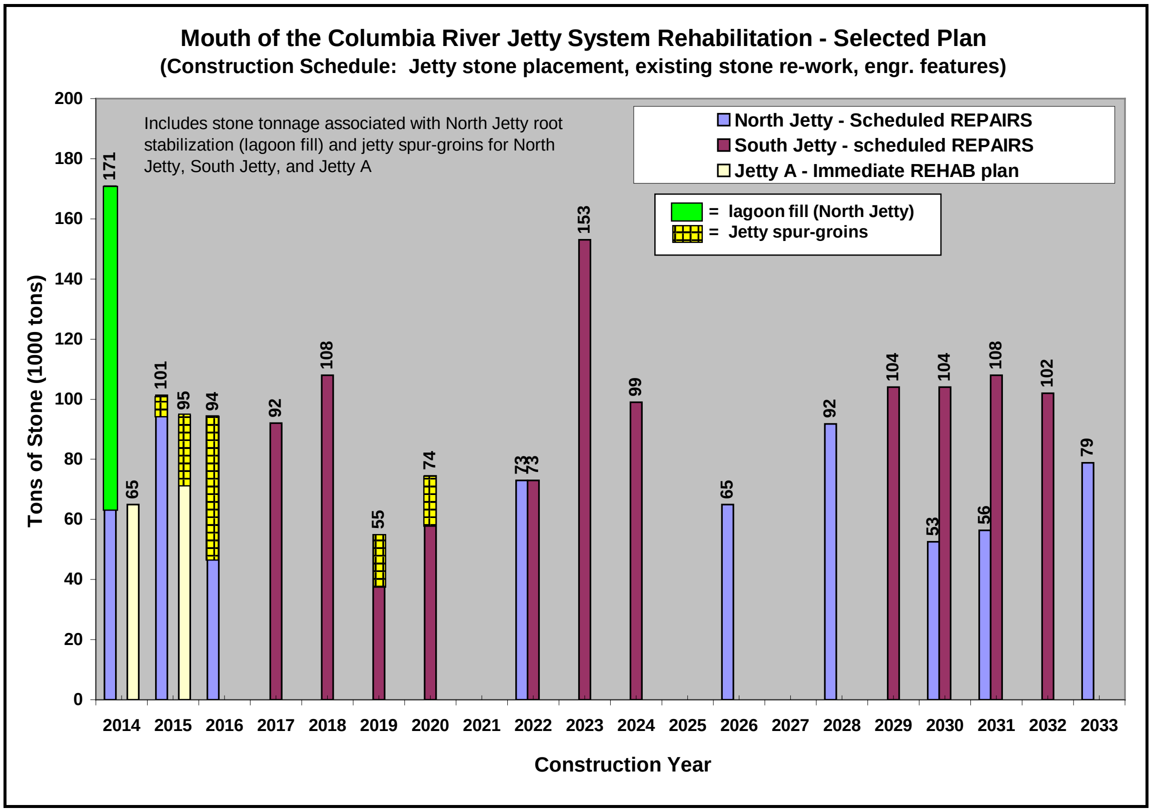
Most landward work on the jetties will be occurring from 1 April to 15 October. Work is assumed to occur 1 June to 15 October on the more exposed sections of the jetties. Placement work may extend beyond these windows if weather and wave conditions are conducive to safe construction and delivery. Stone delivery by land or water could occur year-round, depending on delivery location and weather breaks. Barge delivery would most likely occur during the months of April through October or at other times of the year depending on breaks in the weather and which jetty is being used. Quarrying of the rock may be limited to the months of April through October depending on the regulations pertinent to each quarry.

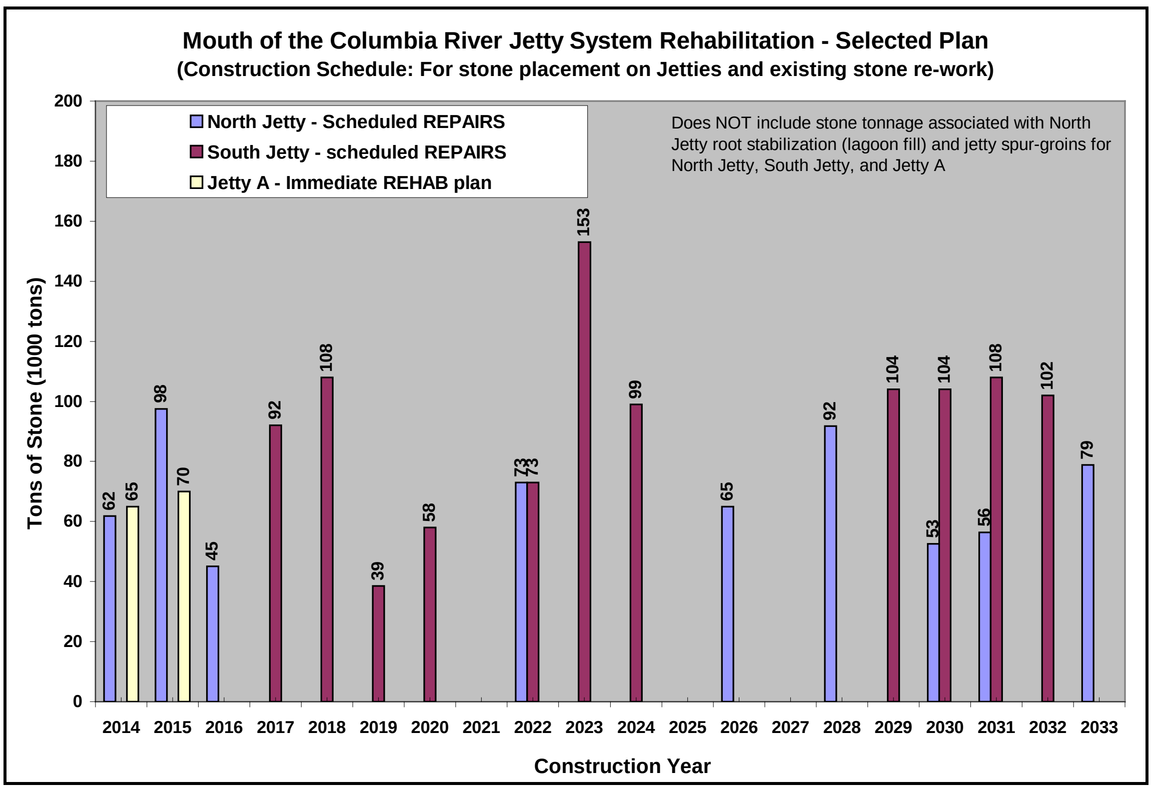
Work elements fall into four general categories for scheduling: (1) rock procurement, quarrying, and delivery transport, (2) construction site preparation, (3) lagoon fill and dune augmentations, and (4) jetty repair and rehabilitation work with construction of the design features including head capping and spur groins. Site preparation would consist of the preparation of the rock stockpile storage and staging areas, as well as the construction of any barge-offloading facilities that may be required. Approximate transport quantities by method are 30 tons per truck and 6,500 tons per barge. The majority of the jetty rehabilitation work is expected to be conducted from the top of the jetty downward using an excavator or a crane. Areas which may require marine plant work include construction at the jetty heads and some of the deeper spur groins.

For design and cost-benefit estimates, the project was modeled and designed for a 50-year operational lifespan. The schedule shown in Figure 26 illustrates construction actions related to building engineered features anticipated to occur at any one or some combination of all three of the jetties for the duration of 20 years. It also includes a predicted schedule of repair actions that the Corps' model estimates will be necessary within that same time period. Additional repairs have also been predicted to occur after the initial 20-year construction schedule and within the 50-year lifespan of the project. Additional repairs beyond the 20-year schedule will be similar in scale and nature to those described above in the standard repair template. Repair actions are generally triggered when a cross-section of the jetty falls below about 30%-40% of the standard repair template profile. The schedule described further in the narrative is a combined reflection of constructing specific engineered features and forecasting needed repairs. Real-time implementation of repair actions will likely vary based on evolving conditions at the jetties and could be shifted within and beyond this 20-year construction schedule.

In the construction schedule, rock production and stockpiling material begins in 2013. The first jetty installation is scheduled for late spring 2014 and continues through 2033. The estimate assumes the work will be accomplished with multi-year contracts.

Figure 26. Construction Schedule





Due to pinniped use at the South Jetty, the Corps proposes to conduct monitoring per conditions in the expected IHA permit. The Corps anticipates that the new IHA permit will entail requirements similar to those in the previous permit. These previous requirements included monitoring and reporting the number of sea lions and seals (by species if possible) present on the South Jetty for 1 week before (re)starting work on this jetty. During construction, the Corps provided weekly reports to the NMFS, which included a summary of the previous week's numbers of sea lions and seals that may have been disturbed as a result of the jetty repair construction activities. These reports included dates, time, tidal height, maximum number of sea lions and seals on the jetty and any observed disturbances. The Corps also included a description of construction activities at the time of observation. Post-construction monitoring occurred with one count every 4 weeks for 8 weeks, to determine recolonization of the south jetty. The Corp anticipates future monitoring and reporting requirements will be similar and will designate a biologically trained on-site marine mammal observer(s) to carry out this monitoring and reporting. The Corps will submit the required reports to the NMFS and the AMT. The Oregon Department of Fish and Wildlife, who monitors sea lion use of the South Jetty, will also be apprised of the Corps work and results of the monitoring efforts.

Conservation Measures the Corps will implement in order to minimize disturbance to Stellar sea lions includes the following; during land-based rock placement, the contractor vehicles and personnel will avoid as much as possible direct approach towards pinnipeds that are hauled out. If it is absolutely necessary for the contractor to make movements towards pinnipeds, the contractor shall approach in a slow and steady manner to reduce the behavioral harassment to the animals as much as possible. Monitoring and reporting will occur as required.

Construction Sequence and General Schedule

Rock procurement activities will be initiated for the North Jetty repair in 2013. In 2014, the on-site work will begin with filling the lagoon area behind the North Jetty root (stations 20 to 60) and installing a culvert to divert overland flow to another area that will not impact the North Jetty root stability. The lagoon area will be filled with rock, gravel, and sand. Once the lagoon is filled, the filled portion will serve as a staging and stockpile area for the rock delivered to the North Jetty site. To control further head recession of the North Jetty, in 2014 construction will focus on reconstructing the jetty head (station 88 to 99). This work will require haul road construction on top of the jetty from station 70 out to the head requiring approximately 31,000 tons of rock. The North Jetty will require installing a barge offloading facility on the channel side of the jetty at approximately station 45+00. Dredging of 30,000 cy is anticipated to provide the minimum 25-ft working clearance. Concurrently, work will begin on Jetty A beginning with constructing the off-loading facility, 60,000 cy of dredging to accommodate the rock delivery by barge, and constructing the jetty crest haul road from station 40+00 to 80+00. Total new stone consists of approximately 50,000 tons of imported rock, equivalent to 1,700 trucks or 8 barges.

In 2015 construction will continue on the North Jetty head from station 99 to 101 and installation of one spur groin at station 50 on the channel side. The haul road will need to be reworked with approximately 26,000 tons of new topping material. Work will occur concurrently with Jetty A beginning with 60,000 cy of dredging, completion of the jetty crest haul road from station 80 to 93, and installation of two spur groins. Total new stone for 2015 would consist of approximately

160,000 tons of imported rock, equivalent to 5,400 trucks or 25 barges. Work on Jetty A shall be completed this year.

In 2016, work continues on the North Jetty with placement of 36,000 tons of large armor near the head at station 80 to 88. This requires refurbishing the haul road and building vehicle turnouts. In addition, three spur groins will be installed at station 70-C, 80-O, and 90-C with a total of 50,000 tons of new stone. Total new stone would consist of approximately 86,000 tons of imported rock, equivalent to 2,900 trucks or 13 barges. Site preparation work and stockpiling stone at the South Jetty will occur to prepare staging and stockpile areas for 2017 construction.

In 2017, construction on the South Jetty is projected to begin, starting with construction work near the head from stations 173 to 176 and 180 to 195. South Jetty construction will require either a haul road be constructed on top of the jetty or constructed from a marine plant in order to get out to the head. Total work effort in 2017 is projected to consist of approximately 74,000 tons of rock; equivalent to 2,500 trucks or 12 barges.

Work continues on the South Jetty for the next 3 years working towards the head in 2018 with a total of 86,000 tons of new armor at station 290 to 311. Head construction begins in 2019 with 30,00 tons of new head armor and installation of 4 spur groins at stations 165–O, 210-C, 230-C, and 265-C for a total of 9,000 tons of spur groin rock. The South Jetty head completes in 2020 with 44,000 tons of new stone.

In 2022, construction is projected to occur concurrently on the North and South jetties: (1) continuation of North Jetty stone placement station 40 to 45 and station 65 to 73; and (2) continuation of stone placement on the South Jetty station 160 to 163, station 170 to 173, station 176 to 180, and station 195 to 200. Total rock tonnage for 2022 is estimated at 115,000 tons, equivalent to 3,850 trucks or 18 barges.

In 2023, construction continues on the South Jetty with the placement of approximately 118,000 tons of rock between stations 205 to 250. The haul road will need to be reworked with approximately 62,000 tons of quarry stone road base and topping material. Total jetty stone rock tonnage to be placed would require 4,000 trucks or 18 barge loads.

In 2024, construction continues on the South Jetty with the placement of approximately 76,000 tons of rock between stations 270 to 290. Total rock tonnage to be placed would require 2,600 trucks or 12 barge loads.

In 2026, construction resumes on the North Jetty with the placement of approximately 52,000 tons of rock between stations 20 to 30. The long time frame from the previous construction on the North Jetty will also require rebuilding the jetty haul road from station 20 to 30. Total rock tonnage to be placed would require 1,800 trucks or 8 barge loads.

In 2030, construction is projected to occur on the North and South jetties: (1) continuation of North Jetty stone placement station 30 to 40; and (2) continuation of stone placement on the South Jetty station 223 to 237, and station 250 to 253. Total rock tonnage to be placed is estimated at 129,000 tons, equivalent to 4,300 trucks or 20 barges.

In 2031, construction is projected to occur on the North and South jetties: (1) continuation of North Jetty stone placement station 88 to 99; and (2) continuation of stone placement on the South Jetty station 253 to 270. The North Jetty haul road will need to be re-built from station 65 to 99 and will require 30,000 tons of quarry waste material. Total armor stone rock tonnage to be placed is estimated at 135,000 tons, equivalent to 4,500 trucks or 21 barges.

In 2032, construction continues on the South Jetty with the placement of approximately 85,000 tons of rock between stations 295 to 311. Total rock tonnage to be placed would require 2,850 trucks or 13 barge loads. The offloading facility will be removed and scheduled construction will be complete for the South Jetty.

The final anticipated year of North Jetty rehabilitation is projected for 2033 with construction from stations 80 to 88. Total rock tonnage estimated is 63,000 tons, equivalent to 2,100 trucks or 10 barge loads. The offloading facility will be removed and scheduled construction will be complete for the North Jetty.

Because construction at the North and South jetties is spaced out from 2014 through 2033 with intermittent work, dredging at the barge offloading sites will only be required prior to a year of actual rock delivery in preparation for upcoming construction work. The Jetty A barge offloading site will only require dredging to make that site accessible for 2 years. Dredging will only be needed if the clearance depth at the barge offloading site is not found to be adequate prior to rock delivery activities.

Sources and Transportation of Rock

Rock Quarries and Transport

Currently, it is not exactly known where jetty rock will come from and how it will be transported to the jetty sites. However, one or more of the options discussed below would be employed (Figures 27 to 32 and Table 10). Stone sources located within 150 miles of a jetty are likely to be transported by truck directly to the jetty. Stone sources located at further distances, especially if they are located near waterways, are likely to be transported by truck to a barge onloading facility, then transported by tug and barge to either a Government-provided or commercial barge offloading site located nearby. Railway may also be an option for transporting stone, provided that an onloading site is convenient to the quarry. Most railroads follow main highway arterials, such as Interstate 5. The closest railroad terminal to the MCR South Jetty is at Tongue Point, east of Astoria, Oregon, which is about 15 miles from the jetty. The nearest railroad terminal to the MCR on the north side of the Columbia River is at Longview, Washington.

The Corps intends to use operating quarries rather than opening any new quarries. The Contractor and quarry owner/operator will be responsible for ensuring that quarries selected for use are appropriately permitted and in environmental compliance with all State and Federal laws.

Canadian Quarries. Quarries in British Columbia are typically located adjacent to waterways and rock produced from these quarries will likely have a limited truck haul. Due to the long distance to the MCR, plus the immediate availability to deep water, rock would likely be loaded onto barges and shipped down the Washington Coast to barge offloading sites.

Washington Quarries. Quarries located in northern Washington are typically not on the water, but are generally located within 50 miles of a potential barge on-loading site. As a result, rock would need to be hauled, at least initially, by truck. Rock would be transported by trucks most likely to a barge on-loading facility or possibly all the way to the staging site at the jetty. In the event of a combination of trucking and barging, trucks would be loaded at the quarry, and then traverse public roads to existing facilities. Once the rock is loaded on barges, it would be transported down the coast to barge offloading sites.

It also is possible that railway systems may be used to transport rock much of the way to the jetties. Burlington Northern Railroad operates a rail system that parallels Interstate 5 throughout Washington which would be the most likely route rock would be transported. Rock from the quarry would be taken by truck to a nearby railway station where they would be loaded onto railway cars and transported to an intermediate staging area. Trucks would then again take the rock the remainder of the way to the jetty staging areas.

Truck hauling of rock from northern Washington sources to the North Jetty or Jetty A most likely would be transported by public road to Interstate 5 or any of the main roads over to Highway 101. Trucks using Interstate 5 would either turn at Longview on Highway 4 to Highway 101, or cross over the Longview Bridge to Highway 30 near Rainier, Oregon. From this point they would proceed west to Astoria to Highway 101, crossing the Astoria-Megler Bridge through Ilwaco to the jetty staging areas. Delivery to the South Jetty most likely would use main roads to Interstate 5 or any of the main roads over to Highway 101.

Trucks using Highway 101 south through Washington would likely cross the Astoria-Megler Bridge, go through Warrenton using local roads into Fort Stevens State Park and the staging area. Trucks utilizing Interstate 5 would either turn at Longview on Highway 4 to Highway 101, or on Highway 30 near Rainier, proceeding through Astoria to Highway 101, going through Warrenton through local roads into Fort Stevens State Park and the jetty staging area.

Rock located within southern Washington would likely be trucked to the jetty staging areas. An exception to this would be a quarry that occurs within just a few miles of a port on the Washington Coast or a quarry that is near the Columbia River. In either of these two barge possibilities, rock would be delivered by truck to a barge on-loading facility, loaded on oceangoing or riverine barges, and delivered to one of the barge offloading facilities (see section on barge offloading facilities below). Truck hauling of rock from this area to the jetties would be as described above.

Oregon Quarries. Rock located in northern Oregon within 50 miles of the North Jetty and Jetty A would likely utilize any of the main roads over to Highway 101 or Highway 30. From this point they would cross the Astoria-Megler Bridge and proceed west through Ilwaco to the jetty staging areas. Quarries exceeding 50 miles from the jetties would likely utilize main roads at a farther distance from the jetty sites. This would involve longer haul distances on Highways 101, 30, 26, and others before crossing the Astoria-Megler Bridge and proceeding to the staging areas.

Truck hauling of rock from quarries within 50 miles of the South Jetty will most likely utilize any of the main roads over to Highway 101 or Highway 30. From this point they would proceed through Astoria and Warrenton, or Seaside and Gearhart to local roads leading to Fort Stevens State Park and the jetty staging areas. Quarries exceeding 50 miles from the jetty would likely utilize main roads at a farther distance from the jetty site. This would involve longer haul distances on Highways 101, 30, 26, and others before going through Astoria and Warrenton, or Seaside and Gearhart to local roads leading into Fort Stevens State Park and the staging areas.

The likely mode of transportation from southern Oregon quarries is trucking, or a combination of trucking and barging. Many of the quarries may be near the Oregon Coast; however, they may not be near a port facility that has barge on-loading capability. Providing that barge facilities are available, rock located south of Waldport would be loaded at the quarry onto trucks and traverse main public roads to the barge on-loading site, loaded on ocean-going barges, and shipped up the Oregon Coast to one of the barge offloading facilities (see section on barge offloading facilities below). Quarries north of Waldport would most likely be hauled by truck the entire distance.

Southern Oregon rock sources requiring trucking would be loaded onto lowboy trucks one to three at a time and would traverse main roads to more main arterials such as Highway 101 or, to a lesser degree, Interstate 5. An effort would be made to use the least distance possible to transport the rock without sacrificing transport time.

California Quarries. For northern California quarries, there would be a very long haul distance required to get rock to the jetty repair areas. Barging of rock would be the only economically feasible option. Rock would be transferred by truck from the quarries along main roads leading to Highway 101 to a barge offloading facility.

Figure 27. Potential Quarry Locations (red dots) for Repairs to MCR Jetties

See corresponding quarry information located in Table 10.

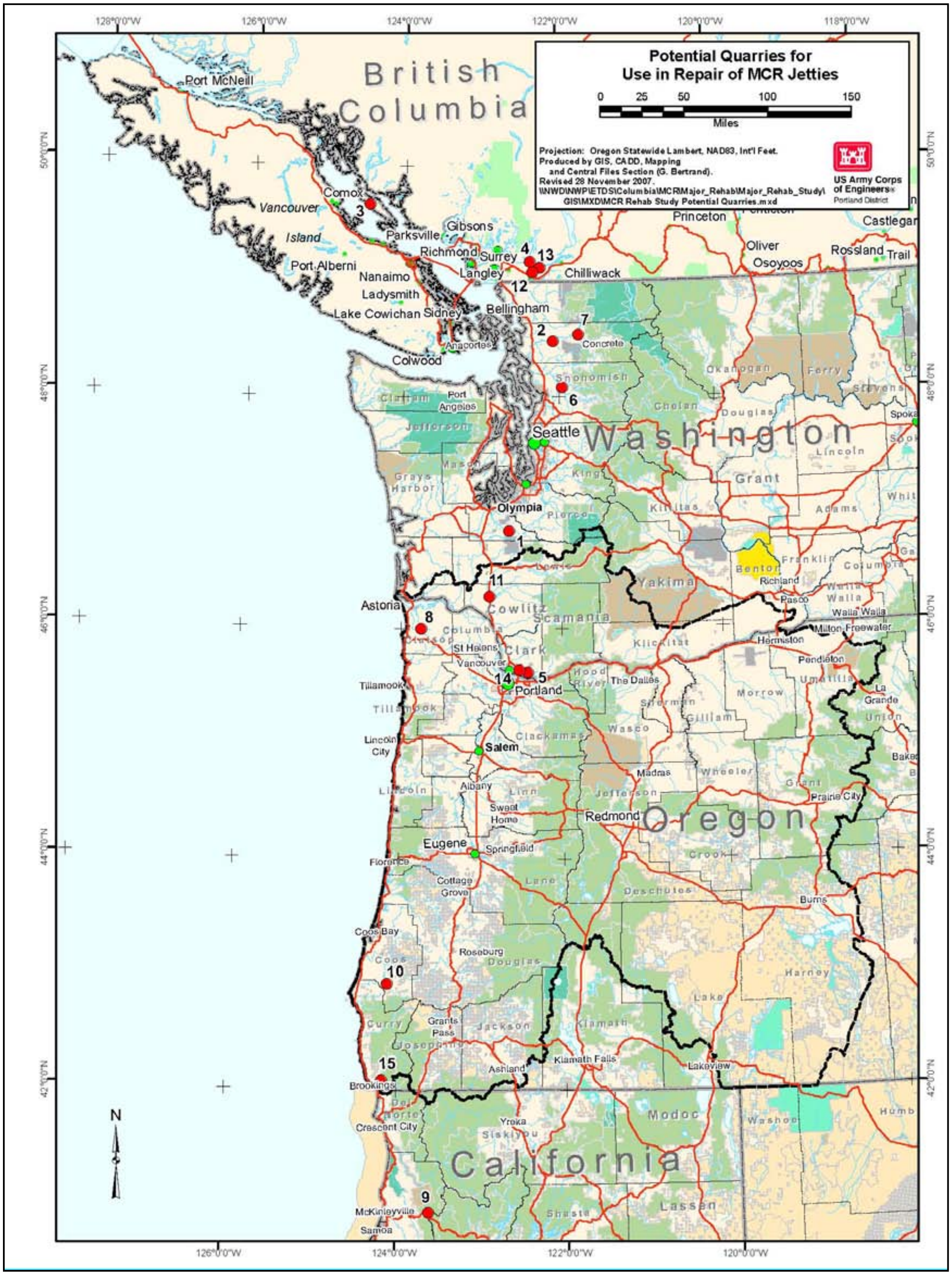


Table 10. Quarry Information

See Figure 27 for site map.

No.	Quarry	County and State	Nearest City	Road Miles from MCR	Unit Weight (pcf)	Reserves Available (tons)	Likely Transportation Method	Nearest Barge Facility
1	Columbia Granite Quarry	Thurston, WA	Vail, WA	129	168.5	28 M	Truck	N/A
2	Beaver Lake Quarry	Skagit, WA	Clear Lake, WA	251	181.1	1.86 M	Truck, then Barge	Anacortes, WA
3	Texada Quarry	BC, CANADA	Texada Island, BC	363	173.5+	275 M	Barge	Onsite
4	Stave Lake Quarry	BC, CANADA	Mission, BC	311	169.1	74 M	Truck, then Barge	Mission, BC, Canada
5	192nd Street Quarry	Clark, WA	Camas, WA	109	168.5	0.5 M	Truck/Barge	Camas, WA
6	Iron Mountain Quarry	Snohomish, WA	Granite Falls, WA	225	174	Unknown	Truck	N/A
7	Marble Mount Quarry	Skagit, WA	Concrete, WA	276	189.7	2 M	Truck, then Barge	Anacortes, WA
8	Youngs River Falls Quarry	Clatsop, OR	Astoria, OR	20	181.8	0.5 M+	Truck	N/A
9	Liscomb Hill Quarry	Humboldt, CA	Willow Creek, CA	515	179.1	0.5 M	Truck, then Barge	Eureka, CA
10	Baker Creek Quarry	Coos, OR	Powers, OR	275	200	Unknown	Truck, then Barge	Coos Bay, OR
11	Phipps Quarry	Cowlitz, WA	Castle Rock, WA	69	167.4	0.5 M	Truck	N/A
12	Cox Station Quarry	BC, CANADA	Abbotsford, BC	313	167.9	150 M	Barge	Onsite
13	Ekset Quarry	BC, CANADA	Mission, BC	309	172.2	10 M	Truck, then Barge	Mission, BC, Canada
14	Fisher Quarry	Clark, WA	Camas, WA	108	168.5	2 M	Barge	Camas, WA
15	Bankus Quarry	Curry, OR	Brookings, OR	347	183 & 195	0.7M	Truck, then Barge	Crescent City, CA

Figure 28. Potential Canadian Rock Source Transportation Routes

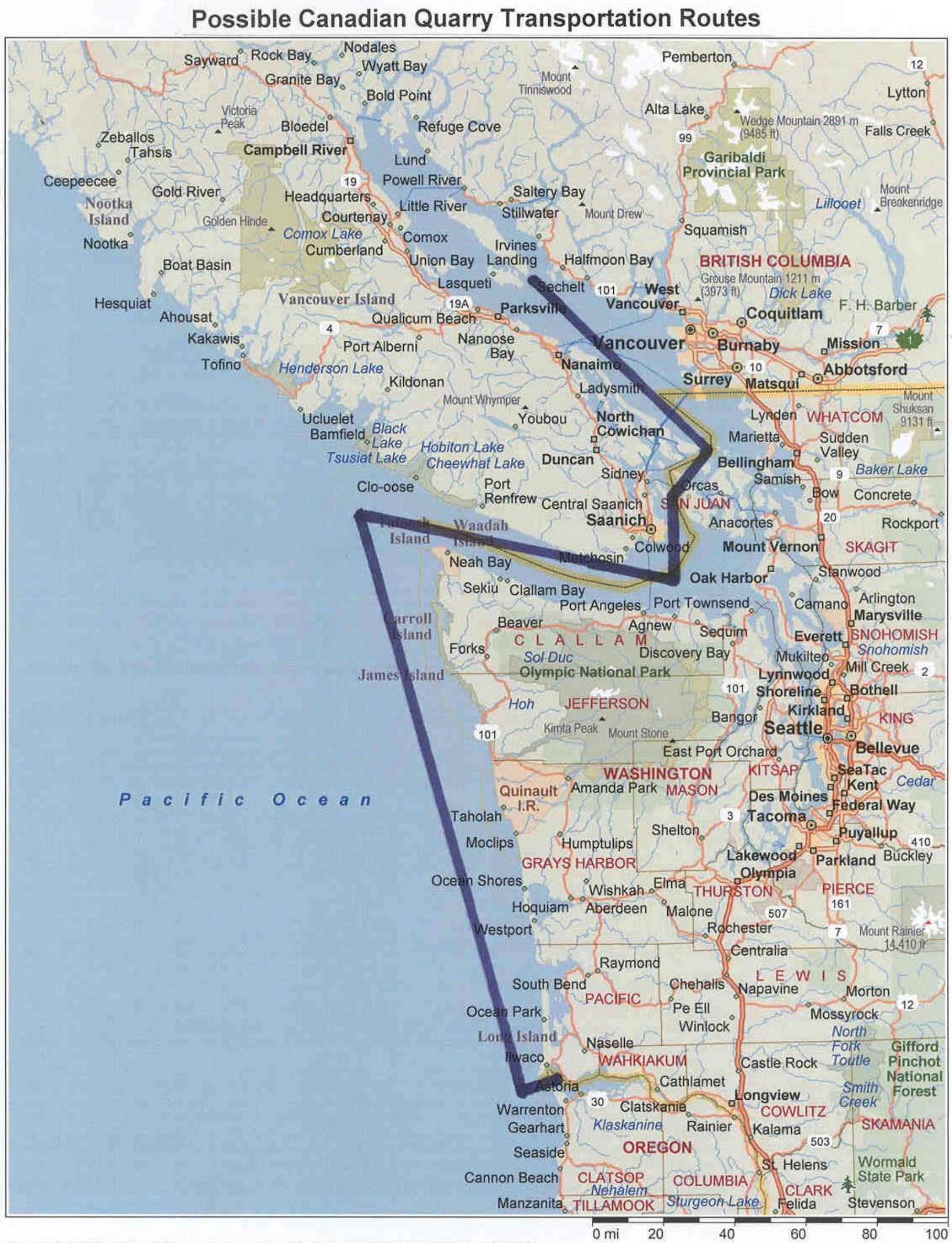


Figure 29. Potential Washington Rock Source Transportation Routes

Figure 30. Potential Oregon Rock Source Transportation Routes

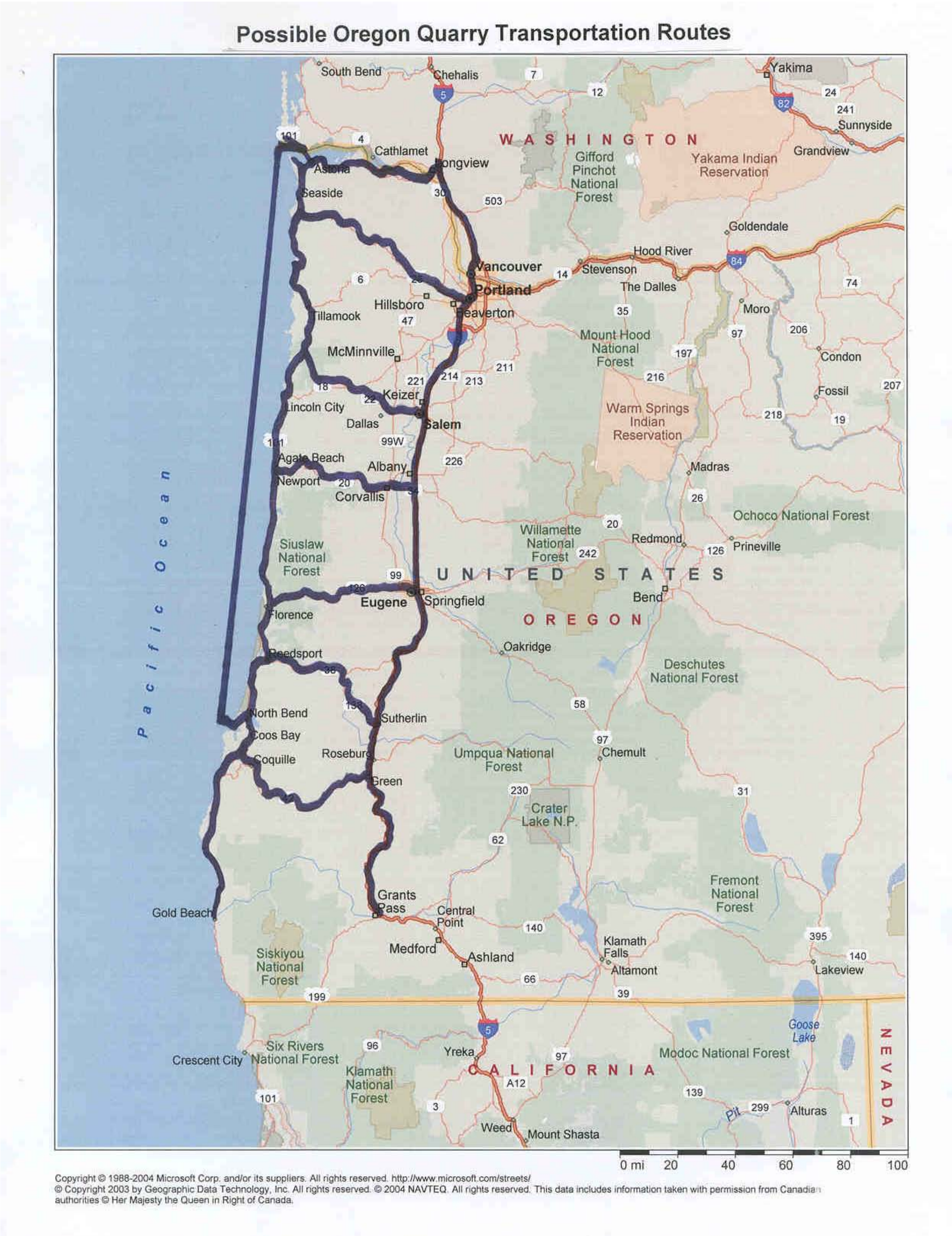


Figure 31. Potential Northern California Rock Source Transportation Routes

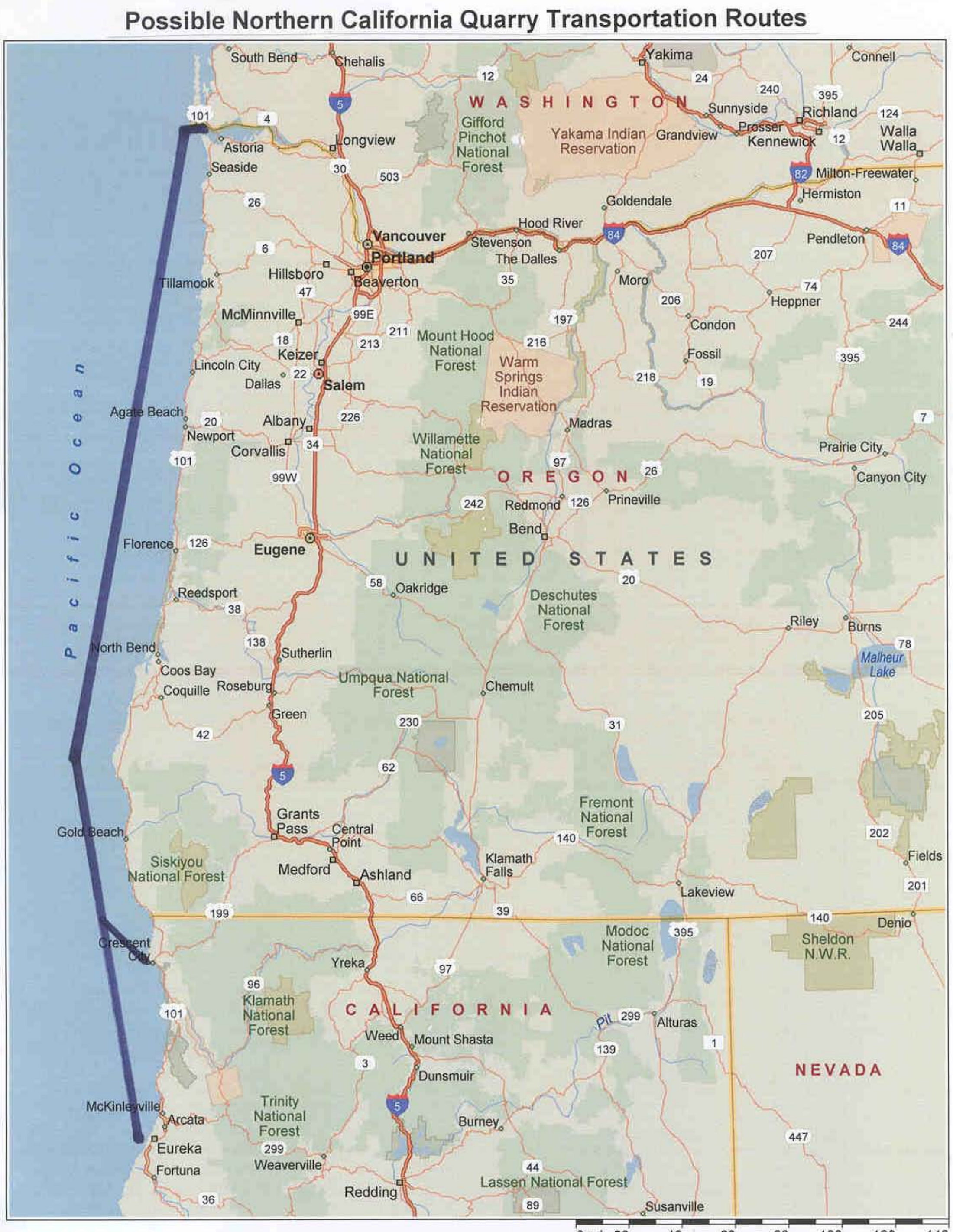


Figure 32. Potential Railway Transportation Routes

For water-based delivery of rock, a tow boat and barge would deliver the rock to the channel side of the jetties where water depth, waves, and current conditions permit. During rock offloading, the barge may be secured to approximately 4 to 8 temporary dolphins/H-piles to be constructed within 200 feet of the jetty. Rock would be off-loaded from the barge by a land- or water-based crane and either placed directly within the jetty work area or stock piled on the jetty crest for subsequent placement at a later time.

For land-based delivery of rock, jetty access for rock hauling trucks would be via an existing paved road to the Benson Beach parking lot at Cape Disappointment State Park (North Jetty) and via an existing paved road to the Parking Lots C and D at the South Jetty. An existing overland route between Jetty A and North Jetty may also be used for land-based hauling. Work areas for delivery of rock, maneuvering of equipment, and stockpiling of rock near the jetties have been identified and are shown in Figures 33-35.

Barge Offloading Facilities

Stone delivery by water could require up to four barge offloading facilities that allow ships to unload cargo onto the jetty so that it can then be placed or stockpiled for later sorting and placement. The range of locations for these facilities is shown in Figures 33-35. Depending on site-specific circumstances, offloading facilities may be converted to spur groins, may be partially removed and rebuilt, may be permanently removed, or may remain as permanent facilities upon project completion. Facility removal will depend on access needs and evolving hydraulic, wave, and jetty cross-section conditions at each offloading locations.

Facilities will range from approximately 200- to 500-ft long and 20- to 50-ft wide, which ranges from about 0.48 to 2.41 acres in total area. For initial construction of all four facilities combined, approximately up to 96 Z- or H-piles could be installed as dolphins, and up to 373 sections of Z- or H-piles to retain rock fill. Figure 36 shows a cross section diagram for stone access ramp at potential barge offloading facilities and photos illustrating typical barge offloading facilities. Facilities will have a 15-ft NGVD crest elevation and will be installed at channel depths between -20 and -30 NGVD. A vibratory hammer will be used for pile installation and only untreated wood will be used, where applicable. Removal and replacement of the facilities could occur within the duration of the construction schedule. Volume and acreage of fill for these facilities are shown in Table 11.

Table 11. Approximate Rock Volume and Area of Barge Offloading Facilities and Causeways

Location	Approximate Length (ft)	Approximate Rock Volume (cy) Below 0 MLLW	Total Approximate Rock Volume (cy)	Approximate Square Feet	Acres
North Jetty	200	7,778	29,640 cy	21,000	0.48
Jetty A – near head	200	7,778	29,640 cy	21,000	0.48
Jetty A – mid-section causeway	5000	38,888	38,888	105,000	2.41
South Jetty – Parking Area D	450	17,417	33,688 cy	47,250	1.08
South Jetty – Along Jetty Turn-out	200		18,640 cy	21,000	0.48

Figure 33. North Jetty Offloading, Staging, Storage and Causeway Facilities

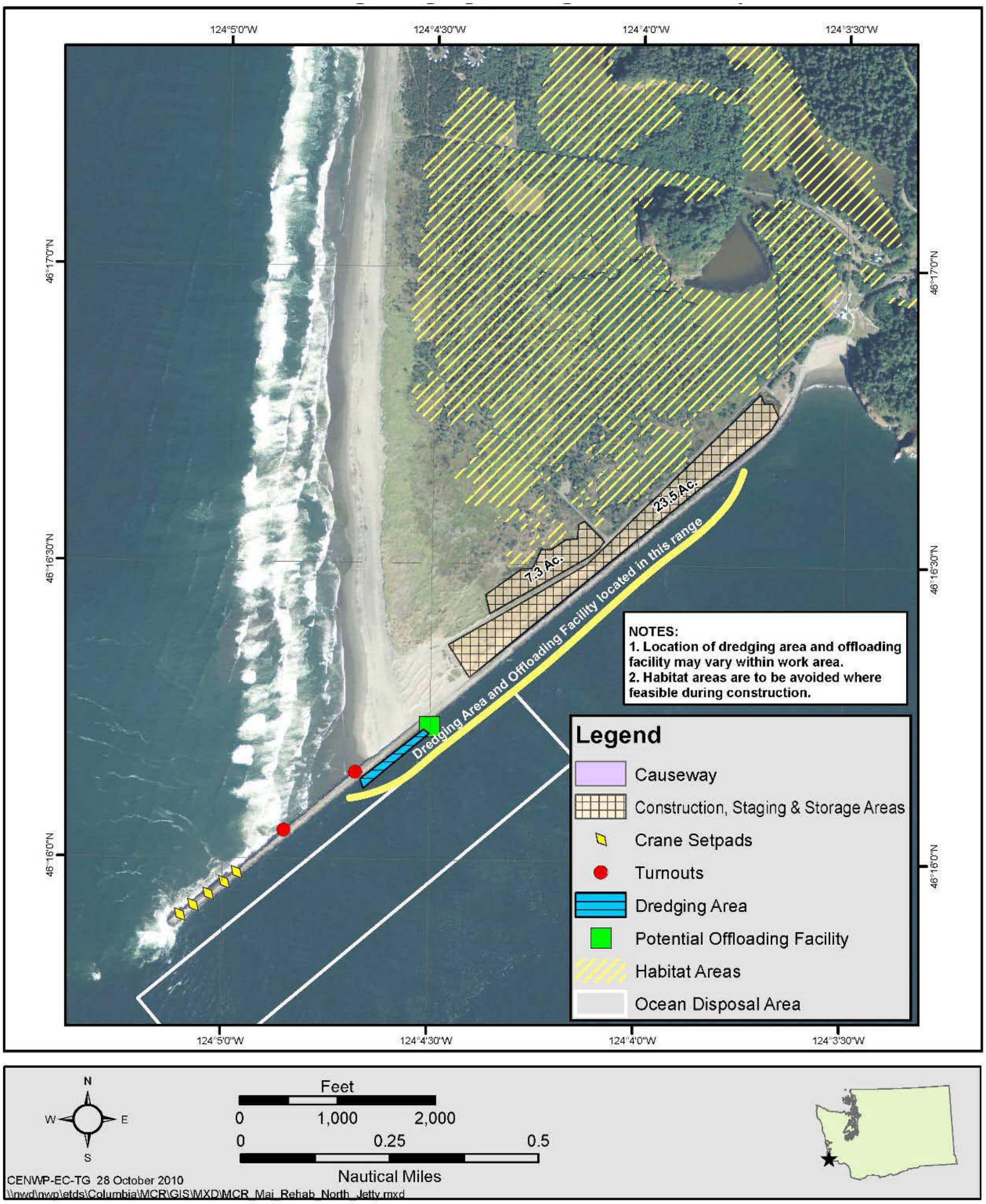


Figure 34. South Jetty Offloading, Staging, Storage and Causeway Facilities

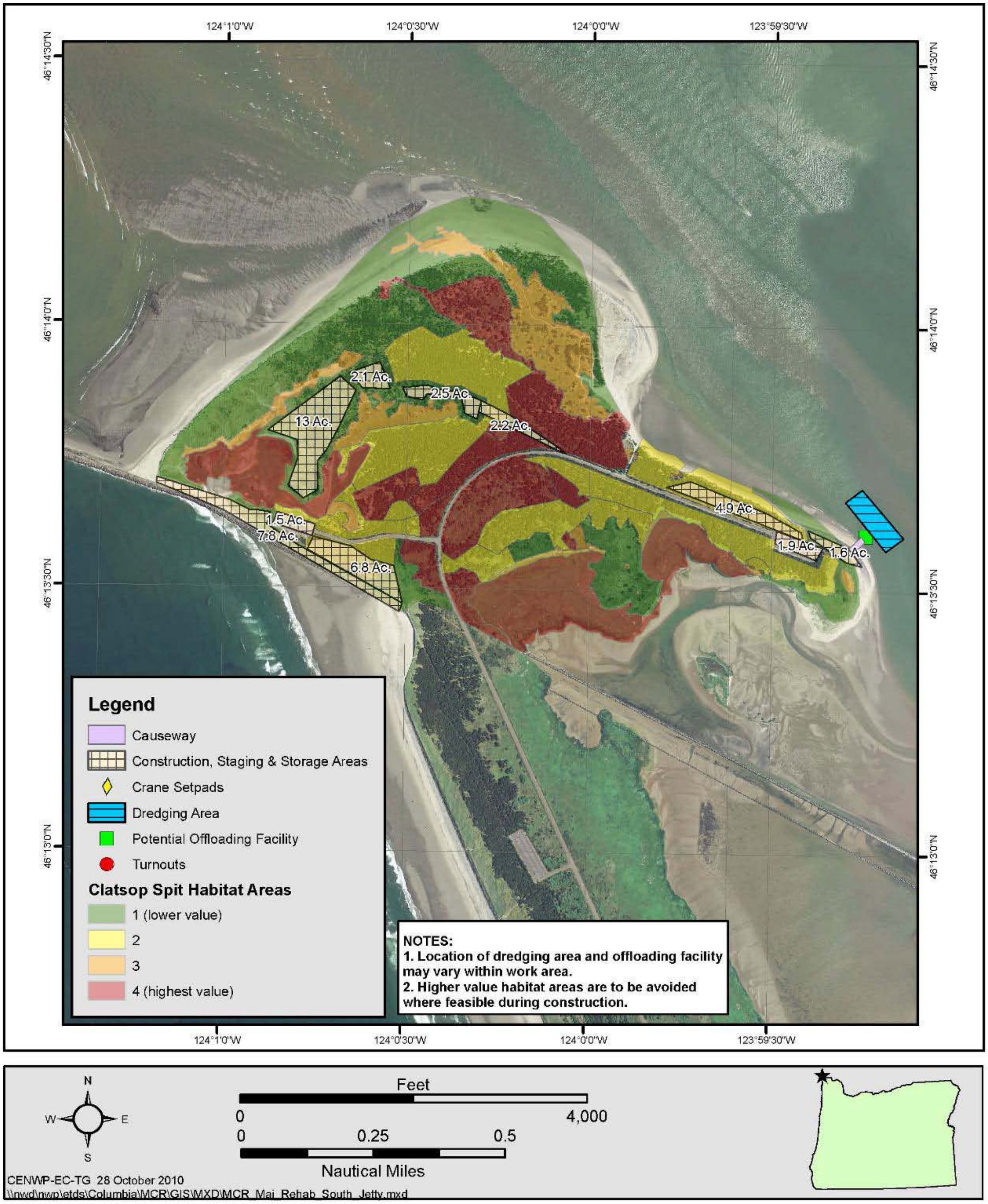


Figure 34 (continued). South Jetty Offloading, Staging, Storage and Causeway Facilities

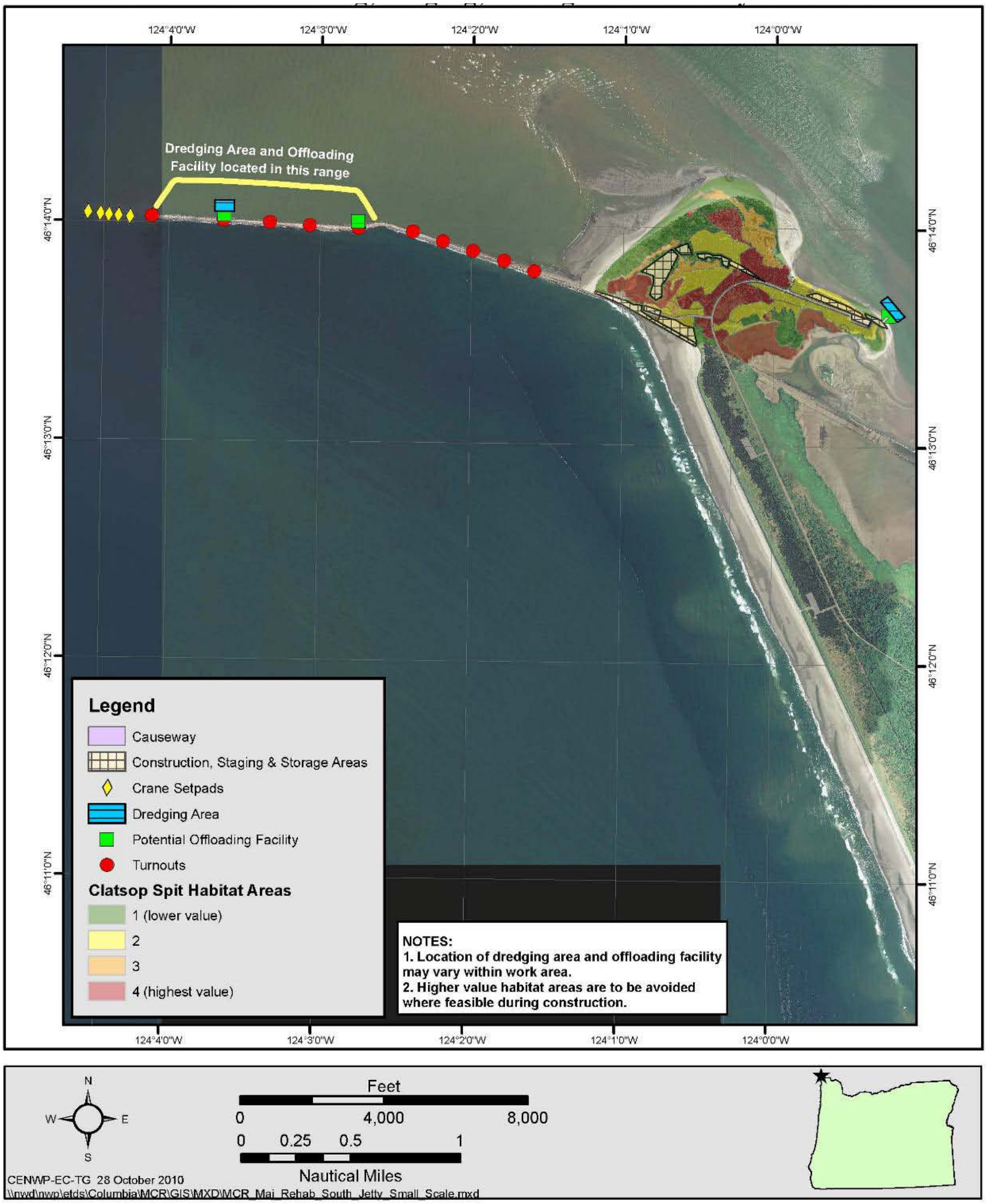


Figure 35. Jetty A Offloading, Staging, Storage and Causeway Facilities

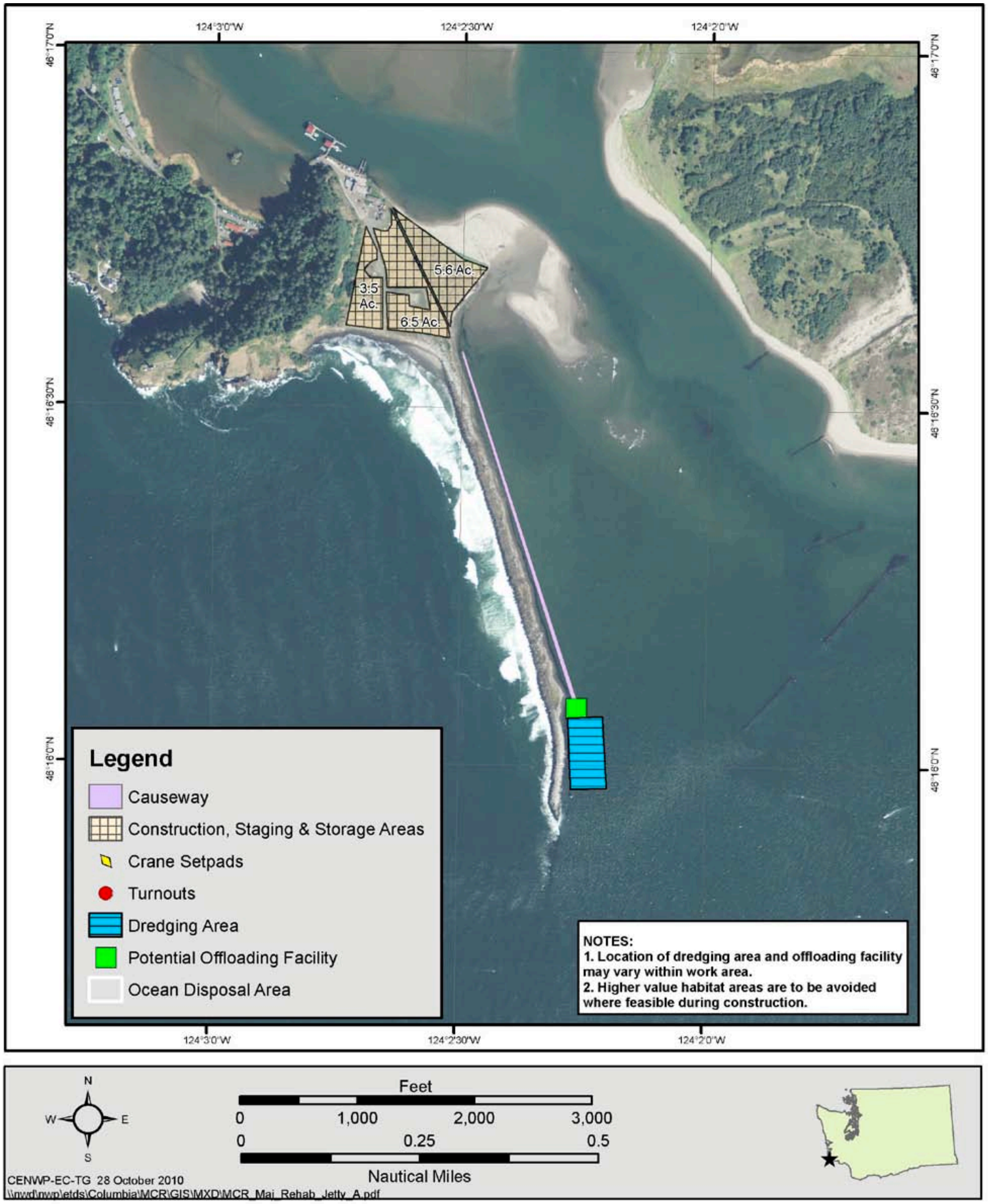


Figure 36. Cross Section of Stone Access Ramp at Barge Offloading Facilities at East End of Clatsop Spit near Parking Area D and Photos of Typical Barge Offloading Facilities

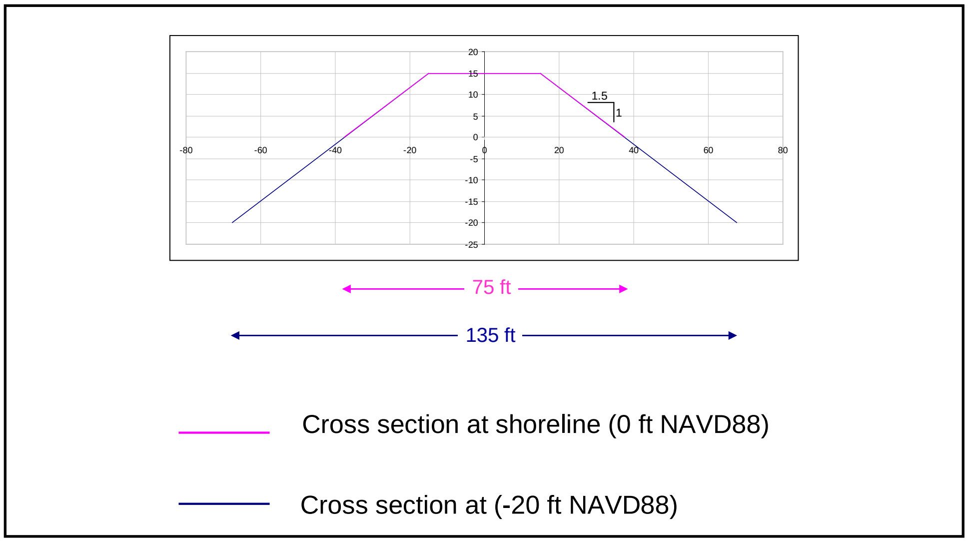


Figure 36 (continued)

The following existing private facilities may serve as potential offloading sites depending on availability for Corps' use:

- Commercial Site in Ilwaco. For the North Jetty, barges would pull up to a dock at Ilwaco where rock would be transferred by crane onto trucks that would proceed by public road to Cape Disappointment State Park. Trucks would then pass through the park grounds to the staging area adjacent to the jetty. For Jetty A, trucks would proceed through the Coast Guard facility to the staging area near the root of the jetty.

- Commercial Site in Warrenton. Nygaard Logging has a deep-water offloading site that could be used to offload rock. For the North Jetty/Jetty A, rock would be transferred to trucks that would likely use Highway 101 into Astoria, cross the Astoria-Megler Bridge, and head west through Ilwaco to Cape Disappointment State Park. Trucks would then pass through the park grounds to the staging area adjacent to the jetty. For the South Jetty, rock would be transferred to trucks which would then proceed west through Hammond to Fort Stevens State Park and use the existing park road to staging area adjacent to the jetty. This site needs no improvement to accommodate deep-draft vessels.

If existing facilities are not available or do not have adequate capacity to provide access, barge offloading facilities could be constructed at each jetty.

- North Jetty: Between or on the spur groin at/between Station 50 or 70, a barge offloading facility will be constructed. If wave conditions make it feasible, the spur groin designed for this area will first function as an offloading facility prior to conversion and stone removal to reach the spur's design depth. Otherwise, a separate facility will be installed in the reach between these two stations such that wave conditions allow safe offloading. This offloading facility will require 4-8 dolphins of 3 piles each for vessel tie-up, and sheet-pile installation will be required to shore-up and retain rock at the offloading point.

- Jetty A: An offloading facility will be sited near the location of the proposed spur groin around Station 81, at the upstream portion of the jetty near the head. The proposed spur groin could not be used for dual purposes, because it would have required additional, unnecessary rock in order to connect the offloading facility with the causeway. A 15-ft causeway will also be constructed along the entire length of the jetty on existing relic stone that runs adjacent to and abutting the upstream eastern portion of the jetty. This facility will likely remain a permanent facility, but may deteriorate due to wave and tidal action. This offloading facility will require 4-8 dolphins of 3 piles each for vessel tie-up, and sheet-pile installation will be required to shore-up and retain rock at offloading point.

- South Jetty: The South Jetty could have up to two associated offloading sites. One will be located at Parking Lot Area D near the northeastern-most corner of the Spit. The second facility will be located along the jetty and will resemble an extra-large turn-out facility. It is likely to be located somewhere on the northern, channel-side of the jetty and west of Station 270 in order to take advantage of deeper bathymetry and subsequently less need for dredging. The facility at Parking Lot Area D may be removed after 5 or more years depending on hydraulic impacts of the structure and spit. The facility along the jetty will likely be partially removed and rebuilt after each repair to avoid the potential for wave-focusing on the jetty. Otherwise, it will remain in place until around 2033. Each offloading facility will require 4-8 dolphins of 3 piles each for vessel tie-up, and sheet-pile installation will be required to shore-up and retain rock at offloading point.

Dredging for Barge Offloading Facilities

Transport of rock would most likely be done by ocean-going barges that require deeper draft (20-22 feet) and bottom clearance than river-going barges when fully loaded. Therefore, dredging will be required to develop each of the barge offloading facilities. Under-keel clearance should be no less than 2 feet. The elevation at barge offloading sites should have access to navigable waters and a dredge prism with a finish depth no higher than -25 feet MLLW, with advance maintenance and disturbance zone depths not to extend below -32 feet MLLW. These facilities should also provide for a maneuvering footprint of approximately 400 feet x 400 feet. The depth along the barge unloading sites would be maintained during the active period for which the rock barges will be unloaded.

A clamshell dredge would likely be used for all dredging, though there is a small chance that a pipeline dredge could be feasible but is unlikely to be used. The material to be dredged is medium to fine-grained sand, typical of MCR marine sands. Disposal of material would occur in-water at an existing approved disposal site. The volume of material to be dredged is shown in Table 12; these estimates are based on current bed morphology and may change. Also, maintenance dredging to a finish depth of -25 feet MLLW will be needed before offloading during each year of construction. Dredging is likely to occur on a nearly annual basis for the duration of the project construction period, but this will be intermittent per jetty, depending on which one is scheduled for construction in a particular year.

Table 12. Estimated Dredging Volumes for Barge Offloading Facilities

Location*	Estimated Dredging Volume (cy)		Approximate Acres
	Initial	Est. Maintenance**	
North Jetty	30,000	30,000	3.73
Jetty A	60,000	80,000	3.73
South Jetty	20,000	20,000	4.19
South Jetty - Parking Area D	20,000	20,000	4.19

* Some of the locations will not be used on an annual basis; it depends on the construction schedule for each jetty.
**All dredging will be based on surveys that indicate depths shallower than -25 feet MLLW.

Clamshell dredging is done using a bucket operated from a crane or derrick that is mounted on a barge or operated from shore. Sediment removed from the bucket is generally placed on a barge before disposal. This type of dredge is typically used in shallow water areas.

The following overall impact minimization practices and best management practices (BMPs) will be used for all maintenance dredging for offloading facilities.

1. To reduce the potential for entrainment of juvenile salmon or green sturgeon, the cutterheads will remain on the bottom to the greatest extent possible and only be raised 3 feet off the bottom when necessary for dredge operations.

2. To reduce turbidity, if a clamshell bucket is used, all digging passes shall be completed without any material, once in the bucket, being returned to the wetted area. Not dumping of partial or half-full buckets of material back into the project area will be allowed. No dredging of holes or sumps below minimum depth and subsequent redistribution of sediment by dredging dragging or other means will be allowed. All turbidity monitoring will comply with Sate 401 Water Quality Certification Conditions.
3. If the Captain or crew operating the dredges observes any kind of sheen or other indication of contaminants, he/she will immediately stop dredging and notify the Corps' environmental staff to determine appropriate action.
4. If routine or other sediment sampling determines that dredged material is not acceptable for unconfined, in-water placement, then a suitable alternative disposal plan will be developed in cooperation with the NMFS, EPA, Oregon Department of Environmental Quality (ODEQ), Washington Department of Ecology (WDOE), and other agencies.

Dredged Material Disposal Sites

Two dredged material disposal sites, the Shallow Water Site (SWS) and the North Jetty site, are located near the North Jetty. These are the most likely sites to be used. Modeling has showed that the potential changes to the two disposal sites from the proposed action would not inhibit their use as disposal sites. Spur groin construction at the North Jetty would avoid the North Jetty disposal site. The northern-most cells of this site immediately adjacent to the jetty will be avoided to reduce the possibility of vessel impact with the spur groins.

Pile Installation and Removal

As mentioned earlier, inclement weather and sea conditions during the preferred in-water work window (IWWW) preclude safe working conditions during this time period. Therefore, installation of piles is most likely to occur outside the IWWW. For initial construction of all four facilities combined, approximately up to 96 Z- or H-piles could be installed as dolphins, and up to 373 sections of Z or H pile to retain rock fill. They will be located within 200-ft of the jetty structure. Because the sediments in the region are soft (sand), use of a vibratory driver to install piles is feasible and will be used when necessary. The presence of relic stone may require locating the piling further from the jetty so that use of this method is not precluded by the existing stone. The dolphins/Z- and H-piles would be composed of either untreated timber or steel piles installed to a depth of approximately 15 to 25 feet below grade in order to withstand the needs of off-loading barges and heavy construction equipment. Because vibratory hammers will be implemented in areas with velocities greater than 1.6 ft/s, the need for hydroacoustic attenuation is not an anticipated issue. Piling will be fitted with pointed caps to prevent perching by piscivorous birds to minimize opportunities for avian predation on listed species. Some of the pilings and offloading facilities will be removed at the end of the construction period.

Rock Placement

Placement of armor stone and jetty rock on the MCR jetties would be accomplished by land or limited water-based equipment. Only clean stone will be used for rock placement, where appropriate and feasible. Where appropriate, there may also be some re-working and reuse of the existing relic and jetty prism stone. Fill for the jetty haul roads will not be cleaned prior to installation. Dropping armor stone from a height greater than 2 feet will be prohibited. During placement there is a very small chance of stone slippage down the slope of the jetty. However, this is unlikely to occur due to the size and cost of materials and placement.

Another approach to water-based rock placement would be via a jack-up barge. This would only be applicable at the South Jetty. For armor stone and rock placement at the head, a jack-up barge with crane could be used to serve as a stable work platform (Figure 37). Once into place, the jack-up barge would be jacked up on six legs so that the deck is at the same elevation as the jetty. The legs are designed to use high-pressure water spray from the end of the legs to agitate the sand and sink the legs under their own weight. The jacking process does not use any lubricants that contain oils, grease, and/or other hydrocarbons. The stone and rock will be barged to the jackup barge and offloaded onto the jetty head. The jackup barge will keep moving around the head of the jetty to complete the work. A jack-up barge would not be used on the North Jetty or Jetty A to avoid interference with navigation of fishing boats and crab and fish migrations.

Figure 37. Illustration of a Jack-up Barge

For land-based rock placement, a crane or a large track-hoe excavator could be situated on top of the jetty. The placement operation would require construction of a haul road along the jetty crest within the proposed work area limits. The crane or excavator would use the haul road to move along the top of jetty. Rock would be supplied to the land-based placement operation by land and/or marine-based rock delivery. For marine-based rock, the land-based crane or excavator would pick up rock directly from the barge or from a site on the jetty where rock was previously offloaded and stockpiled, and then place the rock within the work area. For land-based rock, the crane or excavator would supply rock via a truck that transports rock from the stockpile area. The crane or excavator would advance along the top of the jetty via the haul road as the work is completed.

In order to place stones, a haul road will be constructed on the 30-ft crest width of each jetty to allow crane and construction vehicle access. Roads will consist of an additional 3-ft of top fill material, which could also entail an additional 2-ft of width spill-over. These roads will remain in place for the duration of construction. Due to ocean conditions and the wave environment, these roads will likely need yearly repair and replacement. They will not be removed upon completion. Ramps from the beach up to the jetty road will also be constructed to provide access at each jetty.

At approximately 1000-ft intervals, turnouts to allow equipment access and passage will be constructed on the North and South jetties. These will consist of 50-ft long sections that are an additional 20-ft wide. Some of this stone for these facilities may encroach below MLLW. On the North Jetty, there will be approximately 2 turnouts. South Jetty will have approximately 8 turnouts with two additional larger-sized turnouts. These larger turnouts will be in the range of 300-ft long with an additional 20-ft width. One of these larger turnouts will function as an offloading facility on South Jetty. At Jetty A, the causeway will function as the turnout facility.

Towards the head of each jetty, additional crane set up pads will be constructed at approximately 40-ft increment to allow crane operation during the placement of the larger capping stones. Set-up pads will roughly entail the addition of 8 extra feet on each side of the crest for a length of about 50-ft. Some of this stone for these facilities may encroach below MLLW. Approximately 5 set-up pads will be required to construct each jetty head.

Construction Staging, Storage, and Rock Stock Piles

Jetty repairs and associated construction elements entail additional footprints for activities involving equipment and supply staging and storage, parking areas, access roads, scales, general yard requirements, and rock stock pile areas. It was determined that for most efficient work flow and placement, a 2-year rock supply would be maintained on site and would be continuously replenished as placement occurred on each jetty. In order to estimate the area needed, a surrogate area was determined for a reference volume of 8,000 cy, which was then used to extrapolate the area needed at each jetty. These results are shown in Table 13.

Table 13. Acreages Needed for Construction Staging, Storage, and Rock Stock Piles

Location	Approximate Acres
North Jetty	31
Jetty A	23
South Jetty	44

Several actions will be taken to avoid and minimize impacts from these activities. Staging and stockpiles will remain above MHHW and where feasible have also been sited to avoid impacts to wetlands and habitats identified as having higher ecological value. In order to maintain erosive resilience along the shoreline, a vegetative buffer will be preserved. When available and possible, partial use will be made of existing parking lots. Additional measures specific to each jetty have also been considered. Besides access roads in the areas identified in Figures 33-35, no additional roadways or significant roadway improvements are anticipated. Some roadway repair and maintenance will likely be required on existing roads experiencing heavy use by the Corps.

At the North Jetty, the lagoon and wetland fill necessary for root stabilization will also serve a dual purpose as for the bulk of staging and storage activities.

At the South Jetty, a small spur road will be required to connect the existing road with the proposed staging area and is indicated in Figures 33-35. The existing road along the neck of the South Jetty that will be used for dune augmentation work may require minor repair/improvements for equipment access. Construction access to the area receiving dune augmentation will be limited to an existing access road along the relic jetty structures at the neck of the spit. Equipment will be precluded from delivery using the access point from Parking Lot B in order to avoid impacts to water quality and razor clam beds in the vicinity of the proposed dune fill area. Grading equipment may have to access the area by driving along the shore, but this route will be used as a last resort and equipment will be limited to dry sand where feasible. Additionally, the proposed actions will avoid the more sensitive habitat areas south of Parking Lot D.

If possible, the project will avoid and minimize impacts to the adjacent marshland by allowing crossing between the construction area and jetty via a Bailey bridge, which may require small removable abutments on either end of the marsh crossing. Otherwise a series of culverts and associated fill will be installed, or equipment will be required to enter and exit from the same access road on the northeast end of the main staging area indicated in Figures 33-35.

Additionally, at the outlet of the marsh complex a culvert will be installed under the construction access road, which will allow continuous hydrologic connectivity between affected portions of the marsh and ocean exchange through the jetty. This will also avoid equipment passage through marsh waters. To connect the staging area to the jetty haul road, a temporary gravel access road would be constructed from the staging area nearest the jetty to the jetty crest. The access road would measure approximately 400 ft in length by 25 ft in width, would be above MHHW, would require approximately 4,000 cy of sand, gravel and rip rap, and would require the installation and removal of a temporary culvert near station 178+00 to maintain tidal exchange into and out of the intertidal wetland and through the jetty. The staging areas and haul roads, except for the jetty haul road, would be removed and restored to pre-construction conditions once repairs to the jetty are completed.

Prior to in-water work for installing the construction access road and culverts across the southern portion of the marsh wetland outlet at the South Jetty, the Corps will conduct fish salvage and implement fish exclusion to and from the wetland complex upstream of the proposed culvert. Also, post-installation of the culvert, the Corps will develop and implement fish monitoring as necessary to ensure that no listed fish species are stranded. If listed fish species are found, NMFS will be contacted immediately to determine the appropriate course of action.

At Jetty A, adequate area may not be available for the estimated storage and staging needs. Therefore, construction sequencing will accommodate the supply that can be fit into the acreage available. Land-based delivery options may be precluded due to road access constraints, though some existing access may prove available and feasible depending on load and truck sizes.

The following measures will also be required at each location to further avoid and minimize impacts to species. Before significant alteration of the project area, the project boundaries will be flagged. Sensitive resource areas, including areas below ordinary high water, wetlands and trees to be protected will be flagged. Chain link fencing or something functionally equivalent will likely encircle much of the construction areas.

Temporary Erosion Controls

Temporary erosion controls will be in place before any significant alteration of the site. If necessary, all disturbed areas will be seeded and / or covered with coir fabric at completion of ground disturbance to provide immediate erosion control. Erosion control materials (and spill response kits) will remain on-site at all times during active construction and disturbance activities (e.g., silt fence, straw bales). If needed these measures will be maintained on the site until permanent ground cover or site landscaping is established and reasonable likelihood of erosion has passed. When permanent ground cover and landscaping is established, temporary erosion prevention and sediment control measures, pollution control measures and turbidity monitoring will be removed from the site, unless otherwise directed.

An Erosion Sediment and Pollution Control Plan (ESPCP) or Stormwater Pollution Prevention Plan (SWPPP), as applicable to each State, will outline facilities and Best Management Practices (BMPs) that will be implemented and installed prior to any ground disturbing activities on the project site, including mobilization. These erosion controls will prevent pollution caused by surveying or construction operations and ensure sediment-laden water or hazardous or toxic materials do not leave the project site, enter the Columbia River, or impact aquatic and terrestrial wildlife. The Corps retains a general 1200-CA permit from Oregon Department of Environmental Quality (DEQ), and will also work with EPA to obtain use of the NPDES General Permit for Stormwater Discharge from Construction Activities. At a minimum, these ESCP and SWPPP plans will include the following elements and considerations. Construction discharge water generated on-site (debris, nutrients, sediment and other pollutants) will be treated using the best available technology. Water quality treatments will be designed, installed, and maintained in accordance with manufacturer's recommendation and localized conditions. In addition, the straw wattles, sediment fences, graveled access points, and concrete washouts may be used to control sedimentation and construction discharge water. Construction waste material used or stored on-site will be confined, removed, and disposed of properly. No green concrete, cement grout silt, or sandblasting abrasive will be generated at the site.

Emergency Response

To avoid the need for emergency response a Corps' Government Quality Assurance Representative (GQAR) will be on-site or available by phone at all times throughout construction. Emergency erosion/pollution control equipment and best management practices will be on site at all times; Corps' staff will conduct inspections and ensure that a supply of sediment control materials (e.g., silt fence, straw bales), hazardous material containment booms and spill containment booms are available and accessible to facilitate the cleanup of hazardous material spills, if necessary.

Hazardous Materials

A description of any regulated or hazardous products or materials to be used for the project, including procedures for inventory, storage, handling and monitoring, will be kept on-site. Fuels or toxic materials associated with equipment will not be stored or transferred near the water, except in a confined barge. Equipment will be fueled and lubricated only in designated refueling areas at least 150 feet away from the MHHW, except in a confined barge.

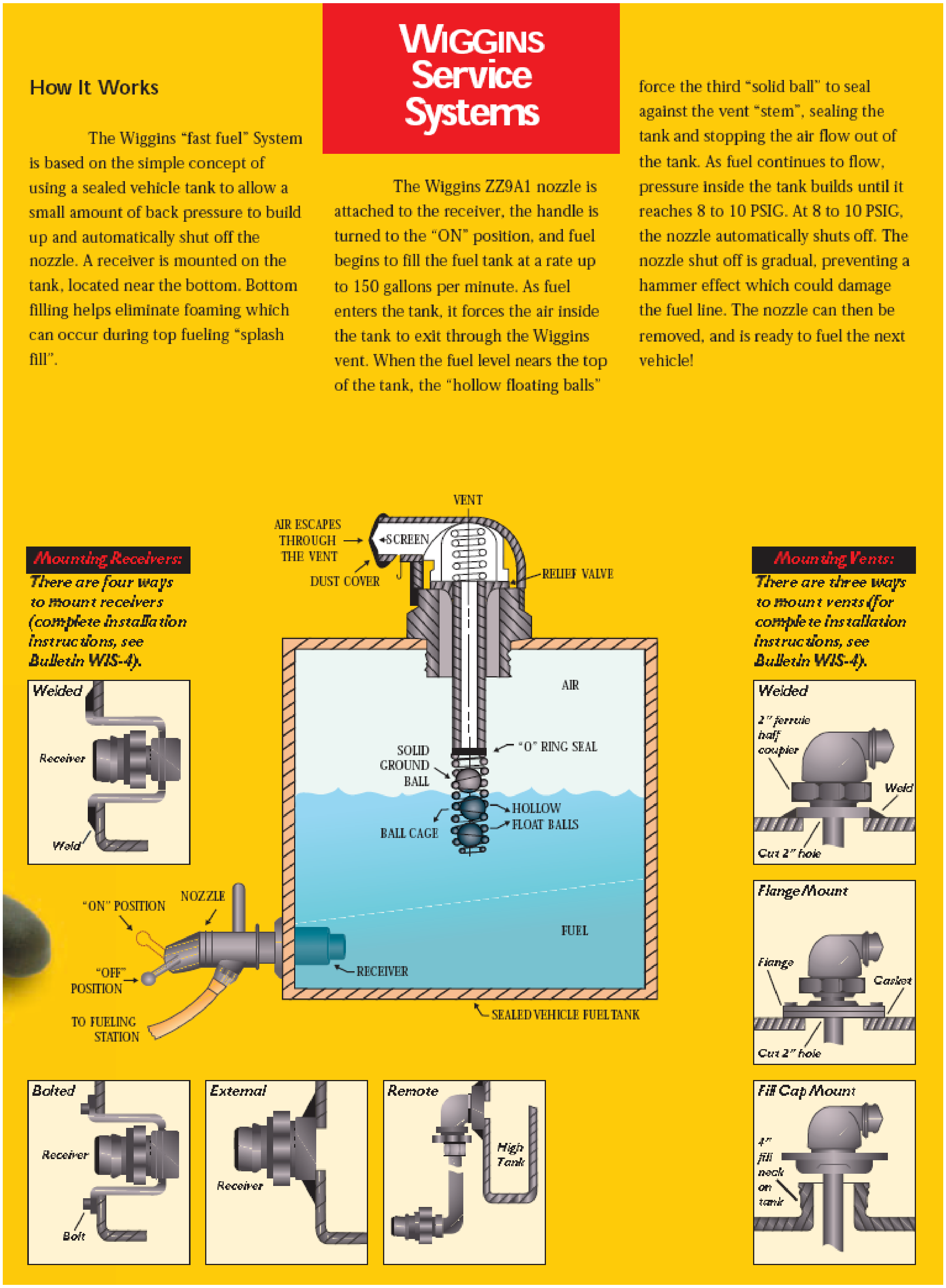
Spill Containment and Control

A description of spill containment and control procedures will be on-site, including: notification to proper authorities, specific cleanup and disposal instructions for different products, quick response containment and cleanup measures that will be available on the site including a supply of sediment control materials, proposed methods for disposal of spilled materials, and employee training for spill containment. Generators, cranes, and any other stationary power equipment operated within 150-feet MHHW will be maintained as necessary to prevent leaks and spills from entering the water. Vehicles / equipment will be inspected daily for fluid leaks and cleaned as needed before leaving staging and storage area for operation within 150 feet of MHHW. Any leaks discovered will be repaired before the vehicle / equipment resumes service. Equipment used below MHHW will be cleaned before leaving the staging area, as often as necessary to remain grease-free. Additionally, the Corps proposes to use a Wiggins fast fuel system or equivalent to reduce leaks during fueling of cranes and other equipment in-place on the jetties (Figure 38). Also, spill pans will be mounted under the crane and monitored daily for leaks.

Water Quality Monitoring

In-water work will require turbidity monitoring that will be conducted in accordance with 401 Water Quality Certifications Conditions to ensure the project maintains compliance with State water quality standards. Turbidity exceedences are expected to be minimal due to the large size of stone being placed. Dynamic conditions at the jetties in the immediate action area preclude the effective use of floating turbidity curtains (or approved equal). Sedimentation and migration of turbid water into the Columbia is not expected to be a significant issue. Best management practices will be used to minimize turbidity during in-water work. Turbidity monitoring will be conducted and recorded each day during daylight hours when in-water work is conducted. Representative background samples will be taken according to the schedule set by the resource agencies at an undisturbed area up-current from in-water work. Compliance samples will be taken on the same schedule, coincident with timing of background sampling, down-current from in-water work. Compliance sample will be compared to background levels during each monitoring interval. Additional 401 Water Quality Certification conditions and protocols may be required.

Figure 38. Fast Fuel System



WETLAND MITIGATION AND HABITAT IMPROVEMENTS

The selected plan design and construction methods for repair and rehabilitation of the MCR jetties have been developed and refined to take advantage of opportunities to avoid and minimize the project's ecological impacts to habitats and species. As required under the Clean Water Act, the Corps will mitigate for impacts to wetlands which could not be otherwise avoided or minimized. The Corps has also incorporated habitat improvements into the proposed action to assist with the recovery of ESA-listed salmonid habitats and ecosystem functions and processes. These actions are not proposed to directly mitigate or compensate for any Project-related impacts to ESA-listed salmonids. The habitat improvement components of the overall ecosystem restoration action are proposed as Conservation Measures under Section 7(a) (1) of the ESA and have been included into the proposed action by the Corps. These actions are the Corps' affirmative commitment to fulfill responsibility to assist with conservation and recovery of ESA-listed salmonids.

Habitat improvement features will be designed to create or improve salmonid habitat, specifically tidal marsh, swamp, and shallow water and flats habitat, and to improve fish access to these habitat features. In addition, one of the features would create habitat for snowy plover. Habitat improvement and wetland mitigation plans currently address three general categories: actions that create, improve, and restore wetlands, actions that improve in-water habitats, and actions that restore upland habitats. From the list of possible wetland mitigation and habitat improvement features shown in Table 14, one or a combination of projects will be selected for further development and implementation. Selection will occur with input from the AMT and work is anticipated to occur concurrent with jetty repair actions.

Table 14. Possible Wetland Mitigation and Habitat Improvement Features

Feature/Site	Area Affected	Type and Function
Trestle Bay	5-8 acres with potential of additional acres	Estuarine Saltwater Marsh Wetland and Intertidal Mudflat Creation and Restoration • Create and expand estuarine intertidal brackish saltwater marsh wetland habitat. • Expand and restore Lyngby sedge plant community. • Expand/increase intertidal shallow water habitat, including dendritic mud flats and off-channel habitat. • Remove and control invasive species and improve/restore diversity and density of native plant assemblages. • Increase habitat complexity for fisheries benefit. • Potentially expand floodplain terrace and improve riparian function. • (Re)introduce natural tidal disturbance regime to area currently upland dunes.
Walooskee to Youngs Bay	~151 acres	Levee Breach for Estuarine Emergent Wetland and Brackish Intertidal Shallow-water Habitat Restoration • Restore connection between Walooskee and Youngs River via levee breach. • Restore and expand estuarine intertidal brackish marsh wetland habitat. • Expand and restore Lyngby sedge and native estuarine vegetation community to improve trophic foodweb functions. • Restore and expand brackish intertidal shallow water habitat including dendritic mud flats and off-channel edge habitat. • Remove and control invasive species and improve/restore diversity and density of native plant assemblages. • Increase habitat access and complexity for fisheries benefit including expanded foraging, rearing, and refugia habitat types. • Improve riparian function. • Potentially restore floodplain terrace and increase flood storage capacity. • (Re)introduce natural tidal disturbance regime to area currently diked pasture land. • Restore hydrologic regime and restore/improve water quality function. • Improve capacity for additional carbon sequestration via native root masses. • Increase and restore hyporheic functions for improved water quality and potential creation of cold water refugia.
Walooskee to Youngs Bay	~39 acres	Levee Breach and/or Tide Gate Retrofits for Emergent Wetland and Intertidal Shallow-water Habitat Restoration • Restore connection with Walooskee River via levee breach and/or tide gate retrofits. • Restore and expand intertidal marsh wetland habitat. • Expand and restore native vegetation community to improve trophic foodweb functions. • Restore and expand intertidal shallow water habitat including dendritic and off-channel edge habitat. • Remove and control invasive species and improve/restore diversity and density of native plant assemblages. • Increase habitat access and complexity for fisheries benefit including expanded foraging, rearing, and refugia habitat types. • Improve riparian function. • Potentially restore floodplain terrace and increase flood storage capacity. • Restore hydrologic and natural tidal disturbance regime and restore/improve water quality function to area currently functioning as diked pasture land. • Improve capacity for additional carbon sequestration via native root masses. • Increase and restore hyporheic functions for improved water quality and potential creation of cold water refugia.
Slough to Youngs River	~250-500 acres	Levee Breach for Estuarine Wetland and Intertidal Restoration • Restore connection between Slough and Youngs River via levee breach. • Restore and expand estuarine intertidal brackish marsh wetland habitat. • Expand and restore Lyngby sedge and native estuarine vegetation community to improve trophic foodweb functions. • Restore and expand brackish intertidal shallow water habitat including dendritic mud flats and off-channel edge habitat.

Feature/Site	Area Affected	Type and Function
		• Remove and control invasive species and improve/restore diversity and density of native plant assemblages. • Increase habitat access and complexity for fisheries benefit including expanded foraging, rearing, and refugia habitat types. • Improve riparian function. • Potentially restore floodplain terrace and increase flood storage capacity. • Restore hydrologic and natural tidal disturbance regimes to an area currently functioning as diked pasture land. • Improve capacity for additional carbon sequestration via native root masses. • Increase and restore hyporheic functions for improved water quality and potential creation of cold water refugia.
Youngs River - Diked Farmland, Freshwater Intertidal Restoration	45-50 acres With potential up to 80 acres	Levee Breach for Wetland and Intertidal Restoration • Restore connection with Youngs River via levee breach. • Restore and expand freshwater intertidal wetland habitat. • Expand and restore native vegetation community to improve trophic foodweb functions. • Restore and expand intertidal shallow water habitat including dendritic mud flats and off-channel edge habitat. • Remove and control invasive species and improve/restore diversity and density of native plant assemblages. • Increase habitat access and complexity for fisheries benefit including expanded foraging, rearing, and refugia habitat types. • Improve riparian function. • Potentially restore floodplain terrace and increase flood storage capacity. • (Re)introduce natural tidal disturbance regime to area currently diked pasture land. • Restore hydrologic regime and restore/improve water quality function. • Increase and restore hyporheic functions for improved water quality and potential creation of cold water refugia.
Tributary Cr. to Youngs River	~5 or more acres	Estuarine Wetland and Intertidal Restoration; Tributary Reconnection to Youngs Bay • Convert diked pasture land to brackish estuarine wetland and shallow water intertidal habitat. • Improve and restore hydrologic regime and increase regular hydrologic connectivity between Crosel Cr. And Youngs Bay estuary. • Improve and restore fish passage and provide access throughout greater range of flows to off-channel juvenile rearing, refuge and foraging habitats. • Remove and control invasive species and improve/restore diversity and density of native plant assemblages. • Increase habitat complexity for fisheries benefit. • Improve adult salmonid access to headwaters and potential spawning habitat. • Potentially expand floodplain terrace and improve riparian function. • (Re)introduce natural flow regime and tidal disturbance regime to area currently functioning as pasture land.
Tributary Cr. and Slough to the Columbia River - near Clatskanie	Up to ~43 acres	Levee Breach and/or Tide Gate Retrofits for Emergent Wetland and Intertidal Shallow-water Habitat Restoration and Tributary Reconnection • Restore connection between Tandy and Graham creeks and Westport Slough and Columbia River via levee berach and/or tide gate retrofits. • Restore and expand intertidal wetland habitat. • Expand and restore native vegetation community to improve trophic foodweb functions. • Restore and expand intertidal shallow water habitat including dendritic and off-channel edge habitat. • Remove and control invasive species and improve/restore diversity and density of native plant assemblages. • Increase habitat access and complexity for fisheries benefit including expanded foraging, rearing, and refugia habitat types. • Improve riparian function. • Potentially restore floodplain terrace and increase flood storage capacity. • Restore hydrologic and natural tidal disturbance regime and restore/improve water quality function to area currently functioning as diked pasture hayfields.

Feature/Site	Area Affected	Type and Function
		• Improve capacity for additional carbon sequestration via native root masses. • Increase and restore hyporheic functions for improved water quality and potential creation of cold water refugia. • Improve adult salmonid access to headwaters and potential spawning habitat.
Knappa - Warren Slough	~100 or more acres	Preservation and Expansion of Estuarine Intertidal Restoration; Improve Tributary Reconnection for Fish Passage • Maintain and enhance evolving restoration that has occurred since inundation of previously diked pasture land to estuarine wetland and shallow intertidal habitat. Maintain restored ecosystem function and intertidal shallow water habitat established post-breach. • Maintain and enhance restored hydrologic regime and increase regular hydrologic connectivity between Hall Cr. and Warren Slough. • Maintain and improve existing fish passage and provide access throughout greater range of flows to off-channel juvenile rearing, refuge and foraging habitat types. • Maintain and increase habitat complexity for fisheries benefit. • Improve adult salmonid access to headwaters and potential spawning habitat. • Remove and control invasive species and improve/restore diversity and density of native plant assemblages; Improve riparian function as appropriate. • Potentially expand floodplain terrace. • Maintain restored natural tidal disturbance regime, dendritic channels, and connection between Hall Cr. and Warren Slough.
Snowy Plover Work on Clatsop Spit	Up to ~22 acres	Forego Revegetation and Convert Upland Areas to Snowy Plover Habitat • Convert upland scrub-shrub habitat with invasive species to snowy plover habitat via periodic tilling and application of shell hash.
Wetland Creation at Cape Disappointment	Up to ~10 acres	Creation and Expansion of Interdunal Wetland Complex • Excavation of new interdunal wetlands adjacent to existing wetlands. • Establishment of native wetland plant communities and removal of invasive species around a buffer zone. • Restoration or provision of hydrology to newly excavated wetlands via appropriate elevation design. • Restoration of wetland connectivity between existing fragmented wetlands via culvert retrofits, if feasible.
Tide Gate Retrofits for Salmonid Passage	Variable	Select Tributaries from ODFW Priority Culvert Repair List - Tributary Reconnection • Restore and improve existing fish passage and provide access throughout greater range of flows to off-channel juvenile rearing, refuge and foraging habitat types. • Restore and increase habitat complexity for fisheries benefit. • Restore and improve adult salmonid access to headwaters and potential spawning habitat.

Wetlands and shallow-water habitat will be filled and converted as a result of the project. Official wetland delineations have not yet been completed for all three of the jetties. However, available preliminary information has allowed the Project Delivery Team (PDT) to site construction activities and features to reduce anticipated impact to wetlands. This information has also been used to calculate initial estimates regarding the possible acreage of impacts. The approximated acreages identified as potentially impacted are North Jetty ~4.78, South Jetty up to ~22 and Jetty A up to ~11. This comes to an estimated total of ~38.28 acres of potential wetlands impacts. To reiterate, official delineations must be completed, and these numbers will be revised accordingly after report results and project design details are further developed and available. These estimates are on the conservatively high end of what final wetland impacts will likely be.

In-water habitats, both shallow intertidal and deeper subtidal areas will also be affected by the project. Habitat conversions will occur from maintenance dredging and placement of the spur groins, jetty cross-sections, turnouts, barge offloading facilities, and causeways. There will also be permanent lagoon fill at the North Jetty root. Without drawing a distinction between depths, initial acreage estimates for all in-water impacts include North Jetty ~11.75, South Jetty ~21.2, and Jetty A ~7.23. This comes to an approximated total of ~40.18 acres of potential in-water conversions. Shallow-water habitat is especially important to several species in the estuary; therefore, specific initial estimates were also calculated regarding shallow-water habitat (shallow here defined as -20-ft or -23-ft below MLLW). About 30 acres (out of the ~40 mentioned above) of area at these depths will be affected by groins, maintenance dredging, and construction of the causeways and barge offloading facilities. However, this estimate does NOT including any expansion of the jetty's existing footprint or overwater structures from barge offloading facilities. The approximate acreage breakdowns entail: spur groin fill = 1.56 (shallow defined as -20-ft or less below MLLW; ~3.26 total area including all depths); dredge for barges ~20, likely all shallow (less than -23-ft deep below MLLW); and causeway fill~ 7, likely all shallow (less than -23 ft deep below MLLW). For this analysis, there was no distinction drawn between periodically exposed intertidal habitat and shallow-water sandflat habitat. As with wetland estimates, these approximations will be updated as project designs are refined and as additional analyses and surveys are completed to quantify changes in jetty and dune cross sections.

Ultimately the project seeks to achieve no net loss in wetland habitat, to protect, improve and restore overall ecosystem functions, and to provide actions that are anticipated to benefit listed species in the vicinity of the project. Towards that end, specific project footprints and activities described above have been identified, categorized, and quantified with conservative estimates where appropriate. The calculated extents were strictly based on the area of habitat that was converted. They did not include value or functional assignments regarding the significance of the conversion, whether it was a beneficial, neutral, or detrimental effect, nor if conversions created unforeseen, indirect far-field effects. For example, acreage of conversion for shallow sandy sub-tidal habitat to rocky sub-tidal habitat was calculated in the same manner as conversion from shallow intertidal habitat to shallow sub-tidal habitat. Per initial consultation with resource agencies, a preliminary suggested ratio of 2:1 for wetland mitigation will likely be required. This is described in Table 15. These estimated footprints will likely change slightly during final design and after updated wetland delineations are completed.

Table 15. Maximum Estimated Acreages for Habitat Improvement and Wetland Mitigation

Jetty	Wetland	In-water	Upland Replanting
North Jetty Total	9.56	--	--
South Jetty Total	44.00	--	--
Jetty A Total	23.00	--	--
TOTAL Wetland and Habitat Improvements	76.56	60.00	55.00

Specific opportunities have been identified in the Columbia River estuary and Youngs Bay (see Table 14) and are under consideration to improve and restore functions affected in each of the generalized habitat categories (wetland, in-water, and upland). Depending on further development of wetland mitigation and habitat improvement alternatives, a specific project or combination of projects will be designed and constructed concurrently as the proposed repair and rehabilitation options are completed over time. Mitigation actions and extents will be commensurate with wetland impacts and ratios identified. Proposed projects are subject to further analysis, and unforeseen circumstances may preclude further development of any specific project. In all cases, final selection, design, and completion of specific improvement features is contingent on evolving factors and further analyses including hydraulic and hydrologic conditions, real estate actions, cultural resource issues, etc. For this reason a suite of potential proposals has been identified, and subsequent selection of one or some combination of projects and designs will occur during continued discussion with resource agencies participating on the Adaptive Management Team. These wetland mitigation and habitat improvement measures will therefore require additional Consultations, and it is anticipated that the AMT will facilitate in this process. It is also anticipated that a programmatic Opinion similar to SLOPES or Limit 8 may be useful to fulfill clearance requirements.

Actions adjacent to or onsite in the vicinity of the North and South Jetties that could potentially mitigate wetland impacts include: excavation of low and high saltwater marsh wetlands and new interdunal wetlands adjacent to existing wetlands; establishment of native wetland plant communities and removal of invasive species around a buffer zone for wetlands; restoration or provision of hydrology to newly excavated wetlands via appropriate elevation design; and/or restoration of wetland connectivity between existing fragmented wetlands. Offsite opportunities for wetland mitigation in the estuary that warrant further investigation are associated with: levee breaches, inlet improvements, or tide gate retrofits, as appropriate. Purchasing mitigation bank credits may be a possibility, though this is currently constrained by limitations of service area and availability of appropriate wetland types. However, private farmlands behind existing levees may provide wetland mitigation opportunities to pursue further. Hydrology and vegetative communities are heavily influenced by elevation; therefore providing improved hydrology combined with strategic excavation and appropriate plantings should result in a simple and self-sustaining design and outcome.

Actions to provide benefits and improvements to in-water habitat include the following opportunities: levee breaches, inlet improvements, or tide gate retrofits, as appropriate. Additional associated actions include: excavation in sand dunes and uplands to specified design elevations in order to create additional intertidal shallow water habitat with dendritic channels and mud flats, and excavation for potential expansion of the floodplain terraces. Though conceptually considered, specific opportunities for additional projects such as the following were not identified but could warrant further investigation if none of the projects in the list is determined to be feasible: removal of overwater structures and fill in the estuary; removal of relic pile-dike fields; removal of fill from Trestle Bay or elsewhere; removal of shoreline erosion control structures and replacement with bioengineering features; beneficial use of dredge material to create ecosystem restoration features (Lois Island Embayment is an example from Columbia River Channel Improvement that may be applicable here); and restoration of eelgrass beds. Certain pile fields and engineering features may be providing current habitat benefits that could be lost with removal, and such actions would require appropriate hydraulic analysis coordination with engineers and resource agencies.

For potential habitat improvement projects located in Trestle Bay, there is additional monitoring and assessment opportunity. A separate hydraulic/engineering study should investigate whether or not an expansion of low-energy, intertidal habitat near Swash Lake could effectively provide additional storage capacity and affect circulation in the Bay such that erosive pressure at neck of Clatsop Spit could be reduced. The previous 1135 action which breached a section of the relic jetty structure is speculated to have been the cause of increased circulation and erosion. It would be worth evaluating whether or not projects that expand floodplain and intertidal areas in the Bay provide significant energy dissipation and additional low-energy storage capacity to offset or redirect erosive pressures. Alternatively, if other habitat improvement concepts are pursued that include removal of additional piles or creation of additional inlets; it would be worth investigating whether these actions could have indirect positive impacts that further reduce concern with erosion at the neck. Evaluating actions in this light would provide valuable information and insight regarding possible solutions and concerns for erosion and breaching at the neck area of Clatsop Spit on Trestle Bay.

Post-construction upland restoration would include the following actions: re-establishing native grasses, shrubs, and trees where appropriate; controlling and removing invasive species like scotch broom and European beach grass in the project vicinity; and re-grading/tilling the area to restore natural contours. Oregon Parks and Recreation Department has requested that the Corps utilize the State Forester as one resource for determining optimal revegetation plans.

On the Clatsop Spit there is also a unique opportunity to partner with U.S. Fish and Wildlife and Oregon Parks and Recreation Department (OPRD) regarding creation and management of snowy plover habitat on the Spit. This would be an alternative to re-vegetative restoration of the uplands. The OPRD is currently developing a Habitat Conservation Plan in the area to address snowy plover habitat management prior to an anticipated designation of Critical Habitat by US Fish and Wildlife. There may be locations in the vicinity and away from projected construction and staging areas to convert upland habitat to snowy plover habitat via invasive species removal, tilling, and application of shell hash. Ongoing operation and maintenance during the project via regular tilling and shell hash distribution could possibly be coordinated between the agencies through a vehicle such as a Memorandum of Agreement or similar avenue.

Refinement and implementation of this wetland mitigation and habitat improvement plan will help protect species and habitats while restoring wetland functions affected by the MCR project.

Monitoring and maintenance of wetland mitigation and habitat improvement actions will likely be required to ensure successful establishment of goals and satisfactory return on investment. Regular coordination with the AMT will further facilitate selection and implementation of wetland mitigation and habitat improvement actions that appropriately meet the framework for successful restoration, protection, and preservation of ESA listed species and high-value habitat.

ACTION AREA

"Action area" means all areas to be affected directly or indirectly by the federal action and not merely the immediate area involved in the action (50 CFR 402.02). For this consultation, the action area includes (see Figure 1): (1) an area extending 10 miles offshore from Columbia River mile -1; (2) extending 5 miles north and 5 miles south of river mile -1, including all terrestrial habitats; (3) extending upstream as far as the Astoria-Megler Bridge, river mile 13.5; and (4) all areas where quarried stone will be transported, including offshore and inland navigation channels in the Pacific ocean extending as far north as Vancouver B.C. in the Puget Sound, and as far south as Eureka, and Humbolt Bay, California. See Figures 28-32 for route illustrations. The sixth field HUCs in the vicinity of the MCR include: Baker Bay-Columbia River – 1708000605; Necanicum River-Frontal Pacific Ocean – 1710020101; Youngs River-Frontal Columbia River – 1708000602; Long Beach-Frontal Pacific Ocean – 1710010607 and Wallacut River-Frontal Columbia River – 1708000604.

Federally listed marine and anadromous fish, mammal, and turtle species are present in the action area (Table 16), as well as EFH species including five coastal pelagic species, numerous Pacific Coast groundfish species, and coho and Chinook salmon (Table 17).

Vessels transporting rock from Canada or Puget Sound sources will travel through areas where bocaccio (*Sebastes paucispinis*), canary rockfish (*Sebastes pinniger*), yelloweye rock fish (*Sebastes ruberrimus*), and Puget Sound Steelhead (*Oncorhynchus mykiss*) are generally found. However, barge traffic is not expected to encounter these species and therefore will not affect behavior or habitat of these species. Furthermore, these species are not expected to occur in the vicinity of the MCR jetties where the bulk of the proposed actions will occur. Critical habitat also has not been designated for these species. Therefore, it is anticipated that the proposed action will have no effect on these species, and they will not be included further in this analysis. The same scenario is applicable to Puget Sound Chinook salmon (*Oncorhynchus tshawytscha*), Hood Canal summer-run Chum salmon (*O. keta*), and Ozette Lake Sockeye salmon (*O. nerka*), which do have critical habitat listed in areas where barge traffic may occur. However, the proposed action is also not expected to have any effects on these species or their critical habitat; therefore, these species will also not be included further in this analysis.

Table 16. Federal Register Notices for Final Rules that List Threatened and Endangered Species, Designate Critical Habitats, or Apply Protective Regulations to Species under Consideration

Listing status: 'T' means listed as threatened under the ESA; 'E' means listed as endangered; 'P' means proposed.

Species		Listing Status	Critical Habitat	Protective Regulations
Marine and Anadromous Fish				
Chinook salmon (*Oncorhynchus tshawytscha*)				
	Lower Columbia River	T 6/28/05; 70 FR 37160	9/02/05; 70 FR 52630	6/28/05; 70 FR 37160
	Upper Willamette River	T 6/28/05; 70 FR 37160	9/02/05; 70 FR 52630	6/28/05; 70 FR 37160
	Upper Columbia River spring-run	E 6/28/05; 70 FR 37160	9/02/05; 70 FR 52630	ESA section 9 applies
	Snake River spring/summer run	T 6/28/05; 70 FR 37160	10/25/99; 64 FR 57399	6/28/05; 70 FR 37160
	Snake River fall-run	T 6/28/05; 70 FR 37160	12/28/93; 58 FR 68543	6/28/05; 70 FR 37160
Chum salmon (*O. keta*)				
	Columbia River	T 6/28/05; 70 FR 37160	9/02/05; 70 FR 52630	6/28/05; 70 FR 37160
Coho salmon (*O. kisutch*)				
	Lower Columbia River	T 6/28/05; 70 FR 37160	Not applicable	6/28/05; 70 FR 37160
	Oregon Coast	T 2/11/08; 73 FR 7816	2/11/08; 73 FR 7816	2/11/08; 73 FR 7816
	S. Oregon/N. California Coasts	T 6/28/05; 70 FR 37160	5/5/99; 64 FR 24049	6/28/05; 70 FR 37160
Sockeye salmon (*O. nerka*)				
	Snake River	E 6/28/05; 70 FR 37160	12/28/93; 58 FR 68543	ESA section 9 applies
Steelhead (*O. mykiss*)				
	Lower Columbia River	T 1/05/06; 71 FR 834	9/02/05; 70 FR 52630	6/28/05; 70 FR 37160
	Upper Willamette River	T 1/05/06; 71 FR 834	9/02/05; 70 FR 52630	6/28/05; 70 FR 37160
	Middle Columbia River	T 1/05/06; 71 FR 834	9/02/05; 70 FR 52630	6/28/05; 70 FR 37160
	Upper Columbia River	T 1/05/06; 71 FR 834	9/02/05; 70 FR 52630	2/018/06; 71 FR 5178
	Snake River Basin	T 1/05/06; 71 FR 834	9/02/05; 70 FR 52630	6/28/05; 70 FR 37160
Green sturgeon (*Acipenser medirosris)*				
	Southern	T 4/07/06; 71 FR 17757	10/09/09; 74 FR 52300	P 5/21/09; 74 FR 23822
Eulachon (*Thaleichthys pacificus*)		T 3/18/10; 75 FR 13012	Not applicable	Not applicable
Marine Mammals				
Steller sea lion (*Eumetopias jubatus*)				
	Eastern	T 5/5/1997; 63 FR 24345	8/ 27/93; 58 FR 45269	11/26/90; 55 FR 49204 10/1/09; 50 CFR 223.202
Blue whale (*Balaenoptera musculus*)				
		E 12/02/70; 35 FR 18319	Not applicable	ESA section 9 applies
Fin whale (*Balaenoptera physalus*)				
		E 12/02/70; 35 FR 18319	Not applicable	ESA section 9 applies
Humpback whale (*Megaptera novaeangliae*)				
		E 12/02/70; 35 FR 18319	Not applicable	ESA section 9 applies
Killer whale (*Orcinus orca*)				
	Southern Resident	E 11/18/05; 70 FR 69903	11/26/06; 71 FR 69054	ESA section 9 applies
Sei whale (*Balaenoptera borealis*)				
		E 12/02/70; 35 FR 18319	Not applicable	ESA section 9 applies
Sperm whale (*Physeter macrocephalus*)				
		E 12/02/70; 35 FR 18319	Not applicable	ESA section 9 applies
Marine Turtles				
Green turtle (*Chelonia mydas*)				
	Excludes Pacific Coast of Mexico & FL	ET 7/28/78; 43 FR 32800	9/02/98; 63 FR 46693	ESA section 9 applies
Leatherback turtle (*Dermochelys coriacea*)		E 6/02/70 ; 39 FR 19320	1/5/10; 75FR319;	ESA section 9 applies
Loggerhead turtle (*Caretta caretta*)		T 7/28/78; 43 FR 32800	Not applicable	7/28/78; 43 FR 32800
Olive ridley turtle (*Lepidochelys olivacea*)		ET 7/28/78; 43 FR 32800	Not applicable	ESA section 9 applies

Table 17. EFH Species and Potential Life Stages in the Action Area

EFH Species	Egg	Larvae	Young Juvenile	Juvenile	Adult	Spawning
Salmon Species						
Coho salmon *(Oncorhynchus kisutch)*			X	X	X	
Chinook salmon *(Oncorhynchus tshawytscha)*			X	X	X	
Coastal Pelagic Species						
Northern anchovy (*Engraulis mordax*)	X	X		X	X	
Pacific sardine (*Sardinops sagax*)	X	X		X	X	
Pacific mackerel (*Scomber japonicus*)	X	X		X	X	
Jack mackerel (*Trachurus symmetricus*)					X	
Market squid (*Loligo opalescens*)					X	
California Skate (*Raja inornata*)	X		X		X	X
Soupfin Shark (*Galeorhinus galeus*)	X		X		X	X
Spiny Dogfish (*Squalus acanthias*)	X		X	X	X	
Ratfish (*Hydrolagus colliei*)			X		X	X
Lingcod (*Ophiodon elongates*)	X	X	X	X	X	X
Cabezon (*Scorpaenichthys marmoratus*)	X	X	X	X	X	X
Kelp Greenling (*Hexagrammos decagrammus*)	X	X	X	X	X	X
Pacific Cod (*Gadus macrocephalus*)	X	X	X		X	X
Pacific Hake (*Merluccius productus*)	X	X	X		X	
Sablefish (*Anoplopoma fimbria*)				X		
Butter Sole (*Isopsetta isolepis*)					X	X
Curlfin Sole (*Pleuronichthys decurrens*)					X	X
English Sole (*Parophyrs vetulus*)	X	X	X		X	X
Flathead Sole (*Hippoglossoides elassodon*)			X			
Pacific Sanddab (*Citharichthys sordidus*)	X	X	X		X	
Petrale Sole (*Eopsetta jordani*)			X		X	
Rex Sole (*Glyptocephalus zachirus*)			X		X	
Rock Sole (*Lepidopsetta bilineata*)	X		X		X	X

EFH Species	Egg	Larvae	Young Juvenile	Juvenile	Adult	Spawning
Sand Sole (*Psettichthys melanostictus*)			X		X	X
Starry Flounder (*Platichthys stellatus*)	X	X	X		X	X
Black Rockfish (*Sebastes melanops*)			X		X	
Brown Rockfish (*Sebastes auriculatus*)	X	X	X		X	X
China Rockfish (*Sebastes nebulosus*)						
Copper Rockfish (*Sebastes caurinus*)	X	X	X	X	X	X
Quillback Rockfish (*Sebastes maliger*)	X	X	X	X	X	X
Vermilion Rockfish (*Sebastes miniatus*)			X			

ENDANGERED SPECIES ACT ENVIRONMENTAL ASSESSMENT

INTRODUCTION

The summaries that follow describe the status of the ESA-listed species, and their designated critical habitats, that occur within the geographic area of this proposed action and are considered in this Assessment. More detailed information on the status and trends of these listed resources, and their biology and ecology can be found in the listing regulations and critical habitat designations published in the Federal Register (see Table 16) and in many publications available from the NMFS Northwest Region, Protected Resources Division in Portland, Oregon.

It is likely that climate change will play an increasingly important role in determining the abundance of ESA-listed species, and the conservation value of designated critical habitats, in the Pacific Northwest. During the last century, average regional air temperatures increased by 1.5°F, and increased up to 4°F in some areas (USGCRP 2009). Warming is likely to continue during the next century as average temperatures increase another 3° to 10°F (USGCRP 2009). Overall, about one-third of the current cold-water fish habitat in the Pacific Northwest is likely to exceed key water temperature thresholds by the end of this century (USGCRP 2009).

Precipitation trends during the next century are less certain than for temperature but more precipitation is likely to occur during October through March and less during summer, and more of the winter precipitation is likely to fall as rain rather than snow (ISAB 2007, USGCRP 2009). Where snow occurs, a warmer climate will cause earlier runoff so stream flows in late spring, summer, and fall will be lower and water temperatures warmer (ISAB 2007, USGCRP 2009).

Higher winter stream flows increase the risk that winter floods in sensitive watersheds will damage spawning redds and wash away incubating eggs (USGCRP 2009). Earlier peak stream flows will also flush some young salmon and steelhead from rivers to estuaries before they are physically mature, increasing stress and the risk of predation (USGCRP 2009). Lower stream flows and warmer water temperatures during summer will degrade summer rearing conditions, in part by increasing the prevalence and virulence of fish diseases and parasites (USGCRP 2009). Other adverse effects are likely to include altered migration patterns, accelerated embryo development, premature emergence of fry, and increased competition and predation risk from warm-water, non-native species (ISAB 2007).

The earth’s oceans are also warming, with considerable inter-annual and inter-decadal variability superimposed on the longer-term trend (Bindoff et al. 2007). Historically, warm periods in the coastal Pacific Ocean have coincided with relatively low abundances of salmon and steelhead, while cooler ocean periods have coincided with relatively high abundances (Scheuerell and Williams 2005, Zabel et al. 2006, USGCRP 2009). Ocean conditions adverse to salmon and steelhead may be more likely under a warming climate (Zabel et al. 2006).

STATUS OF THE SPECIES AND CRITICAL HABITAT

Salmon and Steelhead

Species Description and Limiting Factors

The summaries that follow describe the status of ESA-listed salmon and steelhead, and their designated critical habitats that occur within the geographic area of the Proposed Action. Over the past few decades, the sizes and distributions of the populations considered generally have declined due to natural phenomena and human activity, including the operation of hydropower systems, over-harvest, hatcheries, and habitat degradation. Enlarged populations of terns, seals, sea lions, and other aquatic predators in the Pacific Northwest have been identified as factors that may be limiting the productivity of some Pacific salmon and steelhead populations (Bottom et al. 2005, Fresh et al. 2005).

The status of species and critical habitat sections are organized by recovery domains to better integrate recovery planning information that NMFS is developing on the conservation status of the species and critical habitats considered in this consultation. Recovery domains are the geographically-based areas that NMFS is using to prepare multi-species recovery plans. Southern green sturgeon are under the jurisdiction of the NMFS Southwest Region, which has not yet convened a recovery team for this species. The four recovery domains relevant to this consultation and the ESA-listed salmon and steelhead species that reproduce in each recovery domain are shown in Table 18. For this consultation, populations that reproduce in Oregon are also identified as one indication of the importance of the action area to the recovery of these species. However, all populations spawning within the Columbia River Basin use the Columbia River mainstem and estuary to complete part of their life history.

Table 18. NMFS Recovery Planning Domains and ESA-listed Salmon and Steelhead Species

Recovery Domain	Species
Willamette-Lower Columbia (WLC)	LCR Chinook salmon
	UWR Chinook salmon
	CR chum salmon
	LCR coho salmon
	LCR steelhead
	UWR steelhead
Interior Columbia (IC)	UCR spring-run Chinook salmon
	SR spring/summer Chinook salmon
	SR fall-run Chinook salmon
	SR sockeye salmon
	UCR steelhead
	MCR steelhead
	SRB steelhead
Oregon Coast (OC)	OC coho salmon
Southern Oregon Northern California Coasts	SONCC coho salmon

For each recovery domain, a technical review team (TRT) appointed by NMFS has developed, or is developing, criteria necessary to identify independent salmon populations within each species, recommend viability criteria for that species, and analyze factors that limit species survival. The definition of a population used by each TRT is set forth in the "viable salmonid population" (VSP) document prepared by NMFS for use in conservation assessments of Pacific salmon and steelhead (McElhany et al. 2000). The boundaries of each population are defined using a combination of genetic information, geography, life-history traits, morphological traits, and population dynamics that indicate the extent of reproductive isolation among spawning groups.

Understanding population size and spatial extent is critical for the viability analyses, and a necessary step in recovery planning and conservation assessments for any species. If a species consists of multiple populations, the overall viability of that species is a function of the VSP attributes of its constituent populations. Until a viability analysis of a species is completed, the VSP guidelines recommend that all populations should be managed to retain the potential to achieve viable status to ensure a rapid start along the road to recovery, and that no significant parts of the species are lost before the full recovery plan is implemented (McElhany et al. 2000).

The status of critical habitat was based primarily on a watershed-level analysis of conservation value that focused on the presence of listed ESA-listed salmon and steelhead and the biological and physical features (i.e., the PCEs) that are essential to their conservation. This analysis for the 2005 designations was completed by Critical Habitat Analytical Review Teams (CHARTs) that focused on large geographical areas corresponding approximately to recovery domains (NOAA Fisheries 2005). Each watershed was ranked using a conservation value attributed to the quantity of stream habitat with PCEs, the present condition of those PCEs, the likelihood of achieving PCE potential (either naturally or through active restoration), support for rare or important genetic or life history characteristics, support for abundant populations, and support for spawning and rearing populations. In some cases, our understanding of these interim conservation values has been further refined by the work of TRTs and other recovery planning efforts that have better explained the habitat attributes, ecological interactions, and population characteristics important to each species.

Natural variations in freshwater and marine environments have substantial effects on the abundance of Pacific salmon and steelhead populations. Of the various natural phenomena that affect most populations of salmon and steelhead, changes in ocean productivity are generally considered the most important. Pacific salmon and steelhead are exposed to high rates of natural predation, particularly during freshwater rearing and migration stages. Ocean predation probably contributes to significant natural mortality, although the levels of predation are largely unknown. In general, Pacific salmon and steelhead are eaten by pelagic fishes, birds, and marine mammals.

Over the past few decades, the size and distribution of the salmon and steelhead populations considered here, like the other salmon and steelhead that NMFS has listed, generally have declined because of natural phenomena and human activity, including the operation of hydropower systems, over-harvest, hatcheries, and habitat degradation. Enlarged populations of terns, seals, and sea lions in the Pacific Northwest have reduced the survival of some Pacific salmon and steelhead populations. As noted more fully in the status of the critical habitats section below, climate change is likely to play an increasingly important role in determining the abundance of salmon and steelhead by exacerbating long-term problems related to temperature, stream flow, habitat access, predation, and marine productivity (CIG 2004, Scheuerell and Williams 2005, Zabel et al. 2006, ISAB 2007).

Willamette and Lower Columbia (WLC) Recovery Domain. Species in the WLC Recovery Domain include LCR Chinook salmon, UWR Chinook salmon, CR chum salmon, LCR coho salmon, LCR steelhead, and UWR steelhead. The WLC-TRT identified 107 demographically-independent populations of those species (Table 19), including 47 populations that spawn within Oregon. These populations were further aggregated into strata, groupings above the population level that are connected by some degree of migration, based on ecological subregions. All 107 populations use parts of the mainstem of the Columbia River and the Columbia River estuary that flow through Oregon for migration, rearing, and smoltification.

The WLC-TRT recommended viability criteria that follow the VSP framework and described biological or physical performance conditions that, when met, indicate a population or species has a 5% or less risk of extinction over a 100-year period (McElhany et al. 2006, see also, NRC 1995). McElhany et al. (2007) applied those criteria to populations in Oregon and found that the combined extinction risk is very high for LCR Chinook salmon, UWR Chinook salmon, CR chum salmon, LCR coho salmon, and moderate for LCR steelhead and UWR steelhead, although the status of those species with populations in Washington is still under assessment.

Table 19. Demographically Independent Salmonid Populations in the WLC Recovery Domain and Spawning Populations

Species	Populations in WLC	Spawning Populations in Oregon
LCR Chinook salmon	32	12
UWR Chinook salmon	7	7
CR chum salmon	17	8
LCR coho salmon	24	9
LCR steelhead	23	6
UWR steelhead	5	5

***LCR Chinook salmon*.** This species includes all naturally-spawned populations of Chinook salmon in the Columbia River and its tributaries from its mouth at the Pacific Ocean upstream to a transitional point between Washington and Oregon east of the Hood River and the White Salmon River; the Willamette River to Willamette Falls, Oregon, exclusive of spring-run Chinook salmon in the Clackamas River; and progeny of seventeen artificial propagation programs. The WLC-TRT identified 32 historical populations of LCR Chinook salmon – seven in the coastal subregion, six in the Columbia Gorge, and nine in the western Cascades. Twelve of those populations occur within the action area (Table 20) and only Sandy River late fall Chinook is considered “viable” (McElhany et al. 2007). The major factors limiting recovery of LCR Chinook salmon include altered channel morphology, loss of habitat diversity, excessive sediment, high water temperature, reduced access to spawning/rearing habitat, and harvest impacts (NMFS 2006).

Table 20. LCR Chinook Salmon Populations Spawning in Oregon

Overall viability risk within 100 years: "extinct or very high" means greater than 60% chance of extinction; "relatively high" means 60% to 25% risk of extinction; "moderate" means 25% to 5% risk of extinction, "low or negligible" means 5% to 1% risk of extinction, "very low" means less than 1% chance of extinction, and NA means not available. A low or negligible risk of extinction is considered "viable."

Stratum		**Spawning Population In Oregon (Watershed)**	**Overall Viability Risk**
Ecological Subregion	**Run Timing**		
Coast Range	Fall	Young Bay	Very High
		Big Creek	Very High
		Clatskanie	Relatively High
		Scappoose	Very High
Columbia Gorge	Spring	Hood	Very High
	Early fall ("tule")	Upper Gorge	Very High
	Fall	Hood	Very High
		Lower Gorge	Very High
West Cascade Range	Spring	Sandy	Moderate
	Early fall ("tule")	Clackamas	Very High
		Sandy	Very High
	Late fall ("bright")	Sandy	Low

UWR Chinook salmon. The species includes all naturally-spawned populations of spring-run Chinook salmon in the Clackamas River and in the Willamette River, and its tributaries, above Willamette Falls, Oregon, and progeny of seven artificial propagation programs. All seven historical populations of UWR Chinook salmon identified by the WLC-TRT occur within the action area and are contained within a single ecological subregion, the western Cascade Range (Table 21); only the Clackamas population is characterized as "viable" (McElhany et al. 2007). The major factors limiting recovery of UWR Chinook salmon identified by NMFS include lost/degraded floodplain connectivity and lowland stream habitat, degraded water quality, high water temperature, reduced streamflow, and reduced access to spawning/rearing habitat (NMFS 2006).

Table 21. UWR Chinook Salmon Populations

Overall viability risk within 100 years: "extinct or very high" means greater than 60% chance of extinction; "relatively high" means 60% to 25% risk of extinction; "moderate" means 25% to 5% risk of extinction, "low or negligible" means 5% to 1% risk of extinction, "very low" means less than 1% chance of extinction, and NA means not available. A low or negligible risk of extinction is considered "viable."

Stratum		Spawning Population In Oregon (Watershed)	Overall Viability Risk
Ecological Subregion	**Run Timing**		
West Cascade Range	Spring	Clackamas	Low
		Molalla	Relatively High
		North Santiam	Very high
		South Santiam	Very high
		Calapooia	Very high
		McKenzie	Moderate
		Middle Fork Willamette	Very high

CR Chum salmon. This species includes all naturally-spawned populations of chum salmon in the Columbia River and its tributaries in Washington and Oregon, and progeny of three artificial propagation programs. The WLC-TRT identified 17 historical populations of CR chum salmon and aggregated these into four strata (Myers et al. 2006). Unlike other species in the WLC Recovery Domain, CR chum salmon spawning aggregations were identified in the mainstem Columbia River. These aggregations generally were included in the population associated with the nearest river basin. Three strata and eight historical populations of CR chum salmon occur within the action area (Table 22); of these, none are "viable" (McElhany et al. 2007). The major factors limiting recovery of CR chum salmon include altered channel morphology, loss of habitat diversity, excessive sediment, reduced streamflow, harassment of spawners and harvest impacts (NMFS 2006).

Table 22. CR Chum Salmon Populations Spawning in Oregon

Overall viability risk within 100 years: "extinct or very high" means greater than 60% chance of extinction; "relatively high" means 60% to 25% risk of extinction; "moderate" means 25% to 5% risk of extinction, "low or negligible" means 5% to 1% risk of extinction, "very low" means less than 1% chance of extinction, and NA means not available. A low or negligible risk of extinction is considered "viable."

Stratum		Spawning Population In Oregon (Watershed)	Overall Viability Risk
Ecological Subregion	**Run Timing**		
Coast Range	Fall	Young's Bay	Very high
		Big Creek	Very high
		Clatskanie	Very high
		Scappoose	Very high
Columbia Gorge	Fall	Lower Gorge	Very high
		Upper Gorge	Very high
West Cascade Range	Fall	Clackamas	Very high
		Sandy	Very high

LCR coho salmon. This species includes all naturally-spawned populations of coho salmon in the Columbia River and its tributaries in Washington and Oregon, from the mouth of the Columbia up to and including the Big White Salmon and Hood rivers, in the Willamette River to Willamette Falls, Oregon, and progeny of 25 artificial propagation programs. The WLC-TRT identified 24 historical populations of LCR coho salmon and divided these into two strata based on major run timing: early and late (Myers et al. 2006). Three strata and nine historical populations of LCR coho salmon occur within the action area (Table 23). Of these nine populations, Clackamas River is the only population characterized as "viable" (McElhany et al. 2007). The major factors limiting recovery of LCR coho salmon include degraded floodplain connectivity and channel structure and complexity, loss of riparian areas and large wood recruitment, degraded stream substrate, loss of stream flow, reduced water quality, and impaired passage (NMFS 2007).

In general, late coho salmon spawn in smaller rivers or the lower reaches of larger rivers from mid-November to January, coincident with the onset of rain-induced freshets in the fall or early winter. Spawning typically takes place within a few days to a few weeks of freshwater entry. Late-run fish also tend to undertake oceanic migrations to the north of the Columbia River, extending as far as northern British Columbia and southeast Alaska. As a result, late coho salmon are known as "Type N" coho. Alternatively, early coho salmon spawn in the upper reaches of larger rivers in the Lower Columbia River and in most rivers inland of the Cascade Crest. During their oceanic migration, early coho salmon tend to migrate to the south of the Columbia River and are known as "Type S" coho salmon. They may migrate as far south as the waters off northern California. While the ecological significance of run timing in coho salmon is fairly well understood, it is not clear how important ocean migratory pattern is to overall diversity and the relative historical abundance of Type N and Type S life histories largely is unknown.

Table 23. LCR Coho Salmon Populations Spawning in Oregon

Overall viability risk within 100 years: "extinct or very high" means greater than 60% chance of extinction; "relatively high" means 60% to 25% risk of extinction; "moderate" means 25% to 5% risk of extinction, "low or negligible" means 5% to 1% risk of extinction, "very low" means less than 1% chance of extinction, and NA means not available. A low or negligible risk of extinction is considered "viable."

Stratum		Spawning Population In Oregon (Watershed)	Overall Viability Risk
Ecological Subregion	**Run Type**		
Coast Range	N	Young's Bay	Very High
		Big Creek	Very High
		Clatskanie River	Relatively High
		Scappoose River	Relatively High
Columbia Gorge	N and S	Lower Gorge	Very High
		Upper Gorge	NA
		Hood River	Very high
West Cascade Range	S	Clackamas River	Low
		Sandy River	Relatively High

LCR steelhead. The species includes all naturally-spawned steelhead populations below natural and artificial impassable barriers in streams and tributaries to the Columbia River between and including the Cowlitz and Wind rivers, Washington; in the Willamette and Hood rivers, Oregon; and progeny of ten artificial propagation programs; but excluding all steelhead from the Upper Willamette River basin above Willamette Falls, Oregon, and from the Little and Big White Salmon rivers, Washington. The WLC-TRT identified 23 historical populations of LCR steelhead (Myers et al. 2006). Within these populations, the winter-run timing is more common in the west Cascade subregion, while farther east summer steelhead are found almost exclusively.

Summer steelhead return to freshwater long before spawning. Winter steelhead, in contrast, return from the ocean much closer to maturity and spawn within a few weeks. Summer steelhead spawning areas in the Lower Columbia River are found above waterfalls and other features that create seasonal barriers to migration. Where no temporal barriers exist, the winter-run life history dominates. Three strata and six historical populations of LCR steelhead occur within the action area (Table 24). Of the populations in Oregon, only Clackamas is "viable" (McElhany et al. 2007). The major factors limiting recovery of LCR steelhead include altered channel morphology, lost/degraded floodplain connectivity and lowland stream habitat, excessive sediment, high water temperature, reduced streamflow, and reduced access to spawning/rearing habitat (NMFS 2006).

Table 24. LCR Steelhead Populations Spawning in Oregon

Overall viability risk within 100 years: "extinct or very high" means greater than 60% chance of extinction; "relatively high" means 60% to 25% risk of extinction; "moderate" means 25% to 5% risk of extinction, "low or negligible" means 5% to 1% risk of extinction, "very low" means less than 1% chance of extinction, and NA means not available. A low or negligible risk of extinction is considered "viable."

<table>
<tr><th colspan="2">Stratum</th><th rowspan="2">Population Spawning In Oregon (Watershed)</th><th rowspan="2">Overall Viability Risk</th></tr>
<tr><th>Ecological Subregion</th><th>Run Timing</th></tr>
<tr><td rowspan="4">Columbia Gorge</td><td>Summer</td><td>Hood River</td><td>Very High</td></tr>
<tr><td rowspan="3">Winter</td><td>Lower Gorge</td><td>Relatively High</td></tr>
<tr><td>Upper Gorge</td><td>Moderate</td></tr>
<tr><td>Hood River</td><td>Moderate</td></tr>
<tr><td rowspan="2">West Cascade Range</td><td rowspan="2">Winter</td><td>Clackamas</td><td>Low</td></tr>
<tr><td>Sandy</td><td>Relatively High</td></tr>
</table>

UWR steelhead. This species includes all naturally-spawned steelhead populations below natural and artificial impassable barriers in the Willamette River, Oregon, and its tributaries upstream from Willamette Falls to the Calapooia River. The WLC-TRT identified four historical populations of UWR steelhead, all with winter run timing and all within Oregon (Myers et al. 2006). Only winter steelhead historically existed in this area, because flow conditions over Willamette Falls allowed only late winter steelhead to ascend the falls, until a fish ladder was constructed in the early 1900s and summer steelhead were introduced. Summer steelhead have become established in the McKenzie River where historically no steelhead existed, although these fish were not considered in the identification of historical populations.

UWR steelhead currently are found in many tributaries that drain the west side of the Upper Willamette River basin. Analysis of historical observations, hatchery records, and genetic analysis strongly suggested that many of these spawning aggregations are the result of recent introductions and do not represent a historical population. Nevertheless, the WLC-TRT recognized that these tributaries may provide juvenile rearing habitat or may be temporarily (for one or more generations) colonized during periods of high abundance.

One stratum and five historical populations of UWR steelhead occur within the action area (Table 25), although the west-side tributaries population was included only because it is important to the species as a whole, and not because it is independent. Of these five populations, none are "viable" (McElhany et al. 2007). The major factors limiting recovery of UWR steelhead include lost/degraded floodplain connectivity and lowland stream habitat, degraded water quality, high water temperature, reduced streamflow, and reduced access to spawning/rearing habitat (NMFS 2006).

Table 25. UWR Steelhead Populations

Overall viability risk within 100 years: "extinct or very high" means greater than 60% chance of extinction; "relatively high" means 60% to 25% risk of extinction; "moderate" means 25% to 5% risk of extinction, "low or negligible" means 5% to 1% risk of extinction, "very low" means less than 1% chance of extinction, and NA means not available. A low or negligible risk of extinction is considered "viable."

Stratum		Population Spawning In Oregon (Watershed)	Overall Viability Risk
Ecological Subregion	Run Type		
West Cascade Range	Winter	Molalla	Moderate
		North Santiam	Moderate
		South Santiam	Moderate
		Calapooia	Moderate
		West-side Tributaries	Moderate

Interior Columbia (IC) Recovery Domain. Species in the IC Recovery Domain include UCR spring-run Chinook salmon, SR spring/summer run Chinook salmon, SR fall-run Chinook salmon, SR sockeye salmon, UCR steelhead, MCR steelhead, and SRB steelhead. The IC-TRT identified 82 demographically-independent populations of those species based on genetic, geographic (hydrographic), and habitat characteristics (Table 26). In some cases, the IC-TRT further aggregated populations into "major groupings" based on dispersal distance and rate, and drainage structure, primarily the location and distribution of large tributaries (IC-TRT 2003). Of the 82 populations identified, 24 have all or part of their spawning range in Oregon, and all 82 use the lower mainstem of the Snake River, the mainstem of the Columbia River, and the Columbia River estuary, or part thereof, in Oregon for migration, rearing, and smoltification.

Table 26. Demographically Independent Salmonid Populations in the IC Recovery Domain and Spawning Populations

Species	Populations in IC	Spawning Populations in Oregon
UCR spring-run Chinook salmon	3	0
SR spring/summer Chinook salmon	31	7
SR fall-run Chinook salmon	1	1
SR sockeye salmon	1	0
UCR steelhead	4	0
MCR steelhead	17	10
SRB steelhead	25	6

The IC-TRT also recommended viability criteria that follow the VSP framework (McElhany et al. 2006) and described biological or physical performance conditions that, when met, indicate a population or species has a 5% or less risk of extinction over a 100-year period (IC-TRT 2007, see also, NRC 1995). As of this writing, the IC-TRT has applied the viability criteria to 68 populations although it has only completed a draft assessment for 55 populations (see IC-TRT - Current Status Assessments, as of April 21, 2006, available from NMFS Northwest Region, Protected Resources Division in Portland, Oregon). Of those assessments, the only population that the TRT found to be viable was the North Fork John Day population of MCR steelhead. The strength of this population is due to a combination of high abundance and productivity, and good spatial structure and diversity, although the genetic effects of the large number of out-of-species strays and of natural spawners that are hatchery strays are still significant long-term concerns.

UCR spring-run Chinook salmon. This species includes all naturally-spawned populations of Chinook salmon in all river reaches accessible to Chinook salmon in Columbia River tributaries upstream of the Rock Island Dam and downstream of Chief Joseph Dam in Washington (excluding the Okanogan River), the Columbia River from a straight line connecting the west end of the Clatsop jetty (South Jetty, Oregon side) and the west end of the Peacock jetty (North Jetty, Washington side) upstream to Chief Joseph Dam in Washington, as well as progeny of six artificial propagation programs. The IC-TRT identified four independent populations of UCR spring-run Chinook salmon in the upriver tributaries of Wenatchee, Entiat, Methow, and Okanogan (extirpated), but no major groups due to the relatively small geographic area affected (IC-TRT 2003, McClure et al. 2005). Although none of these populations spawn in Oregon, they all use the Columbia River mainstem and estuary so all adult and juvenile individuals of this species must pass through part of the action area. The IC-TRT considered that this species, as a whole, is at high risk of extinction because all extant populations are at high risk (IC-TRT - Current Status Assessments, as of April 21, 2006, available from NMFS Northwest Region, Protected Resources Division in Portland, Oregon). The major factors limiting recovery of UWR spring-run Chinook salmon include altered channel morphology and floodplain, riparian degradation and loss of in-river large wood, reduced streamflow, impaired passage, hydropower system mortality, and harvest impacts (NMFS 2006).

SR spring/summer run Chinook salmon. This species includes all naturally-spawned populations of spring/summer run Chinook salmon in the mainstem Snake River and the Tucannon River, Grande Ronde River, Imnaha River, and Salmon River subbasins; and progeny of fifteen artificial propagation programs. The IC-TRT identified 31 historical populations of SR spring/summer run Chinook salmon, and aggregated these into major population groups (IC-TRT 2003, McClure et al. 2005). This species includes those fish that spawn in the Snake River drainage and its major tributaries, including the Grande Ronde River and the Salmon River, and that complete their adult, upstream migration past Bonneville Dam between March and July. Of the 31 historical populations of SR spring/summer run Chinook salmon identified by the IC-TRT, seven occur entirely or partly within Oregon (Table 27). Each of these populations is part of the Grande Ronde and Imnaha River major group, and all face a high risk of extinction (IC-TRT - Current Status Assessments, as of April 21, 2006, available from NMFS Northwest Region, Protected Resources Division in Portland, Oregon).

The major factors limiting recovery of SR spring/summer run Chinook salmon include altered channel morphology and floodplain, excessive sediment, degraded water quality, reduced streamflow, and hydropower system mortality (NMFS 2006).

Table 27. SR Spring/Summer Run Chinook Salmon Populations in Oregon

Overall viability risk within 100 years: "high" means greater than 25% risk of extinction; "moderate" means 5% to 25% risk of extinction, "low" means 1% to 5% risk of extinction; and "very low" means less than 1% chance of extinction.

Major Group	Spawning Populations in Oregon (Watershed)	Viability Assessment		
		Abundance Productivity Risk	Spatial Diversity Risk	Overall Viability Risk
Grande Ronde and Imnaha Rivers	Wenaha River	High	Moderate	High
	Wallowa-Lostine River	High	Moderate	High
	Minam River	High	Moderate	High
	Catherine Creek	High	Moderate	High
	Upper Grande Ronde	High	High	High
	Imnaha River mainstem	High	Moderate	High
	Big Sheep Creek	High	Moderate	High

SR fall-run Chinook salmon. This species includes all naturally-spawned populations of fall-run Chinook salmon in the mainstem Snake River below Hells Canyon Dam, and in the Tucannon River, Grande Ronde River, Imnaha River, Salmon River, and Clearwater River, and progeny of four artificial propagation programs. The IC-TRT identified three populations of this species, although only the lower mainstem population exists at present, and it spawns in the lower main stem of the Clearwater, Imnaha, Grande Ronde, Salmon and Tucannon rivers (IC-TRT 2003, McClure et al. 2005). Unlike the other listed Chinook species in this recovery domain, most SR fall-run Chinook have a subyearling, ocean-type life history in which juveniles outmigrate the next summer, rather than rearing in freshwater for 13 to 14 months before outmigration. Adults return to the Snake River basin in September and October and spawn shortly thereafter. The lower mainstem population spawns in the Columbia River mainstem, in part adjacent to Oregon. All adult and juvenile individuals of this species must pass through part of the action area. The IC-TRT has not completed a viability assessment of this species. The major factors limiting recovery of SR fall-run Chinook include reduced spawning/rearing habitat, degraded water quality, hydropower system mortality, and harvest impacts (NMFS 2006).

SR sockeye salmon. This species includes all anadromous and residual sockeye salmon from the Snake River basin, Idaho, and artificially-propagated sockeye salmon from the Redfish Lake captive propagation program. The IC-TRT identified historical sockeye production in at least five Stanley Basin lakes and in lake systems associated with Snake River tributaries currently cut off to anadromous access (e.g., Wallowa and Payette lakes), although current returns of SR sockeye are extremely low and limited to Redfish Lake (IC-TRT 2007). SR sockeye salmon do not spawn in Oregon, but all adult and juvenile individuals of this species must pass through part of the action area. The major factors limiting recovery of SR sockeye salmon include altered channel morphology and floodplain, reduced streamflow, impaired passage, and hydropower system mortality (NMFS 2006).

MCR steelhead. This species includes all naturally-spawned steelhead populations below natural and artificial impassable barriers in streams from above the Wind River, Washington, and the Hood River, Oregon (exclusive), upstream to, and including, the Yakima River, Washington, excluding steelhead from the Snake River basin; and progeny of seven artificial propagation programs. The IC-TRT identified 20 historical populations of MCR steelhead in major groups (IC-TRT 2003, McClure et al. 2005). Ten populations of MCR steelhead occur in Oregon, divided among three major groups (Table 28). Of the 20 historical populations of MCR steelhead identified by the IC-TRT, only the North Fork John Day population currently meets viability criteria, and none of the major groups or the species are considered viable (IC-TRT - Current Status Assessments, as of April 21, 2006, available from NMFS Northwest Region, Protected Resources Division in Portland, Oregon). The major factors limiting recovery of MCR steelhead include altered channel morphology and floodplain, excessive sediment, degraded water quality, reduced streamflow, impaired passage, and hydropower system mortality (NMFS 2006).

Table 28. MCR Steelhead Populations in Oregon

The Walla Walla population also occurs partly in Washington.

Major Group	**Population (Watershed)**
Cascade East Slope Tributaries	Fifteenmile Creek
	Deschutes Eastside Tributaries
	Deschutes Westside Tributaries
John Day River	Lower Mainstem John Day River
	North Fork John Day River
	Middle Fork John Day River
	South Fork John Day River
	Upper Mainstem John Day River
Walla Walla and Umatilla Rivers	Umatilla River
	Walla Walla River

UCR steelhead. This species includes all naturally-spawned steelhead populations below natural and artificial impassable barriers in streams in the Columbia River Basin upstream from the Yakima River, Washington, to the U.S./Canada border, and progeny of six artificial propagation programs. Four independent populations of UCR steelhead were identified by the IC-TRT in the same upriver tributaries as for the previous species (*i.e.*, Wenatchee, Entiat, Methow, and Okanogan) and, similarly, no major population groupings were identified due to the relatively small geographic area involved (IC-TRT 2003, McClure et al. 2005). None of these populations spawn in Oregon, although all adult and juvenile individuals of this species must pass through part of the action area. The IC-TRT has not completed a viability assessment of this species, although all extant populations are considered to be at high risk of extinction (IC-TRT - Current Status Assessments, as of April 21, 2006, available from NMFS Northwest Region, Protected Resources Division in Portland, Oregon). The major factors limiting recovery of UCR steelhead include altered channel morphology and floodplain, riparian degradation and loss of in-river large wood, excessive sediment, degraded water quality, reduced streamflow, hydropower system mortality, harvest impacts, and hatchery impacts (NMFS 2006).

SRB steelhead. This species includes all naturally-spawned steelhead populations below natural and artificial impassable barriers in streams in the Snake River basin of southeast Washington, northeast Oregon and Idaho, and progeny of six artificial propagation programs. These fish are genetically differentiated from other interior Columbia steelhead populations and spawn at higher altitudes (up to 6,500 feet) after longer migrations (more than 900 miles). The IC-TRT identified 24 populations in five major groups (IC-TRT 2003, McClure et al. 2005). Of those, six populations divided among three major groups spawn in Oregon (Table 29). The IC-TRT has not completed a viability assessment of this species. The major factors limiting recovery of SRB steelhead include altered channel morphology and floodplain, excessive sediment, degraded water quality, reduced streamflow, hydropower system mortality, harvest impacts, and hatchery impacts (NMFS 2006).

Table 29. SRB Steelhead Populations in Oregon

Major Group	Population (Watershed)
Grande Ronde	Lower Grande Ronde
	Joseph Creek
	Wallowa River
	Upper Grande Ronde
Imnaha River	Imnaha River
Hells Canyon Tributaries	Hells Canyon Tributaries

Oregon Coast (OC) Salmon Recovery Domain. The OC recovery domain includes one species, the OC coho salmon, and covers Oregon coastal streams south of the Columbia River and north of Cape Blanco. Streams and rivers in this area drain west into the Pacific Ocean, and vary in length from less than a mile to more than 210 miles in length. All, with the exception of the largest, the Umpqua River, drain from the crest of the Coast Range. The Umpqua transects the Coast Range and drains from the Cascade Mountains. The OC recovery domain covers cities along the coast and inland, including Tillamook, Lincoln City, Newport, Florence, Coos Bay and Roseburg, and has substantial amounts of private forest and agricultural lands. It also includes portions of the Siuslaw and Umpqua National Forests, lands managed by the U.S. Bureau of Land Management, and the Tillamook and Elliott State Forests.

OC coho salmon. This species includes all naturally-spawned populations of coho salmon in Oregon coastal streams south of the Columbia River and north of Cape Blanco, and progeny of five artificial propagation programs. The OC-TRT identified 56 historical populations, grouped into five major "biogeographic strata," based on consideration of historical distribution, geographic isolation, dispersal rates, genetic data, life history information, population dynamics, and environmental and ecological diversity (Table 30) (Lawson et al. 2007). The OC-TRT concluded that, if recent past conditions continue into the future, OC coho salmon are moderately likely to persist over a 100-year period without artificial support, and have a low to moderate likelihood of being able to sustain their genetic legacy and long-term adaptive potential for the foreseeable future (Wainwright et al. 2008). The major factors limiting recovery of OC coho salmon include altered stream morphology, reduced habitat complexity, loss of overwintering habitat, excessive sediment, high water temperature, and variation in ocean conditions (NMFS 2006).

Table 30. OC Coho Salmon Populations in Oregon

Population type "D" means dependent; "FI" means functionally independent; and "PI" means potentially independent.

Stratum	Population	Type	Stratum	Population	Type
North Coast	Necanicum	PI	Mid-Coast (cont.)	Alsea	FI
	Ecola	D		Big (Alsea)	D
	Arch Cape	D		Vingie	D
	Short Sands	D		Yachats	D
	Nehalem	FI		Cummins	D
	Spring	D		Bob	D
	Watseco	D		Tenmile	D
	Tillamook	FI		Rock	D
	Netarts	D		Big (Siuslaw)	D
	Rover	D		China	D
	Sand	D		Cape	D
	Nestucca	FI		Berry	D
	Neskowin	D		Sutton	D
Mid-Coast	Salmon	PI	Lakes	Siuslaw	FI
	Devils	D		Siltcoos	PI
	Siletz	FI		Tahkenitch	PI
	Schoolhouse	D		Tenmile	PI
	Fogarty	D	Umpqua	Lower Umpqua	FI
	Depoe	D		Middle Umpqua	FI
	Rocky	D		North Umpqua	FI
	Spencer	D		South Umpqua	FI
	Wade	D	Mid-South Coast	Threemile	D
	Coal	D		Coos	FI
	Moolack	D		Coquille	FI
	Big (Yaquina)	D		Johnson	D
	Yaquina	FI		Twomile	D
	Theil	D		Floras	PI
	Beaver	PI		Sixes	PI

Southern Oregon and Northern California Coasts (SONCC) Recovery Domain. The SONCC recovery domain includes one ESA-listed species: the SONCC coho salmon. The SONCC recovery domain extends from Cape Blanco, Oregon, to Punta Gorda, California. This area includes many small-to-moderate-sized coastal basins, where high quality habitat occurs in the lower reaches of each basin, and three large basins (Rogue, Klamath and Eel) where high quality habitat is in the lower reaches, little habitat is provided by the middle reaches, and the largest amount of habitat is in the upper reaches.

SONCC coho salmon. This species includes all naturally-spawned populations of coho salmon in coastal streams between Cape Blanco, Oregon, and Punta Gorda, California; and progeny of three artificial propagation programs. The SONCC-TRT identified 50 populations that were historically present based on consideration of historical distribution, geographic isolation, dispersal rates, genetic data, life history information, population dynamics, and environmental and ecological diversity (Williams et al. 2006). In some cases, the SONCC-TRT also identified groups of populations referred to as "diversity strata" largely based on the geographical arrangement of the populations and basin-scale environmental and ecological characteristics. Of those populations, 13 strata and 17 populations occur within the action area (Table 31). The SONCC-TRT has not yet developed viability criteria for use in setting recovery goals. The major factors limiting recovery of SONCC coho salmon include loss of channel complexity, loss of estuarine and floodplain habitat, loss of riparian habitat, loss of in-river wood, excessive sediment, degraded water quality, high water temperature, reduced streamflow, unscreened water diversions, and structures blocking fish passage (NMFS 2006).

Table 31. SONCC Coho Salmon Populations in Oregon

Populations that also occur partly in California are marked with an asterisk. Population type "D" means dependent; "E" means ephemeral; "FI" means functionally independent; and "PI" means potentially independent.

Population		Population Type
River Basin	**Subbasin**	
Elk River		FI
Mill Creek		D
Hubbard Creek		E
Brush Creek		D
Mussel Creek		D
Euchre Creek		E
Rogue River *	Lower Rogue River	PI
	Illinois River*	FI
	Mid Rogue/Applegate*	FI
	Upper Rogue River	FI
Hunter Creek		D
Pistol River		D
Chetco River		FI
Winchuck River		PI
Smith River *		FI
Klamath River *	Middle Klamath River	PI
	Upper Klamath River	FI

Southern green sturgeon. The southern green sturgeon was recently listed as threatened under the ESA (see Table 16). This species includes all naturally-spawned populations of green sturgeon that occur south of the Eel River in Humboldt County, California. The principal factor for the decline of southern green sturgeon is the reduction of its spawning area to a single known population limited to a small portion of the Sacramento River. Unless spawning, green sturgeon are broadly distributed in nearshore marine areas from Mexico to the Bering Sea and are commonly observed in bays, estuaries, and sometimes the deep riverine mainstem in lower elevation reaches of non-natal rivers along the west coast of North America. The principal threat to southern green sturgeon is the reduction of available spawning habitats due to the construction of barriers along the Sacramento and Feather rivers. Other threats are insufficient flow rates, increased water temperatures, water diversion, nonnative species, poaching, pesticide and heavy metal contamination, and local fishing. The viability of this species is still under assessment.

Salmon and Steelhead Critical Habitat

The NMFS designated critical habitat for all species considered, except LCR coho salmon and southern green sturgeon, for which critical habitat has not been proposed or designated (see Table 16). To assist in the designation of critical habitat in 2005, NMFS convened CHARTs, organized by major geographic areas that roughly correspond to salmon recovery planning domain (NOAA Fisheries 2005). Each CHART consisted of federal biologists and habitat specialists from NMFS, U.S. Fish and Wildlife Service, Forest Service, and Bureau of Land Management, with demonstrated expertise regarding salmon and steelhead habitat and related protective efforts within that domain.

Each CHART assessed biological information pertaining to areas under consideration for designation as critical habitat to identify the areas occupied by ESA-listed salmon and steelhead, determine whether those areas contained PCEs essential for the conservation of those species, and whether unoccupied areas existed within the historical range of the ESA-listed salmon and steelhead that may also be essential for conservation. The CHART then scored each habitat area based on the quantity and quality of the physical and biological features; rated each habitat area as having a ‘‘high,’’ ‘‘medium,’’ or ‘‘low’’ conservation value; and identified management actions that could affect habitat for ESA-listed salmon and steelhead. CHART reports are available from NMFS Northwest Region, Protected Resources Division in Portland, Oregon.

The ESA gives the Secretary of Commerce discretion to exclude areas from designation if he determines that the benefits of exclusion outweigh the benefits of designation. Considering economic factors and information from CHARTs, NMFS partially or completely excluded the following types of areas from the 2005 critical habitat designations:

1. Military areas. All military areas were excluded because of the current national priority on military readiness, and in recognition of conservation activities covered by military integrated natural resource management plans.

2. Tribal lands. Native American lands were excluded because of the unique trust relationship between tribes and the federal government, the federal emphasis on respect for tribal sovereignty and self governance, and the importance of tribal participation in numerous activities aimed at conserving salmon.

3. Areas With Habitat Conservation Plans. Some lands covered by habitat conservation plans were excluded because NMFS had evidence that exclusion would benefit our relationship with the landowner, the protections secured through these plans outweigh the protections that are likely through critical habitat designation, and exclusion of these lands may provide an incentive for other landowners to seek similar voluntary conservation plans.

4. Areas With Economic Impacts. Areas where the conservation benefit to the species would be relatively low compared to the economic impacts.

In designating these critical habitats, NMFS organized information at scale of the watershed or 5th field hydrologic unit code (HUC5) because that scale largely corresponds to the spatial distribution and site fidelity of Pacific salmon and steelhead populations (WDF et al. 1992, McElhany et al. 2000). For earlier critical habitat designations for Snake River salmon and SONCC coho salmon, similar information was not available at the watershed scale, so NMFS used the scale of the subbasin or 4th field HUC to organize critical habitat information.

The NMFS reviews the status of designated critical habitat affected by the proposed action by examining the condition and trends of PCEs throughout the designated area. PCEs consist of the physical and biological features identified as essential to the conservation of the listed species in the documents that designate critical habitat (Tables 32 and 33).

Climate change is likely to have negative implications for the conservation value of designated critical habitats in the Pacific Northwest (CIG 2004, Scheuerell and Williams 2005, Zabel et al. 2006, ISAB 2007). Average annual Northwest air temperatures have increased by approximately 1^{o}C since 1900, or about 50% more than the global average warming over the same period (ISAB 2007). The latest climate models project a warming of 0.1 to 0.6^{o}C per decade over the next century. According to the Independent Scientific Advisory Board (ISAB), these effects may have the following physical impacts within the next forty or so years:

- Warmer air temperatures will result in a shift to more winter/spring rain and runoff, rather than snow that is stored until the spring/summer melt season.
- With a shift to more rain and less snow, the snowpacks will diminish in those areas that typically accumulate and store water until the spring freshet.
- With a smaller snowpack, these watersheds will see their runoff diminished and exhausted earlier in the season, resulting in lower streamflows in the June through September period.
- River flows in general and peak river flows are likely to increase during the winter due to more precipitation falling as rain rather than snow.
- Water temperatures will continue to rise, especially during the summer months when lower streamflow and warmer air temperatures will contribute to the warming regional waters.

Table 32. PCEs of Critical Habitats Designated for ESA-listed Salmon and Steelhead Species and Corresponding Species Life History Events

Except SR spring/summer run Chinook salmon, SR fall-run Chinook salmon, and SR sockeye salmon.

Primary Constituent Elements		Species Life History Event
Site Type	**Site Attribute**	
Freshwater spawning	Substrate Water quality Water quantity	Adult spawning Embryo incubation Alevin development
Freshwater rearing	Floodplain connectivity Forage Natural cover Water quality Water quantity	Fry emergence Fry/parr growth and development
Freshwater migration	Free of artificial obstructions Natural cover Water quality Water quantity	Adult sexual maturation Adult upstream migration, holding Kelt (steelhead) seaward migration Fry/parr seaward migration
Estuarine areas	Forage Free of obstruction Natural cover Salinity Water quality Water quantity	Adult sexual maturation Adult "reverse smoltification" Adult upstream migration, holding Kelt (steelhead) seaward migration Fry/parr seaward migration Fry/parr smoltification Smolt growth and development Smolt seaward migration
Nearshore marine areas	Forage Free of obstruction Natural cover Water quantity Water quality	Adult sexual maturation Smolt/adult transition
Offshore marine areas	Forage Water quality	Adult growth and development

Table 33. PCEs of Critical Habitats Designated for SR Spring/Summer Run Chinook Salmon, SR Fall Run Chinook Salmon, SR Sockeye Salmon, SONCC Coho Salmon, and Life History Events

Primary Constituent Elements		Species Life History Event
Site	**Site Attribute**	
Spawning and juvenile rearing areas	Access (sockeye) Cover/shelter Food (juvenile rearing) Riparian vegetation Space (Chinook and coho) Spawning gravel Water quality Water temperature (sockeye) Water quantity	Adult spawning Embryo incubation Alevin development Fry emergence Fry/parr growth and development Fry/parr smoltification Smolt growth and development
Juvenile migration corridors	Cover/shelter Food Riparian vegetation Safe passage Space Substrate Water quality Water quantity Water temperature Water velocity	Fry/parr seaward migration Smolt growth and development Smolt seaward migration
Areas for growth and development to adulthood	Ocean areas – not identified	Adult growth and development Adult sexual maturation Fry/parr smoltification Smolt/adult transition
Adult migration corridors	Cover/shelter Riparian vegetation Safe passage Space Substrate Water quality Water quantity Water temperature Water velocity	Adult sexual maturation Adult "reverse smoltification" Adult upstream migration Kelt (steelhead) seaward migration

These changes will not be spatially homogeneous across the entire Columbia River basin. Areas with elevations high enough to maintain temperatures well below freezing for most of the winter and early spring would be less affected. Low-lying areas that historically have received scant precipitation contribute little to total streamflow and are likely to be more affected. The ISAB also identified the likely effects of projected climate changes on Columbia basin salmon. These long-term effects may include, but are not limited to, depletion of cold water habitat, variation in quality and quantity of tributary rearing habitat, alterations to migration patterns, accelerated embryo development, premature emergence of fry, and increased competition among species.

To mitigate for the effects of climate change on listed salmonids, the ISAB (2007) recommends planning now for future climate conditions by implementing protective tributary, mainstem, and estuarine habitat measures; as well as protective hydropower mitigation measures. In particular, the ISAB (2007) suggests increased summer flow augmentation from cool/cold storage reservoirs to reduce water temperatures or to create cool water refugia in mainstem reservoirs and the estuary; the protection and restoration of riparian buffers, wetlands, and floodplains; removal of stream barriers; implementation of fish ladders; and assurance of high summer and autumn flows.

Willamette and Lower Columbia (WLC) River Recovery Domain

Critical habitat was designated in the WLC Recovery Domain for UWR spring-run Chinook salmon, LCR Chinook salmon, LCR steelhead, UWR steelhead, and CR chum salmon. In addition to the Willamette and Columbia river mainstems, important tributaries on the Oregon side of the WLC include Youngs Bay, Big Creek, Clatskanie River, and Scappoose River in the Oregon Coast subbasin; Hood River in the Gorge; and the Sandy, Clackamas, Molalla, North and South Santiam, Calapooia, McKenzie, and Middle Fork Willamette rivers in the West Cascades subbasin.

The Willamette River, once a highly braided river system, has been dramatically simplified through channelization, dredging, and other activities that have reduced rearing habitat by as much as 75%. In addition, the construction of 37 dams in the basin blocked access to more than 435 miles of stream and river spawning habitat. The dams alter the temperature regime of the Willamette River and its tributaries, affecting the timing and development of naturally-spawned eggs and fry. Agriculture, urbanization, and gravel mining on the valley floor and timber harvesting in the Cascade and Coast ranges contribute to increased erosion and sediment loads throughout the basin.

The mainstem Willamette River has been channelized and stripped of large wood. Development began to encroach on the riparian forest beginning in the 1870s (Sedell and Frogatt 1984). Hulse et al. (2002) calculated that total mainstem Willamette River channel area decreased from 41,000 to 23,000 acres between 1895 and 1995. They noted that the lower reach, from the mouth of the river to Newberg (RM 50), is confined within a basaltic trench and that due to this geomorphic constraint, less channel area has been lost than in upstream areas. The middle reach from Newberg to Albany (RM 50-120) incurred losses of 12% primary channel area, 16% side channels, 33% alcoves, and 9% islands. Even greater changes occurred in the upper reach from Albany to Eugene (RM 187). There, approximately 40% of both channel length and channel area were lost, along with 21% of the primary channel, 41% of side channels, 74% of alcoves, and 80% of island areas.

The banks of the Willamette River have more than 96 miles of revetments; approximately half were constructed by the Corps. Generally, the revetments were placed in the vicinity of roads or on the outside bank of river bends, so that while only 26% of the total length is revetted, 65% of the meander bends are revetted (Hulse et al. 2002). The majority of dynamic sections have been armored, reducing adjustments in channel bed and sediment storage by the river, and thereby diminishing both the complexity and productivity of aquatic habitats (Hulse et al. 2002).

Riparian forests have diminished considerably in the lower reaches of the Willamette River (Hulse et al. 2002). Sedell and Frogatt (1984) noted that agriculture and cutting of streamside trees were major agents of change for riparian vegetation, along with snagging of large wood in the channel. The reduced shoreline, fewer and smaller snags, and reduced riparian forest comprise large functional losses to the river, reducing structural features, organic inputs from litter fall, entrained allochthonous materials, and flood flow filtering capacity. Extensive changes began before the major dams were built, with navigational and agricultural demands dominating the early use of the river. The once expansive forests of the floodplain provided valuable nutrients and organic matter during flood pulses, food sources for macroinvertebrates, and slow-water refugia for fish during flood events. These forests also cooled river temperatures as the river flowed through its many channels.

Hulse et al. (2002) described the changes in riparian vegetation in river reaches from the mouth to Newberg, from Newberg to Albany, and from Albany to Eugene. They noted that the riparian forests were formerly a mosaic of brush, marsh, and ash tree openings maintained by annual flood inundation. Below the City of Newberg, the most noticeable change was that conifers were almost eliminated. Above Newberg, the formerly hardwood-dominated riparian forests along with mixed forest made up less than half of the riparian vegetation by 1990, while agriculture dominated. This conversion represents a loss of recruitment potential for large wood, which functions as a component of channel complexity, much as the morphology of the streambed does, to reduce velocity and provide habitat for macroinvertebrates that support the prey base for salmon and steelhead. Declining extent and quality of riparian forests have also reduced rearing and refugia habitat provided by large wood, shading by riparian vegetation which can cool water temperatures, and the availability of leaf litter and the macroinvertebrates that feed on it.

Hyporheic flow in the Willamette River has been examined through discharge measurements and was found to be significant in some areas, particularly those with gravel deposits (Fernald et al. 2001). The loss of channel complexity and meandering that fosters creations of gravel deposits decreases the potential for hyporheic flows, as does gravel mining. Hyporheic flow processes water and affects its quality on reemerging into the main channel, stabilizing variations in physical and chemical water characteristics. Hyporheic exchange was found to be significant in the National Water Quality Assessment of the Willamette Basin (Wentz et al. 1998). In the transient storage zone, hyporheic flow is important for ecological functions, some aspects of water quality (such as temperature and dissolved oxygen), and some benthic invertebrate life stages. Alcove habitat, limited by channelization, combines low hydraulic stress and high food availability with the potential for hyporheic flows across the steep hydraulic gradients in the gravel separating them from the main channel (Fernald et al. 2001).

On the mainstem of the Columbia River, hydropower projects, including the Federal Columbia River Hydropower System (FCRPS), have significantly degraded salmon and steelhead habitats (Bottom et al. 2005, Fresh et al. 2005, NMFS 2005a, NOAA Fisheries 2006). The series of dams and reservoirs that make up the FCRPS block an estimated 12 million cubic yards of debris and sediment that would otherwise naturally flow down the Columbia and replenish shorelines along the Washington and Oregon coasts.

Industrial harbor and port development are also significant influences on the Lower Willamette and Lower Columbia rivers (Bottom et al. 2005, Fresh et al. 2005, NMFS 2005a, NOAA Fisheries 2006). Since 1878, 100 miles of river channel within the mainstem Columbia River, its estuary, and Oregon's Willamette River have been dredged as a navigation channel by the Army Corps of Engineers. Originally dredged to a 20-foot minimum depth, the Federal navigation channel of the Lower Columbia River is now maintained at a depth of 43 feet and a width of 600 feet. The Lower Columbia River supports five ports on the Washington State side: Kalama, Longview, Skamania County, Woodland, and Vancouver. These ports primarily focus on the transport of timber and agricultural commodities. In addition to loss of riparian habitat, and disruption of benthic habitat due to dredging, high levels of several sediment chemicals, such as arsenic and polycyclic aromatic hydrocarbons (PAHs), have been identified in Lower Columbia River watersheds in the vicinity of the ports and associated industrial activities.

The most extensive urban development in the Lower Columbia River subbasin occurs in the Portland/Vancouver area. Outside of this major urban area, the majority of residences and businesses rely on septic systems. Common water quality issues with urban development and septic systems include higher water temperatures, lowered dissolved oxygen, increased fecal coliform bacteria, and increased chemicals associated with pesticides and urban runoff.

The Columbia River estuary has lost a significant amount of tidal marsh and tidal swamp habitat that are critical to juvenile salmon and steelhead, particularly small or ocean-type species (Bottom et al. 2005, Fresh et al. 2005, NMFS 2005a, NOAA Fisheries 2006). Edges of marsh areas provide sheltered habitats for juvenile salmon and steelhead where food, in the form of amphipods or other small invertebrates which feed on marsh detritus, is plentiful, and larger predatory fish can be avoided. Historically, floodwaters of the Columbia River inundated the margins and floodplains along the estuary, allowing juvenile salmon and steelhead access to a wide expanse of low-velocity marshland and tidal channel habitats. In general, the riverbanks were gently sloping, with riparian and wetland vegetation at the higher elevations of the river floodplain becoming habitat for salmon and steelhead during flooding river discharges or flood tides. Sherwood et al. (1990) estimated that the estuary lost 20,000 acres of tidal swamps, 10,000 acres of tidal marshes, and 3,000 acres of tidal flats between 1870 and 1970. This study further estimated an 80% reduction in emergent vegetation production and a 15% decline in benthic algal production.

Habitat and food-web changes within the estuary, and other factors affecting salmon population structure and life histories, have altered the estuary's capacity to support juvenile salmon (Bottom et al. 2005, Fresh et al. 2005, NMFS 2005a, NOAA Fisheries 2006). Diking and filling activities that decrease the tidal prism and eliminate emergent and forested wetlands and floodplain habitats have likely reduced the estuary's salmon-rearing capacity. Moreover, water and sediment in the lower Columbia River and its tributaries have levels of toxic contaminants that are harmful to fish and wildlife (LCREP 2007). Contaminants of concern include dioxins and furans, heavy metals, polychlorinated biphenyls (PCBs) and organochlorine pesticides such as DDT. Simplification of the population structure and life-history diversity of salmon possibly is yet another important factor affecting juvenile salmon viability. Restoration of estuarine habitats, particularly diked emergent and forested wetlands, reduction of avian predation by terns, and flow manipulations to restore historical flow patterns might significantly enhance the estuary's productive capacity for salmon, although historical changes in population structure and salmon life histories may prevent salmon from making full use of the productive capacity of estuarine habitats, even in their presently altered state.

Interior Columbia (IC) Recovery Domain

Critical habitat has been designated in the IC Recovery Domain, which includes the Snake River basin, for SR spring/summer run Chinook salmon, SR fall-run Chinook salmon, UCR spring-run Chinook salmon, SR sockeye salmon, MCR steelhead, UCR steelhead, and SRB steelhead. Major tributaries in the Oregon portion of the IC Recovery Domain include the Deschutes, John Day, Umatilla, Walla Walla, Grande Ronde, and Imnaha rivers.

Habitat quality in tributary streams in the IC Recovery Domain varies from excellent in wilderness and roadless areas to poor in areas subject to heavy agricultural and urban development (Wissmar et al. 1994, Carmichael 2006). Critical habitat throughout the IC recovery domain was degraded by intense agriculture, alteration of stream morphology (*i.e*., channel modifications and diking), riparian vegetation disturbance, wetland draining and conversion, livestock grazing, dredging, road construction and maintenance, timber harvest, mining, and urbanization. Reduced summer stream flows, impaired water quality, and reduction of habitat complexity are common problems for critical habitat in developed areas.

Migratory habitat quality in this area has been severely affected by the development and operation of the FCRPS dams and reservoirs in the mainstem Columbia River, Bureau of Reclamation tributary projects, and privately-owned dams in the Snake and Upper Columbia river basins. For example, construction of Hells Canyon Dam eliminated access to several likely production areas in Oregon and Idaho including the Burnt, Powder, Weiser, Payette, Malheur, Owyhee, and Boise river basins (Good et al. 2005), and Grande Coulee and Chief Joseph dams completely block anadromous fish passage on the upper mainstem Columbia River. Hydroelectric development modified natural flow regimes, resulting in higher water temperatures, changes in fish community structure leading to increased rates of piscivorous and avian predation on juvenile salmon and steelhead, and delayed migration for both adult and juveniles. Physical features of dams such as turbines also kill migrating fish. In-river survival is inversely related to the number of hydropower projects encountered by emigrating juveniles.

Similarly, development and operation of extensive irrigation systems and dams for water withdrawal and storage in tributaries have drastically altered hydrological cycles. A series of large regulating dams on the middle and upper Deschutes River affect flow and block access to upstream habitat, and have extirpated one or more populations from the Cascades Eastern Slope major population (IC-TRT 2003). Pelton Round Butte Dam blocked 32 miles of MCR steelhead habitat in the mainstem Deschutes below Big Falls and removed the historically-important tributaries of the Metolius River and Squaw Creek from production. Similarly, Condit Dam on the White Salmon River extirpated another population from the Cascades Eastern Slope major group. In the Umatilla River subbasin, the Bureau of Reclamation developed the Umatilla Project beginning in 1906. The project blocked access to more than 108 miles of historically highly productive tributary habitat for MCR steelhead in upper McKay Creek with construction of the McKay Dam and Reservoir in 1927. A flood control and irrigation dam on Willow Creek was built near RM 5, completely blocking MCR steelhead access to productive habitat upstream in this subbasin. Construction of Lewiston Dam, completed in 1927, eliminated access for Snake River basin steelhead and salmon to a major portion of the Clearwater basin. Continued operation and maintenance of large water reclamation systems such as the Umatilla Basin and

Yakima Projects have significantly reduced flows and degraded water quality and physical habitat in these rivers.

Many stream reaches designated as critical habitat in the IC Recovery Domain are over-allocated under state water law, with more allocated water rights than existing streamflow conditions can support. Irrigated agriculture is common throughout this region and withdrawal of water increases summer stream temperatures, blocks fish migration, strands fish, and alters sediment transport (Spence et al. 1996). Reduced tributary stream flow has been identified as a major limiting factor for all listed salmon and steelhead species in this area except SR fall-run Chinook salmon (NMFS 2005).

Summer stream temperature is the primary water quality problem, with many stream reaches designated as critical habitat listed on the Clean Water Act's section 303(d) list for water temperature. Many areas that were historically suitable rearing and spawning habitat are now unsuitable due to high summer stream temperatures. Removal of riparian vegetation, alteration of natural stream morphology, and withdrawal of water for agricultural or municipal use all contribute to elevated stream temperatures. Contaminants such as insecticides and herbicides from agricultural runoff and heavy metals from mine waste are common in some areas of critical habitat.

Oregon Coast (OC) Coho Salmon Recovery Domain

In this recovery domain, critical habitat has been designated for OC coho salmon. Many large and small rivers supporting significant populations of coho salmon flow through this domain, including the Nehalem, Nestucca, Siletz, Yaquina, Alsea, Siuslaw, Umpqua, Coos, and Coquille. The historical disturbance regime in the central Oregon Coast Range was dominated by a mixture of high and low-severity fires, with a natural rotation of approximately 271 years. Old-growth forest coverage in the Oregon Coast Range varied from 25-75% during the past 3000 years, with a mean of 47%, and never fell below 5% (Wimberly et al. 2000). Currently the Coast Range has approximately 5% old-growth, almost all of it on Federal lands. The dominant disturbance now is timber harvesting on a cycle of 30-100 years, with fires suppressed.

In 2005, ODFW mapped the distribution of streams with high intrinsic potential for coho salmon rearing by land ownership categories (ODFW 2005). Agricultural lands and private industrial forests have by far the highest percentage of land ownership in high intrinsic potential (HIP) areas and along all coho stream miles. Federal lands have only about 20% of coho stream miles and 10% of HIP stream reaches. Because of this distribution, activities in lowland agricultural areas are particularly important to the conservation of coastal coho.

The coho assessment concluded that at the scale of the entire domain, pools are generally abundant, although slow-water and off-channel habitat (which are important refugia for coho during high winter flows) are limited in the majority of streams when compared to reference streams in minimally-disturbed areas. Amounts of large wood in streams are low in all four ODFW monitoring areas and land-use types relative to reference conditions. Amounts of fine sediment are high in three of the four monitoring areas, and were comparable to reference conditions only on public lands. Approximately 62% to 91% of tidal wetland acres (depending on estimation procedures) have been lost for functionally and potentially independent populations of coho.

As part of the coastal coho assessment, the Oregon Department of Environmental Quality (ODEQ) analyzed the status and trends of water quality in the range of OC coho using the Oregon water quality index, which is based on a combination of temperature, dissolved oxygen, biological oxygen demand, pH, total solids, nitrogen, total phosphates, and bacteria. Using the index at the species scale, 42% of monitored sites had excellent to good water quality, and 29% show poor to very poor water quality. Within the four monitoring areas, the North Coast had the best overall conditions (six sites in excellent or good condition out of nine sites), and the Mid-South coast had the poorest conditions (no excellent condition sites, and only two out of eight sites in good condition). For the 10-year period monitored between 1992 and 2002, no sites showed a declining trend in water quality. The area with the most improving trends was the North Coast, where 66% of the sites (six out of nine) had a significant improvement in index scores. The Umpqua River Basin, with one out of nine sites (11%) showing an improving trend, had the lowest number of improving sites.

Southern Oregon and Northern California Coasts (SONCC) Coho Salmon Recovery Domains

Critical habitat in this recovery domain has been designated for SONCC coho salmon. Many large and small rivers supporting significant populations of coho salmon flow through the area, including the Elk, Rogue, Chetco, Smith and Klamath. The following summary of critical habitat information in the Elk, Rogue, and Chetco rivers is also applicable to habitat characteristics and limiting factors in other basins in this area.

The Elk River flows through Curry County, drains approximately 92 square miles (or 58,678 acres) (Maguire 2001). Major tributaries of the Elk River include the North Fork, South Fork, Blackberry Creek, Panther Creek, Butler Creek, and Bald Mountain Creek. The upper portion of the Elk River basin is characterized by steeply sloped forested areas with narrow valleys and tributary streams that have steep to very steep gradients. Grazing, rural and residential development and other agricultural uses are the dominant land uses in the lower basin (Maguire 2001). Over half of the Elk River basin is in the Grassy Knob wilderness area. Historical logging, mining, and road building have degraded stream and riparian habitats in the basin. Limiting factors identified for salmon and steelhead production in this basin include sparse riparian cover, especially in the lower reaches, excessive fine sediment, high water temperatures, and noxious weed invasions (Maguire 2001).

The Rogue River drains approximately 5,160 square miles within Curry, Jackson and Josephine counties in southwest Oregon. The mainstem is about 200 miles long and traverses the coastal mountain range into the Cascades. The Rogue River estuary has been modified from its historical condition. Jetties were built by the Corps in 1960, which stabilized and deepened the mouth of the river. A dike that extends from the south shore near Highway 101 to the south jetty was completed in 1973. This dike created a backwater for the large shallow area that existed here, which has been developed into a boat basin and marina, eliminating most of the tidal marsh.

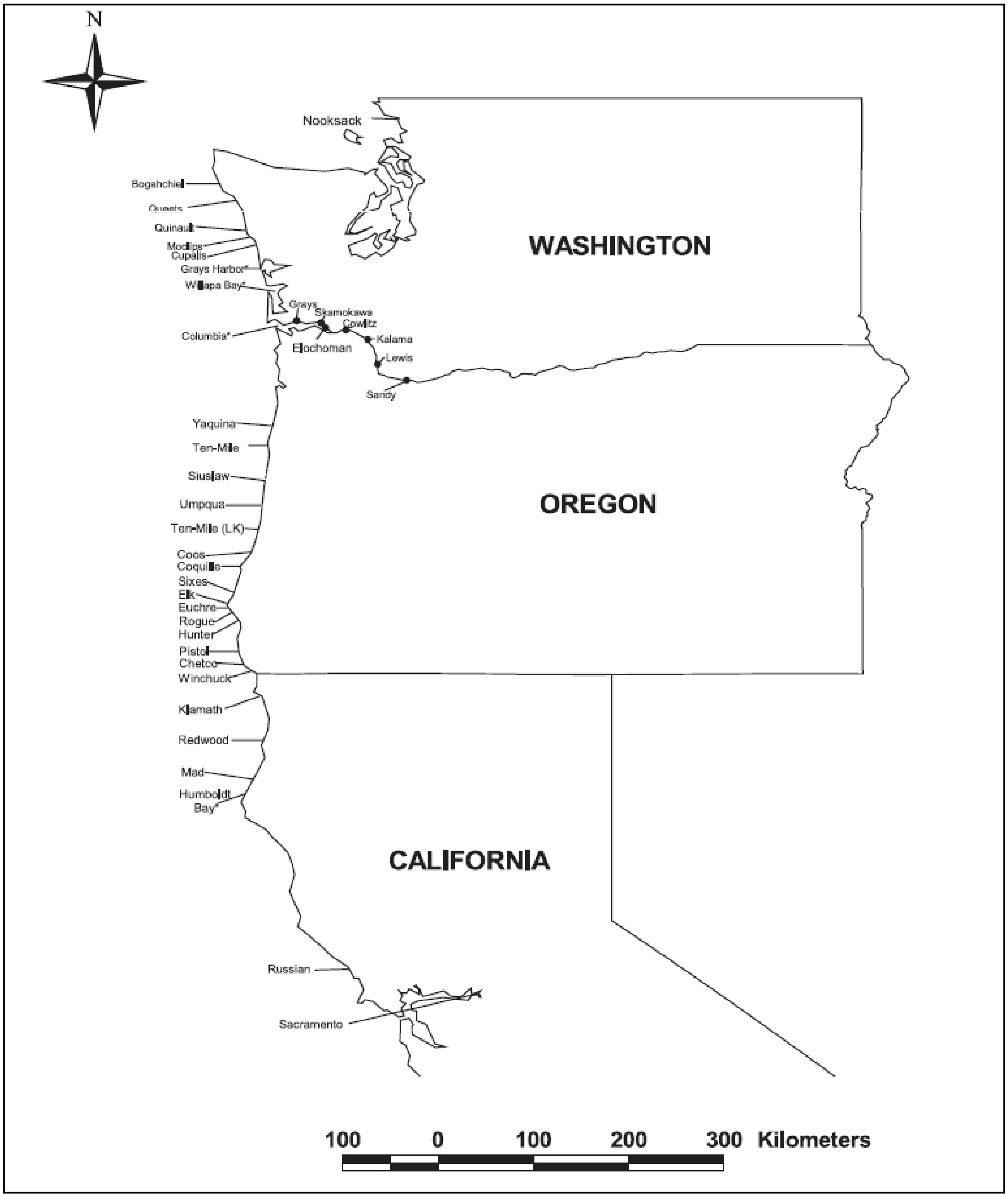
The quantity of estuary habitat is naturally limited in the Rogue River. The Rogue River has a drainage area of 5,160 square miles, but the estuary at 1,880 acres is one of the smallest in Oregon. Between 1960 and 1972, approximately 13 acres of intertidal and 14 acres of subtidal land were filled in to build the boat basin dike, the marina, north shore riprap and the other north shore developments (Hicks 2005). Jetties constructed in 1960 to stabilize the mouth of the river and prevent shoaling have altered the Rogue River, which historically formed a sill during summer months (Hicks 2005).

The Lower Rogue Watershed Council's watershed analysis (Hicks 2005) lists factors limiting fish production in tributaries to Lower Rogue River watershed. The list includes water temperatures, low stream flows, riparian forest conditions, fish passage and over-wintering habitat. Limiting factors identified for the Upper Rogue River basin include fish passage barriers, high water temperatures, insufficient water quantity, lack of large wood, low habitat complexity, and excessive fine sediment (RBCC 2006).

The Chetco River is in the southwest corner of Oregon, almost entirely within Curry County, with a drainage of approximately 352 square miles. The Chetco River mainstem is about 56 miles long, and the upper 28 miles are within the Kalmiopsis Wilderness Area. Elevations in the watershed range from sea level to approximately 5,098 feet. The upper portion of the basin is characterized by steep, sloping forested areas with narrow valleys and tributary streams that have moderately steep to very steep gradient. The lowest 11 miles of the river are bordered by private land in rural/residential, forestry, and urban land uses.

The Chetco River estuary has been significantly modified from its historical condition. Jetties were erected by the Corps 1957, which stabilized and deepened the mouth of the river. These jetties have greatly altered the mouth of the Chetco River and how the estuary functions as habitat for salmon migrating to the ocean. A boat basin and marina were built in the late 1950s and eliminated most of the functional tidal marsh. The structures eliminated shallow water habitats and vegetation in favor of banks stabilized with riprap. Since then, nearly all remaining streambank in the estuary has been stabilized with riprap. The South Coast Watershed Council's watershed analysis (Maguire 2001) states the factors limiting fish production in the Chetco River appear to be high water temperature caused by lack of shade, especially in tributaries, high rates of sedimentation due to roads, poor over-wintering habitat due to a lack of large wood in tributaries and the mainstem, and poor quality estuary habitat (Maguire 2001).

Eulachon



Eulachon (smelt) are endemic to the eastern Pacific Ocean ranging from northern California to southwest Alaska and into the southeastern Bering Sea. Eulachon occur only on the coast of northwestern North America, from northern California to southwestern Alaska. In the portion of the species' range that lies south of the U.S./Canada border, most eulachon production originates in the Columbia River Basin. In this basin, the major and most consistent spawning runs occur in the mainstem of the Columbia River (from just upstream of the estuary, RM 25 to immediately downstream of Bonneville Dam at RM 146). Periodic spawning occurs in the Grays, Skamokawa, Elochoman, Kalama, Lewis, Cowlitz, and Sandy rivers (Emmett et al. 1991, Musick et al. 2000). In the Columbia River and its tributaries, spawning usually begins in January or February (Beacham et al. 2005).

Eulachon are anadromous fish that spawn in the lower reaches of rivers in early spring. They typically spend 3 to 5 years in saltwater before returning to freshwater to spawn from late winter through mid-spring. Spawning occurs over sand or coarse gravel substrates, eggs are fertilized in the water column, sink, and adhere to the river bottom. Most adults die after spawning and eggs hatch in 20-40 days. Larvae are carried downstream and are dispersed by estuarine and ocean currents shortly after hatching. Runs tend to be erratic, appearing in some years but not others, and appearing only rarely in some river systems (Hinrichsen 1998). Eulachon are important in the food web as a prey species (Alaska Department of Fish and Game 1994). Newly-hatched and juvenile eulachon are food for a variety of larger marine fish such as salmon and for marine mammals including seals, sea lions and beluga whales. Spawned-out eulachon are eaten by gulls, eagles, bears and sturgeon.

Eulachon spawning runs have declined in the past 20 years, especially since the mid-1990s (Hay and McCarter 2000). The cause of these declines remains uncertain. Eulachon are caught as bycatch during shrimp fishing, but in most areas the total bycatch is small (Beacham *et al*. 2005). Predation by pinnipeds may be substantial, and other risk factors could include global climate change and deterioration of marine and freshwater conditions (73 FR 13185).

In 1999, NMFS received a petition to list the Columbia River populations of eulachon as an endangered or threatened species and to designate critical habitat under the ESA. NMFS determine the petition did not present enough substantial evidence to warrant the listed (64 FR 66601). In 2007, NMFS received a petition from the Cowlitz Indian Tribe to list southern eulachon (populations in Washington, Oregon and California) as a threatened or endangered species under the ESA. After reviewing the information contained in the petition and other information, NMFS proposed listing eulachon as a threatened on March 13, 2009 (74 FR 10857). The final listing of the southern DPS of Pacific eulachon as threatened under the ESA by NOAA Fisheries occurred on March 18, 2010 (NMFS 2010b). Take prohibitions via section 4(d) of the ESA have not yet been promulgated, nor has critical habitat yet been designated for the southern DPS, although both actions are expected to occur in 2011.

Limiting Factors

The major factors limiting recovery of eulachon include climate change on ocean conditions, climate change on freshwater habitat, eulachon by-catch, dams and water diversions, and predation (NMFS 2009).

Critical Habitat

NMFS has not designated critical habitat for eulachon.

Marine Mammals

Blue Whale

Blue whales occur primarily in the open ocean from tropical to polar waters worldwide. Blue whales are highly mobile, and their migratory patterns are not well known (Perry et al. 1999; Reeves et al. 2004). However, the distribution of blue whales is probably determined primarily by food requirements, with seasonal migration toward the poles in spring to feed on zooplankton during the summer months. Blue whales migrate toward the warmer waters of the subtropics in the fall to reduce energy costs, to avoid ice entrapment, and to reproduce (NMFS 1998a). Blue whales are typically found swimming alone or in groups of two or three to up to five animals, although larger foraging aggregations of up to 50 blue whales have been reported including aggregations mixed with other rorquals such as fin whales (Corkeron et al. 1999; Shirihai 2002).

Little is known about population and stock structure[1] of blue whales. Studies suggest a wide range of alternative population and stock scenarios based on movement, feeding, and acoustic data. Some suggest that as many as 10 putative stocks of blue whales exist globally, while others suggest that the species is composed of a single panmictic stock (see Gambell 1979, Clark 1994, and Reeves et al. 1998). For management purposes, the International Whaling Commission (IWC) considers all Pacific blue whales as a single stock, whereas under the MMPA, NMFS presently recognizes four stocks of blue whales: western North Pacific Ocean, the eastern North Pacific Ocean, the Northern Indian Ocean, and the Southern Hemisphere.

Historical catch records suggest that "true" blue whales (*Balaenoptera musculus*) and "pygmy" blue whale (*B. m. brevicada*) may be geographically distinct (Brownell and Donaghue 1994, Kato *et al.* 1995). "Pygmy" blue whales occur north of the Antarctic Convergence (between 60° to 80° E and 66° to 70° S), while "true" blue whales are south of the Convergence (58° S) in the austral summer (Kato et al. 1995; Kasamatsu et al. 1996). During austral summers, "true" blue whales are found close to edge of Antarctic ice with concentrations.

Until recently, blue whale stock structure had not been tested using molecular or nuclear genetic analyses (Reeves et al. 1998). A recent study by Conway (2005) suggests that the global population can be divided into four major subdivisions, which roughly correspond to major ocean basins: the eastern North and tropical Pacific Ocean, the Southern Indian Ocean, the Southern Ocean, and the western North Atlantic Ocean. The eastern North/tropical Pacific Ocean subpopulation, which according to the samples analyzed by Conway (2005) includes California, western Mexico, western Costa Rica, and Ecuador, and the western North Atlantic Ocean subpopulation occur within the action area for the aquatic life criteria. Further study is needed to firmly establish population structures, but it is apparent that blue whale populations do not interbreed enough to maintain the genetic cohesion of a single stock. For the purposes of this assessment and until further information is available, NMFS is treating blue whales as four distinct populations.

"Populations" herein are a group of individual organisms that live in a given area and share a common genetic heritage. While genetic exchange may occur with neighboring populations, the rate of exchange is greater between individuals of the same population than among populations - a population is driven more by internal dynamics, birth and death processes than by immigration or emigration of individuals. To differentiate populations, NMFS considers geographic distribution and spatial separation, life history, behavioral and morphological traits, as well as genetic differentiation where it has been examined. In many cases, behavioral and morphological differences may evolve and be detected before genetic variation occurs. In some cases, the term "stock" is synonymous with this definition of "population" while other usages of "stock" are not.

In the North Pacific, acoustic monitoring has recorded blue whales off Oahu and the Midway Islands), although sightings or strandings in Hawaiian waters have not been reported (Northrop et al. 1971; Thompson and Friedl 1982; Barlow et al. 1997. Nishiwaki (1966) notes the occurrence of blue whales among the Aleutian Islands and in the Gulf of Alaska, but no one has sighted a blue whale in Alaska for sometime despite several surveys (Leatherwood et al. 1982; Stewart et al. 1987; Forney and Brownell 1996; Carretta et al. 2005). Minimal distributional information suggest that whales in the western region of the North Pacific may summer southwest of Kamchatka, south of the Aleutians, and in the Gulf of Alaska, and winter in the lower latitudes of the western Pacific (Sea of Japan, the East China, Yellow, and Philippine seas) and less frequently in the central Pacific, including Hawaii (Watkins et al. 2000; Stafford 2003; Carretta et al. 2005; Stafford et al. 2001 *in* Carretta et al. 2005). However, acoustic recordings made off Oahu showed bimodal peaks of blue whales, suggesting that the animals were migrating into the area during summer and winter (Thompson and Friedl 1982; McDonald and Fox 1999). In the eastern North Pacific, blue whales appear to summer off the U.S. West Coast in waters off California and occasionally as far north as British Columbia, migrating south to productive areas off Mexico and as far south as the Costa Rica Dome (10° N) from June through November due to high prey density (Reilly and Thayer 1990; Calambokidis et al. 1990; Calambokidis et al. 1998; Mate et al. 1999; Stafford et al. 1999). Blue whale sightings have occurred year-round in the northern Indian Ocean (Gulf of Aden, Persian Gulf, Arabian Sea, and across the Bay of Bengal to Burma and the Strait of Malacca; Mizroch et al. 1984).
Blue whale reproductive activities occur primarily in winter (see Yochem and Leatherwood 1985). Gestation takes 10-12 months, followed by a nursing period that continues for about 6-7 months. They reach sexual maturity at about 5 years of age (see Yochem and Leatherwood 1985). The age distribution of blue whales is unknown and little information exists on natural sources of mortality (such as disease) and mortality rates. Killer whales are known to attack blue whales, but the rate of these attacks or their effect on blue whale populations is unknown.

Important foraging areas include the edges of continental shelves and ice edges in polar regions (Yochem and Leatherwood 1985; Reilly and Thayer 1990). Data indicate that some summer feeding takes place at low latitudes in upwelling-modified waters, and that some whales remain year-round at either low or high latitudes (Yochem and Leatherwood 1985; Reilly and Thayer 1990; Clark and Charif 1998). The krill species, *Thysanoessa inermi*s, *T. longipe*s, *T. raschii*, and *Nematoscelis megalops* have been listed as prey of blue whales in the North Pacific (Kawamura 1980; Yochem and Leatherwood 1985).

Generally, blue whales make 5 to 20 shallow dives at 12 to 20 second intervals followed by a deep dive of 3 to 30 minutes (Mackintosh 1965; Leatherwood et al. 1976; Maser et al. 1981; Yochem and Leatherwood 1985; Strong 1990; Croll et al. 1999). Croll et al. (1999) found that daytime blue whale foraging dives off California averaged 433 feet, with a maximum recorded depth of 672 feet, and a mean dive duration of 7.2 minutes. Nighttime dives are generally shallower (165 feet). Blue whales occur singly or in groups of two or three (Ruud 1956; Slijper 1962; Nemoto 1964; Mackintosh 1965; Pike and MacAskie 1969; Aguayo 1974). However, larger foraging aggregations, even with other species such as fin whales, are regularly reported (Schoenherr 1991; Fiedler et al. 1998).

Status and Trends

Blue whales were originally listed as endangered in 1970 (35 FR 18319), and this status remained since the inception of the ESA in 1973. The estimated size of the global population of blue whales is about 12,000 animals (Maser et al. 1981; U.S. Department of Commerce 1983), which is a fraction of pre-whaling population estimates of 200,000 animals. These estimates, however, are more than 20 years old. The actual size of the blue whale population in the North Atlantic is uncertain, but estimates range from a few hundred individuals to about 2,000 (Allen 1970; Mitchell 1974; Sigurjónsson 1995). Gambell (1976) estimated there were between 1,100 and 1,500 blue whales in the North Atlantic before whaling began, and Braham (1991) estimated there were between 100 and 555 blue whales in the North Atlantic during the late 1980s and early 1990s. Sears et al. (1987) identified 308 individual blue whales in the Gulf of St. Lawrence, which provides a minimum estimate for their population in the North Atlantic. Sigurjónsson and Gunnlaugson (1990) concluded that the blue whale population had been increasing since the late 1950s. These authors concluded that the blue whale population increased at an annual rate of about 5% between 1979 and 1988.

In the eastern North Pacific, the minimum population is thought to be 1,384 whales but due to a lack of sightings in the western North Pacific, no minimum population has been established (Carretta et al. 2006). A lot of uncertainty surrounds estimates of blue whale abundance in the North Pacific Ocean. The population has been estimated to be as high as 3,300 and as low as 1,400 (Wade and Gerrodette 1993; Barlow 1997; Barlow et al. 1997). Estimates of the southern hemisphere population range from 5,000 to 6,000 (review by Yochem and Leatherwood 1985) with an average rate of increase of 4% to 5% per year, but Butterworth et al. (1993) estimated the Antarctic population at 710 individuals. More recently, Branch et al. (2004) estimated the blue whale population in the Southern Ocean at between 860 and 2,900 animals, which is only 0.7% of their pre-exploitation population. The pygmy blue whale population has been estimated at 6,000 individuals (Yochem and Leatherwood 1985).

Threats

As the largest animals in the world, blue whales are only occasionally known to be taken by killer whales (Tarpy 1979; Sears et al. 1990). Blue whales engage in a flight responses to evade killer whales, which involves high energetic output, but show little resistance if overtaken (Ford and Reeves 2008). However, prey limitations may be more significant in population recovery, particularly around Antarctica. After several whale species were severely reduced by hunting in the Southern Ocean, crab eater seal population size exploded due to lack of competition for krill. As a result, populations of crab-eater seals in Antarctica exceed five million individuals, making them the most populous marine mammal species, and reducing prey availability for recovering whale populations. Blue whales are known to become infected with the nematode *Carricauda boopis*, which are believed to have caused fin whales to die as a result of renal failure (Lambertsen 1986).

Blue whales have faced threats from several historical and current sources. Blue whale populations are severely depleted originally due to historical whaling activity. From 1910 to 1965, roughly 9,500 blue whales were taken in the North Pacific (Ohsumi and Wada 1972).

Although the IWC banned commercial whaling in the North Pacific in 1966, Soviet whaling fleets continued to hunt blue whales in the North Pacific. By 1967, Soviet scientists wrote that blue whales in the North Pacific Ocean (including the eastern Bering Sea and Prince William Sound) had been so overharvested by Soviet whaling fleets that some scientists concluded that any additional harvests were certain to cause the species to become extinct in the North Pacific (Latishev 2007). As its legacy, whaling has reduced blue whales to a fraction of their historic population size and, as a result, makes it easier for other human activities to push blue whales closer to extinction. However, since the IWC moratorium was placed on hunting of most whales, blue whale populations appear to be rebounding at an average of 8.2% positive population growth per year from 1978 to 2004 for the most heavily hunted population in the Southern Ocean (IWC 2008).

Ship strike is presently a concern for blue whale recovery. Ship strikes have recently averaged roughly one every other year (eight ship strike incidents are known [Jensen and Silber 2004]), but in September 2007, ships struck five blue whales within a few day period off southern California (Calambokidis pers. comm. 2008). Dive data support a surface-oriented behavior during nighttime that would make blue whales particularly vulnerable to ship strikes. There are concerns that, like right whales, blue whales may surface when approached by large vessels; a behavior that would increase their likelihood of being struck. Protective measures are not currently in place. It is believed based upon gray whale studies that the vast majority of ship strike mortalities are never identified, and that actual mortality is higher. In the California/Mexico stock, annual incidental mortality due to ship strikes averaged one whale every 5 years, but we cannot determine if this reflects the actual number of blue whales struck and killed by ships (i.e., individuals not observed when struck and those who do not strand; Barlow et al. 1997).

Increasing oceanic noise may impair blue whale behavior. Although available data do not presently support traumatic injury from sonar, the general trend in increasing ambient low-frequency noise in the deep oceans of the world from primarily ship engines could impair the ability of blue whales to communicate or navigate through these vast expanses (Aburto et al. 1997; Clark 2006).

There is a paucity of contaminant data regarding blue whales. Available information indicates that organochlorines, including dichloro-diphenyl-trichloroethane (DDT), polychlorinated biphenyls (PCB), benzene hexachloride (HCH), hexachlorobenzene (HCB), chlordane, dieldrin, methoxychlor, and mirex have been isolated from blue whale blubber and liver samples (Gauthier et al. 1997a; Metcalfe et al. 2004). Contaminants transfer between mother and calf mean that young often start life with concentrations of contaminants equal to their mothers, before accumulating additional contaminant loads during life and passing higher loads to the next generation (Gauthier et al. 1997b; Metcalfe et al. 2004).

Critical Habitat

NMFS has not designated critical habitat for blue whales.

Fin Whale

The fin whale is the second largest baleen whale and is widely distributed in the world's oceans. Most fin whales in the Northern Hemisphere migrate seasonally from Antarctic feeding areas in the summer to low latitude breeding and calving grounds in winter. Fin whales tend to avoid tropical and pack ice waters, with the high latitude limit of their range set by ice and the lower latitude limit by warm water of approximately 15°C (60°F) (Sergeant 1977). There are two recognized subspecies of fin whales, *Balaenoptera physalus physalus*, which occurs in the North Atlantic Ocean, while *B. p. quoyi*, which occurs in the Southern Ocean. These subspecies and the North Pacific fin whales appear to be organized into separate populations, although there appears to be a lack of consensus in the published literature as to the population structure of fin whales. In the North Atlantic Ocean, the IWC recognizes seven management units or "stocks" of fin whales: (1) Nova Scotia, (2) Newfoundland-Labrador, (3) West Greenland, (4) East Greenland-Iceland, (5) North Norway, (6) West Norway-Faroe Islands, and (7) British Isles-Spain-Portugal. In addition, a genetically distinct population of fin whales resides in the Ligurian Sea, in the northwestern Mediterranean Sea.

In the North Pacific Ocean, the IWC recognizes two management stocks: (1) East China Sea and (2) the rest of the North Pacific (Donovan 1991). Other author's have suggested other subpopulation structuring for fin whales (Mizroch et al. 1984). Genetic studies by Berube et al. (1998) indicate that there are significant genetic differences among fin whales in differing geographic areas (e.g., Sea of Cortez, Gulf of St. Lawrence and Gulf of Maine). Further, individuals in the Sea of Cortez may represent an isolated population from other eastern North Pacific fin whales (Berube et al. 2002). Even so, mark-recapture studies also demonstrate that individual fin whales are migrating between management units (Mitchell 1974; Gunnlaugsson and Sigurjónsson 1989), which suggests that management units are not geographically isolated. Until further information is available to reduce uncertainties in the fin whale population structure, under the MMPA, NMFS recognizes four stocks, or populations, of fin whales, one in the Atlantic and three in the Pacific: the (1) Western North Atlantic, (2) Northeast Pacific (or Alaska stock), (3) California-Oregon-Washington, and (4) the Hawaii stock.

In the North Atlantic, fin whales are ubiquitous and occur during the summer from Baffin Bay to near Spitsbergen and the Barents Sea, south to Cape Hatteras in North Carolina and off the coasts of Portugal and Spain (Rice 1998). In areas North of Cape Hatteras where fin whales accounted for about 46% of the large whales observed in surveys conducted between 1978 and 1982. Little is known about the winter habitat of fin whales, but in the western North Atlantic the species has been found from off Newfoundland south to the Gulf of Mexico and Greater Antilles, and in the eastern North Atlantic the winter range extends from the Faroes and Norway south to the Canary Islands. In the Atlantic Ocean, a general migration in the fall from the Labrador and Newfoundland region, south past Bermuda, and into the West Indies has been theorized (Clark 1995). A genetically distinct population occurs year-round in the northwestern Mediterranean (IWC 2006a). In the Southern Hemisphere, fin whales are broadly distributed south of 50° S in the summer and migrate to the coasts of South America (as far north as Peru and Brazil), Africa, and the islands in Oceania north of Australia and New Zealand (Gambell 1985a).

Fin whale concentrations generally form along frontal boundaries, or mixing zones between coastal and oceanic waters, which corresponds roughly to the 660 foot isobath (the shelf edge; Nasu 1974). Fin whales are common off the Atlantic coast of the U.S. in waters immediately off the coast seaward to the continental shelf (about the 1,000-fathom contour). In the North Pacific, fin whales are observed year-round off central and southern California with peak numbers in the summer and fall. Peak numbers of fin whales are seen during the summer off Oregon, and in summer and fall in the Gulf of Alaska and southeastern Bering Sea (Perry et al. 1999). Fin whales are observed feeding in Hawaiian waters during mid-May, and their sounds have been recorded there during the autumn and winter (Northrop et al. 1968; Shallenberger 1981; Thompson and Friedl 1982; Balcomb 1987). Fin whales in the western Pacific winter in the Sea of Japan, the East China, Yellow, and Philippine seas (Gambell 1985a).

Fin whales reach sexual maturity between 5 and 15 years of age (Lockyer 1972; Gambell 1985a). Mating occurs primarily in winter, and gestation lasts about 12 months and nursing occurs for 6 to 11 months (Perry et al. 1999). The average calving interval in the North Atlantic is estimated at about 2 years, based on whaling data (Christensen et al. 1992a in NMFS 2006a). The location of winter breeding grounds is uncertain (Perry et al. 1999).

Fin whales in the North Atlantic eat pelagic crustaceans (mainly euphausiids or krill, including *Meganyctiphanes norvegica* and *Thysanoessa inermis*) and schooling fish such as capelin *(Mallotus villosus*), herring (*Clupea harengus*), and sand lance (*Ammodytes* spp.) (Hjort and Ruud 1929; Ingebrigtsen 1929; Jonsgård 1966a; Mitchell 1974; Sergeant 1977; Overholtz and Nicolas 1979; Christensen et al. 1992b; Borobia et al. 1995). In the North Pacific, fin whales apparently prefer euphausiids (mainly *Euphausia pacifica*, *T. longipes*, *T. spinifera*, *T. inermis*, and *Nyctiphanes simplex*) and large copepods (mainly *Calanus cristatus*), followed by schooling fish such as herring, walleye pollock (*Theragra chalcogramma*), and capelin (Nemoto 1970; Kawamura 1982a, b; Ladrón De Guevara et al. 2008; Paloma et al. 2008). Antarctic fin whales feed on krill, *Euphausia superba*, which occurs in dense near-surface schools (Nemoto 1959). However, off the coast of Chile, fin whales are known to feed on the euphausiid *E. mucronata* (Antenzana 1970; Perez et al. 2006). Feeding may occur in waters as shallow as 33 feet when prey are at the surface (Paloma et al. 2008).

The amount of time fin whales spend at the surface varies. Some authors have reported that fin whales make 5 to 20 shallow dives, each of 13 to 20 seconds duration, followed by a deep dive of between 1.5 and 15 minutes (Gambell 1985a). Other authors have reported that the fin whale's most common dives last between 2 and 6 minutes (Watkins 1981; Hain et al. 1992). In waters off the U.S. Atlantic Coast, individual or duos of fin whales represented about 75% of sightings during the Cetacean and Turtle Assessment Program (Hain et al. 1992). Individual whales or groups of less than five individuals represented about 90% of the observations. Out of 2,065 observations, mean group size was 2.9, with a range of 1-65 individuals (Hain et al. 1992).

Status and Trends

Fin whales were originally listed as endangered in 1970 (35 FR 18319), and this status remained since the inception of the ESA in 1973. Although population structure remains undetermined for fin whales, various studies and estimates of abundance are available. Sergeant (1977) suggested that between 30,000 and 50,000 fin whales once populated the North Atlantic Ocean based on assumptions about catch levels during the whaling period. Sigurjónsson (1995) estimated that between 50,000 and 100,000 fin whales once populated the North Atlantic, although he provided no data or evidence to support that estimate. More recently, Palumbi and Roman (2006) estimated that about 360,000 fin whales (95% confidence interval = 249,000 to 481,000) populated the North Atlantic Ocean before whaling based on mutation rates and estimates of genetic diversity. Globally, Braham (1991) compiled available regional estimates and reported a pre-exploitation abundance for fin whales of more than 464,000 individuals worldwide. The estimate for 1991 indicated a global fin whale abundance of 120,000 (Braham 1991).

Current size estimates of fin whale populations and estimates of their global abundance vary widely. NMFS estimates that at least 2,200 fin whales populate the North Atlantic Ocean, with slightly more than 3,000 individuals off California, Oregon, and Washington based on ship surveys in summer/autumn of 1996, 2001, and 2005 (Barlow and Taylor 2001; Barlow 2003; Forney 2007; NMFS 2007a). An estimated 5,000 fin whales inhabit areas off the Kenai Peninsula and estimates suggest only a few hundred fin whales occur around the Hawaiian Islands (Moore et al. 2002; Zerbini et al. 2006; Caretta et al. 2007). These estimates and estimates of the East Greenland-Iceland fin whale population (10,000 animals, 95% C.I. = 7,600 to 14,200), the eastern Atlantic fin whales, which includes the British Isles-Spain-Portugal population (17,000 animals, 95% CI = 10,400 to 28,900), and the western Mediterranean fin whale population (3,583 individuals SE = 967; 95% CI = 2,130 to 6,027) suggest that the global population of fin whales consists of tens of thousands of individuals (Buckland et al. 1992; Forcada et al. 1996; Notarbartoli-di-Sciara et al. 2003).

Threats

Natural sources and rates of mortality are largely unknown, but Aguilar and Lockyer (1987) suggest annual natural mortality rates may range from 0.04 to 0.06 (based on studies of northeast Atlantic fin whales). The occurrence of the nematode *Crassicauda boopis* appears to increase the potential for kidney failure in fin whales and may be preventing some fin whale populations from recovering from whaling (Lambertsen 1992 *in* Perry et al. 1999). Adult sei whales engage in a flight responses (up to 25 miles per hour) to evade killer whales, which involves high energetic output, but show little resistance if overtaken (Ford and Reeves 2008). Killer whale or shark attacks may also result in serious injury or death in very young and sick whales (Perry et al. 1999).

As early as the mid-seventeenth century, the Japanese were capturing fin, blue, and other large whales using a fairly primitive open-water netting technique (Tønnessen and Johnsen 1982; Cherfas 1989). In 1864, explosive harpoons and steam-powered catcher boats were introduced in Norway, allowing the large-scale exploitation of previously unobtainable whale species. After blue whales were depleted in most areas, the smaller fin whale became the focus of whaling operations. Between 1904 and 1970, more than 700,000 fin whales were killed in the Southern Hemisphere, and more than 45,000 were reported as killed throughout the North Pacific (NMFS 2006a).

Fin whales are still hunted in subsistence fisheries off West Greenland. In 2004, five males and six females were killed and landed, and two other fin whales were struck and lost. In 2003, two males and four were landed and two others were struck and lost (IWC 2005). Between 2003 and 2007, the IWC set a catch limit of up to 19 fin whales in this subsistence fishery, however, the scientific recommendation was to limit the number killed up to four individuals until accurate populations could be produced (IWC 2005). In the Antarctic Ocean, fin whales are hunted by Japanese whalers who have been allowed to kill up to 10 fin whales each ear for the 2005-2006 and 2006-2007 seasons under an Antarctic Special Permit (NMFS 2006a). The Japanese whalers plan to kill 50 whales per year starting in the 2007 to 2008 season and continuing for the next 12 years.

Fin whales are also injured and killed by fishing gear and ship strikes (Perkins and Beamish 1979; Lien 1994; Caretta et al. 2007; Waring et al. 2007; Douglas et al. 2008). Between 1969 and 1990, 14 fin whales were captured in coastal fisheries off Newfoundland and Labrador of these seven are known to have died as a result of capture (Perkins and Beamish 1979; Lien 1994); and in 1999, one fin whale was reported as killed in the Gulf of Alaska pollock trawl fishery, and one was killed the same year in the off shore drift gillnet fishery off the west coast (Carretta et al. 2004; Angliss and Outlaw 2006). According to Waring et al. (2007) four fin whales in the western North Atlantic died or were seriously injured in fishing gear, while another five were killed or injured as a result of ship strikes between January 2000 and December 2004. Jensen and Silber's (2004) review of NMFS' ship strike database records from 1975 to 2002 revealed fin whales as the most often confirmed victims of ship strikes (26% of the recorded ship strikes [n = 75/292 records]), with most collisions (of all whale species) occurring off the east coast, followed by the west coast of the U.S. and Alaska/Hawaii. Between 1999 and 2005, there were 15 reports of fin whales being struck by vessels along the U.S. and Canadian Atlantic coasts (Cole et al. 2005; Nelson et al. 2007). Of these, 13 were confirmed, resulting in the deaths of 11 individuals. Five of seven fin whales stranded along Washington State and Oregon showed evidence of ship strike with incidence increasing since 2002 (Douglas et al. 2008). Similarly, 2.4% of living fin whales from the Mediterranean show ship strike injury and 16% of stranded individuals were killed by vessel collision (Panigada et al. 2006). There are also numerous reports of ship strikes off the Atlantic coasts of France and the United Kingdom (Jensen and Silber 2003).

Management measures aimed at reducing the risk of ships hitting right whales should also reduce the risk of collisions with fin whales. In the Bay of Fundy, recommendations for slower vessel speeds to avoid right whale ship strike appear to be largely ignored (Vanderlaan et al. 2008). However, proposed rules for seasonal (June through December) slowing of vessel traffic to 10 knots or changing shipping lanes by less than one nautical mile to avoid the greatest concentrations of right whales are predicted to be capable of reducing ship strike mortality by 62% in the Bay of Fundy region for right whales and reduced the chance of collisions with fin whales by 27%.

The organochlorines DDE, DDT, and PCBs have been identified from fin whale blubber, but levels are lower than in toothed whales due to the lower level in the food chain that fin whales feed at (Aguilar and Borrell 1987, 1988; Borrell 1993; Henry and Best 1983; Marsili and Focardi 1996). Females contained lower burdens than males, likely due to mobilization of contaminants during pregnancy and lactation (Aguilar and Borrell 1988; Borrell 1993; Gauthier et al. 1997b). Contaminant levels increase steadily with age until sexual maturity, at which time levels begin to drop in females and slowly increase in males (Aguilar and Borrell 1988; Aquilar and Borrell 1994). Nevertheless, based on the evidence available, the number of fin whales that are recorded to have been killed or injured in the past 20 years by human activities or natural phenomena, does not appear to be increasing the extinction probability of fin whales, although it may slow the rate at which they recovery from population declines that were caused by commercial whaling.

Critical Habitat

NMFS has not designated critical habitat for fin whales.

Humpback Whale

Humpback whales are a cosmopolitan species that occur in the Atlantic, Indian, Pacific, and Southern oceans. Humpback whales migrate seasonally between warmer, tropical or sub-tropical waters in winter months (where they breed and give birth to calves, although feeding occasionally occurs) and cooler, temperate or sub-Arctic waters in summer months (where they feed; Gendron and Urban 1993). In both regions, humpback whales tend to occupy shallower, coastal waters. However, migrations are undertaken through deep, pelagic waters (Winn and Reichley 1985).

In the North Pacific, humpback whales summer in coastal and inland waters from Point Conception, California, north to the Gulf of Alaska and the Bering Sea, and west along the Aleutian Islands to the Kamchatka Peninsula and into the Sea of Okhotsk (Nemoto 1957; Tomlin 1967; Johnson and Wolman 1984 in NMFS 1991b). These whales migrate to Hawaii, southern Japan, the Mariana Islands, and Mexico during winter. Based on genetic and photo-identification studies, the NMFS currently recognizes four stocks of humpback whales in the North Pacific Ocean: two Eastern North Pacific stocks, one Central North Pacific stock, and one Western Pacific stock (Hill and DeMaster 1998). The central North Pacific stock winters in the waters around Hawaii while the eastern North Pacific stock (also called the California-Oregon-Washington-Mexico stock) winters along coasts of Central America and Mexico. However, Calambokidis et al. (1997) identified individuals from several stocks wintering in the areas of other stocks, highlighting the paucity of knowledge on stock structure. Further, the potential fluidity of stock structure, Herman (1979) presented extensive evidence that humpback whales associated with the main Hawaiian Islands immigrated there only in the past 200 years. Winn and Reichley (1985) identified genetic exchange between the humpback whales that winter off Hawaii and those that winter off Mexico (with further mixing on feeding areas in Alaska) and suggested that humpback whales that winter in Hawaii may have emigrated from Mexican wintering areas.

A “population” of humpback whales winters in the South China Sea east through the Philippines, Ryukyu Retto, Ogasawara Gunto, Mariana Islands, and Marshall Islands, with occurrence in the Mariana Islands, at Guam, Rota, and Saipan from January through March (Darling and Mori 1993; Eldredge 1991, 2003; Rice 1998). During summer, whales from this population migrate to the Kuril Islands, Bering Sea, Aleutian Islands, Kodiak, Southeast Alaska, and British Columbia to feed (Calambokidis 1997, 2001; Angliss and Outlaw 2007).

In the Southern Ocean, eight proposed stocks of humpback whales occur in waters off Antarctica (IWC 2006a). These hypothesized stocks correspond to proposed breeding areas and include Brazil (A), West Africa (B), East Africa (C), Indian Ocean (X), western Australia (D), eastern Australia (E), Oceania (F), and an eighth off of western South America (G). These whales migrate to Central America, Venezuela, Brazil, southern Africa, western and eastern Australia, New Zealand, and islands in the southwest Pacific during the austral winter. Based upon recent satellite telemetry, a revision of stocks A and G may be warranted to reflect stock movements within and between feeding areas separated east of 50º W (Dalla Rosa et al. 2008). A separate population of humpback whales appears to reside in the Arabian Sea in the Indian Ocean off the coasts of Oman, Pakistan, and India (Mikhalev 1997; Rasmussen et al. 2007) and movements of this group are poorly known.

In the Atlantic Ocean, humpback whales range from the mid-Atlantic bight, the Gulf of Maine, across the southern coast of Greenland and Iceland, and along the coast of Norway in the Barents Sea. These humpback whales migrate to the western coast of Africa and the Caribbean Sea during the winter. Humpback whales aggregate in four summer feeding areas: (1) Gulf of Maine, eastern Canada, (2) west Greenland, (3) Iceland, and (4) Norway (Katona and Beard 1990; Smith et al. 1999). Increasing occurrence in the Mediterranean Sea coincides with population growth and may represent reclaimed habitat from pre-commercial whaling (Frantzis et al. 2004). The principal breeding range forAtlantic humpback whales lies from the Antilles and northern Venezuela to Cuba (Winn et al. 1975; Balcomb and Nichols 1982; Whitehead and Moore 1982), but the largest breeding aggregations occur off the Greater Antilles where humpback whales from all of the North Atlantic feeding areas have been photo-identified (Katona and Beard 1990; Clapham et al. 1993b; Mattila et al. 1994; Palsbøll et al. 1997; Smith et al. 1999; Stevick et al. 2003a). Winter aggregations also occur at the Cape Verde Islands in the Eastern North Atlantic (Reiner et al. 1996; Reeves et al. 2002). Accessory and historical aggregations have been found in the eastern Caribbean (Winn et al. 1975; Levenson and Leapley 1978; Mitchell and Reeves 1983; Reeves et al. 2001; Smith and Reeves 2003; Swartz et al. 2003). To further highlight the "open" structure of humpback whales, a humpback whale migrated from the Indian Ocean to the South Atlantic Ocean, demonstrating interoceanic movements can occur (Pomilla and Rosenbaum 2005).

Because of the extensive rate of immigration and emigration that likely occurs between North Pacific stocks, these groups are unlikely to represent separate populations. Although significant life history differences exist, until further information is available to differentiate groups, North Pacific humpback whales herein represent a single population, along with a separate Arabian Sea population (along Oman, Pakistan, and India), North Atlantic, and ill-defined Southern Ocean/Indian Ocean/South Atlantic group that seems to undergo migration between ocean basins (additional data is necessary to define populations herein; Mikhalev 1997).

Humpback whale calving and breeding generally occurs during winter at lower latitudes. Gestation takes about 11 months, followed by a nursing period of up to 1 year (Winn and Reichley 1985; Baraff and Weinrich 1993). Sexual maturity is reached at between 5 and 7 years of age in the western North Atlantic, but may take as long as 11 years in the North Pacific, and perhaps over 11 years of age in the North Pacific (Clapham 1992; Gabriele et al. 2007). Females usually breed every 2 to 3 years, although consecutive calving is not unheard of (Clapham and Mayo 1987, 1990; Weinrich et al. 1993). Calving occurs in the shallow coastal waters of continental shelves and oceanic islands worldwide (Perry et al. 1999).

In Hawaiian waters, humpback whales remain almost exclusively within the 6,000 foot isobath and usually within waters depths of less than 600 feet. Maximum diving depths are approximately 555 feet (but usually <200 feet), with a very deep dive (787 feet) recorded off Bermuda (Hamilton et al. 1997). Dives can last for up to 21 minutes, although feeding dives ranged from 2.1 to 5.1 minutes in the north Atlantic (Dolphin 1987; Goodyear unpublished manuscript). In southeast Alaska, average dive times were 2.8 minutes for feeding whales, 3.0 minutes for non-feeding whales, and 4.3 minutes for resting whales (Dolphin 1987). In the Gulf of California, humpback whale dive durations averaged 3.5 minutes (Strong 1989). Because most humpback prey is likely found within 1,000 feet of the surface, most humpback dives are probably relatively shallow.

During the feeding season, humpback whales form small groups that occasionally aggregate on concentrations of food that may be stable for long-periods of times. Humpbacks use a wide variety of behaviors to feed on various small, schooling prey including krill and fish (Jurasz and Jurasz 1979; Hain et al. 1982, 1995; Weinrich et al. 1992). The principal fish prey in the western North Atlantic are sand lance, herring, and capelin (Kenney et al. 1985). There is good evidence of some territoriality on feeding and calving areas (Tyack 1981; Clapham 1994, 1996). In calving areas, males sing long complex songs directed towards females, other males, or both. The breeding season can best be described as a floating lek or male dominance polygamy (Clapham 1996).

Status and Trends

Humpback whales were originally listed as endangered in 1970 (35 FR 18319), and this status presently remains under the ESA. Winn and Reichley (1985) argued that the global population of humpback whales consisted of at least 150,000 whales in the early 1900s, mostly in the Southern Ocean. Based on analyses of mutation rates and estimates of genetic diversity, Palumbi and Roman (2006) concluded that there may have been as many as 240,000 (95% confidence interval = 156,000 to 401,000) humpbacks in the North Atlantic before whaling began. Historical estimates put the number of humpback whales in the North Atlantic at a minimum of 4,700 individuals in 1865 (Mitchell and Reeves 1983). In 1987, the global population of humpback whales was estimated at about 10,000 (NMFS 1987). Although this estimate is outdated, it appears that humpback whale numbers are likely increasing. The best available estimate of abundance in the North Atlantic comes from the 2001 analyses of photographic mark-recapture data from 1992 to 1993, which generated an estimate of 11,570 humpback whales (Stevick et al. 2003). Estimates of animals in Caribbean breeding grounds exceed 2,000 individuals (Balcomb and Nichols 1982). Several researchers report an increasing trend in abundance for the North Atlantic population, which is supported by an increase in individuals sighted within the Gulf of Maine feeding aggregation (Katona and Beard 1990; Barlow and Clapham 1997; Smith et al. 1999; Waring et al. 2001). The rate of increase for this stock varies from 3.2% to 9.4%, with estimates of the rate of increase slowing over the past two decades (Katona and Beard 1990, Barlow and Clapham 1997; Stevick et al. 2003). If the North Atlantic population has grown according to the estimated instantaneous rate of increase ($r = 0.0311$), this would lead to an estimated 18,400 individual whales in 2008 (Stevick et al. 2003).

In the North Pacific, the pre-exploitation population size may have been as many as 15,000 humpback whales, and current estimates place North Pacific numbers at between 6,000 to 8,000 whales (Rice 1978a *in* Perry et al. 1999; Calambokidis et al. 1997). Estimates of humpback numbers occurring in the different populations that inhabit the northern Pacific population have risen over time. In the 1980s, estimates ranged from 1,407 to 2,100 (Baker 1985; Darling and Morowitz 1986; Baker and Herman 1987). More recently, Calambokidis et al. (1997) relied on resightings estimated from photographic records of individuals to produce an estimate of 6,010 humpback whales in the North Pacific. Because the estimates produced by the different methodologies are not directly comparable, it is not clear which of these estimates is more accurate or if the change from 1,407 to 6,000 individuals results from a real increase in the size of the humpback whale population, sampling bias in one or both studies, or assumptions in the methods used to produce estimates from the individuals that were sampled. There are currently an estimated 394 humpback whales in the western North Pacific stock, 4,005 in the central North Pacific stock, and 1,396 in the eastern North Pacific stock (Angliss and Outlaw 2005; Carretta et al. 2007). Tentative estimates of the eastern North Pacific stock suggest population increase in the realm of 6% to 7% annually, but fluctuations in census data include negative growth in the recent past (Angliss and Outlaw 2005). However, based upon surveys between 2004 and 2006, Calambokidis et al. (2008) estimated that the current population of humpback whales in the North Pacific consisted of about 18,300 whales, not counting calves. Almost half of these whales were estimated to occur in wintering areas around the Hawaiian Islands.

Threats

Natural sources and rates of mortality of humpback whales are not well known. Based upon prevalence of tooth marks, attacks by killer whales appear to be highest among humpback whales migrating between Mexico and California, although populations throughout the Pacific Ocean appear to be targeted to some degree (Steiger et al. 2008). Juveniles appear to be the primary age group targeted. Humpback whales engage in grouping behavior, flailing tails and rolling extensively to fight off attacks. Calves remain protected near mothers or within a group and lone calves have been known to be protected by presumably unrelated adults when confronted with attack (Ford and Reeves 2008).

Parasites and biotoxins from red-tide blooms are other potential causes of mortality (see Perry et al. 1999). The occurrence of the nematode *Crassicauda boopis* appears to increase the potential for kidney failure in humpback whales and may be preventing some populations from recovering from whaling (Lambertsen 1992). Studies of 14 humpback whales that stranded along Cape Cod between November 1987 and January 1988 indicate they apparently died from a toxin produced by dinoflagellates during this period. Both adult and juvenile humpback whales can succumb to such naturally-produced biotoxins (Geraci et al. 1989).

Three human activities are known to threaten humpback whales: whaling, commercial fishing, and shipping. Historically, whaling represented the greatest threat to every population of whales and was ultimately responsible for listing several species as endangered. It is estimated that 15,000 humpback whales resided in the North Pacific in 1905 (Rice 1978a). However, from 1905 to 1965, nearly 28,000 humpback whales were taken in whaling operations, reducing the number of all North Pacific humpback whale to roughly 1,000 (Perry et al. 1999). Prior to 1905, an unknown number of humpback whales were taken (Perry et al. 1999). In 1965, the IWC banned commercial hunting of humpback whales. However, populations have not recovered from whaling harvest, and their small numbers make them more susceptible to other risks.

Humpback whales are also killed or injured during interactions with commercial fishing gear. Like fin whales, humpback whales have been entangled by fishing gear off Newfoundland and Labrador, Canada. A total of 595 humpback whales were reported captured in coastal fisheries in those two provinces between 1969 and 1990, of which 94 died (Perkins and Beamish 1979; Lien 1994). Along the Atlantic coast of the U.S. and the Maritime Provinces of Canada, there were 160 reports of humpback whales being entangled in fishing gear between 1999 and 2005 (Cole et al. 2005; Nelson et al. 2007). Of these, 95 entangled humpback whales were confirmed, with 11 whales sustaining injuries and nine dieing of their wounds. Several humpback whales are also known to have become entangled in the North Pacific (Hill et al. 1997; Angliss and Outlaw 2007)

More humpback whales are killed in collisions with ships than any other whale species except fin whales (Jensen and Silber 2003). Along the Pacific coast, a humpback whale is killed about every other year by ship strikes (Barlow et al. 1997). Of 123 humpback whales that stranded along the Atlantic coast of the U.S. between 1975 and 1996, 10 (8.1%) showed evidence of collisions with ships (Laist et al. 2001). Between 1999 and 2005, there were 18 reports of humpback whales being struck by vessels along the Atlantic coast of the U.S. and the Maritime Provinces of Canada (Cole et al. 2005; Nelson et al. 2007). Of these reports, 13 were confirmed as ship strikes and in 7 cases, ship strike was determined to be the cause of death. In the Bay of Fundy, recommendations for slower vessel speeds to avoid right whale ship strike appear to be largely ignored (Vanderlaan et al. 2008). However, new rules for seasonal (June through December) slowing of vessel traffic to 10 knots and changing shipping lanes by less than 1 nautical mile to avoid the greatest concentrations of right whales are expected to reduce the chance of humpback whales being hit by ships by 9%.

Organochlorines, including PCB and DDT, have been identified from humpback whale blubber (Gauthier et al. 1997b). As with blue whales, these contaminants are transferred to young through the placenta, leaving newborns with contaminant loads equal to the mothers before bioaccumulating additional contaminants during life and passing the additional burden onto the next generation (Metcalfe et al. 2004). Contaminant levels are relatively high in humpback whales as compared to blue whales. Humpback whales feed higher on the food chain, where prey carry higher contaminant loads than the krill that blue whales feed on.

Critical Habitat

NMFS has not designated critical habitat for humpback whales.

Southern Resident Killer Whale

Southern Resident killer whales compose a single population that occurs primarily along Washington State and British Columbia. The listed entity consists of three groups, identified as J, K, and L pods. They are found throughout the coastal waters off Washington, Oregon, and Vancouver Island and are known to travel as far south as central California and as far north as the Queen Charlotte Islands, British Columbia. However, there is limited information on the range of Southern Residents along the outer Pacific Coast, with only 25 confirmed sightings of J, K, and L pods between 1982 and 2006 (Krahn et al. 2004). Southern Resident killer whales spend a significant portion of the year in the inland waterways of the Strait of Georgia, Strait of Juan de Fuca, and Puget Sound, particularly during the spring, summer, and fall, when all three pods are regularly present in the Georgia Basin (defined as the Georgia Strait, San Juan Islands, and Strait of Juan de Fuca) (Heimlich-Boran 1988; Felleman et al. 1991; Olson 1998; Osborne 1999). Typically, K and L pods arrive in May or June and primarily occur in this core area until October or November. During this stay, both pods also make frequent trips lasting a few days to the outer coasts of Washington and southern Vancouver Island (Ford et al. 2000); however, J pod's movements differ considerably and are present only intermittently in the Georgia Basin and Puget Sound. Late spring and early fall movements of Southern Residents in the Georgia Basin have remained fairly consistent since the early 1970s, with strong site fidelity shown to the region as a whole (NMFS 2005a). During late fall, winter, and early spring, the ranges and movements of the Southern Residents are less well known. Offshore movements and distribution are largely unknown for the Southern Resident population.

While the Southern Residents are in inland waters during the warmer months, all of the pods concentrate their activities in Haro Strait, Boundary Passage, the southern Gulf Islands, the eastern end of the Strait of Juan de Fuca, and several localities in the southern Georgia Strait (Heimlich-Boran 1988; Felleman et al. 1991; Olson 1998; Ford et al. 2000). Individual pods are similar in their preferred areas of use, although there are some seasonal and temporal differences in certain areas visited (Olson 1998). For example, J pod is the only group to venture regularly inside the San Juan Islands. The movements of Southern Resident killer whales relate to those of their preferred prey, salmon. Pods commonly seek out and forage in areas where salmon occur, especially those associated with migrating salmon (Heimlich-Boran 1986a; Heimlich-Boran 1988; Nichol and Shackleton 1996).

Southern resident killer whales are significant predators of regional salmon stocks. Killer whales show a strong preference for Chinook salmon (78% of identified prey) during late spring to fall (Hanson et al. 2005; Ford and Ellis 2006). Chum salmon are also taken in significant amounts (11%), especially in autumn. Chinook are preferred despite much lower abundance in comparison to other salmonids (such as sockeye) presumably because of the species' large size, high fat and energy content, and year-round occurrence in the area. Killer whales also captured older (i.e., larger) than average Chinook (Ford and Ellis 2006). Throughout inland waters from May to September, Southern resident killer whale diet is approximately 88% Chinook (Hanson et al. 2007a), with a shift to chum salmon in fall. Little is known about the winter and early spring diet of Southern Residents. Early results from genetic analysis of fecal and prey samples indicate that Southern Residents consume Fraser River-origin Chinook, as well as salmon from

Puget Sound, Washington and Oregon coasts, the Columbia River, and Central Valley of California (Hanson et al. 2007b).

Southern Residents are highly mobile and can travel up to 100 miles per day (Erickson 1978; Baird 2000). Members of K and L pods once traveled a straight line distance of 584 miles from the northern Queen Charlotte Islands to Victoria, Vancouver Island, in seven days. Movements may be related to food availability. Southern Resident killer whales are fish eaters, and predominantly prey upon salmonids, particularly Chinook salmon but are also known to consume more than 20 other species of fish and squid (Scheffer and Slipp 1948; Ford et al. 1998, 2000; Saulitis et al. 2000; Ford and Ellis 2005).

Female Southern Resident killer whales give birth to their first surviving calf between the ages of 12 and 16 years (mean ~14.9 years) and produce an average of 5.4 surviving calves during a reproductive life span lasting about 25 years (Olesiuk et al. 1990a; Matkin et al. 2003). The mean interval between viable calves is four years (Bain 1990). Males become sexually mature at body lengths ranging from 17 to 21 feet, which corresponds to between the ages of 10 to 17.5 years (mean ~15 years), and are presumed to remain sexually active throughout their adult lives (Christensen 1984; Perrin and Reilly 1984; Duffield and Miller 1988; Olesiuk et al. 1990a). Most mating is believed to occur from May to October (Nishiwaki 1972; Olesiuk et al. 1990a; Matkin et al. 1997). However, conception apparently occurs year-round because births of calves are reported in all months. Newborns measure seven to 9 feet long and weigh about 440 lbs (Nishiwaki and Handa 1958; Olesiuk et al. 1990a; Clark et al. 2000; Ford 2002). Mothers and offspring maintain highly-stable, life-long social bonds and this natal relationship is the basis for a matrilineal social structure (Bigg et al. 1990; Baird 2000; Ford et al. 2000).

Killer whales tend to make relatively shallow dives. Of 87 tagged individuals in the Pacific Northwest, 31% of dives were less than 100 feet deep (Baird et al. 2003). However, a free-ranging killer whale was recorded to dive to 264 m off British Columbia (Baird et al. 2005). The longest duration of a recorded dive was 17 minutes (Dahlheim and Heyning 1999).

Status and Trends

Southern Resident killer whales have been listed as endangered since 2005 (70 FR 69903). In general, there is little information available regarding the historical abundance of Southern Resident killer whales. Some evidence suggests that, until the mid- to late-1800s, the Southern Resident killer whale population may have numbered more than 200 animals (Krahn et al. 2002). This estimate was based, in part, on a recent genetic study that found that the genetic diversity of the Southern Resident population resembles that of the Northern Residents (Barrett-Lennard 2000; Barrett-Lennard and Ellis 2001), and concluded that the two populations were possibly once similar in size. Unfortunately, lack of data prior to 1974 hinders long-term population analysis (NMFS 2005a). The only pre- 1974 account of Southern Resident abundance is from Sheffer and Slipp (1948) and merely notes that the species was “frequently seen” during the 1940s in the Strait of Juan de Fuca, northern Puget Sound, and off the coast of the Olympic Peninsula, with smaller numbers along Washington’s outer coast. Olesiuk et al. (1990) estimated the Southern Resident population size in 1967 to be 96 animals. Due to demand for marine mammals in zoos and marine parks, it is estimated that 47 killer whales, mostly immature, were taken from the Southern Resident population for public display between 1967 and 1973. By 1971, the level of removal decreased the population by about 30% to approximately 67 individuals (Olesiuk et al. 1990a). The population went then went through periods of decline and expansion for more than two decades. At the end of an 11-year growth cycle in 1995, the three Southern Resident pods – J, K, and L, reached a peak of 98 animals (NMFS 2008a).

More recently, the Southern Resident population has continued to fluctuate in numbers. After growing to 98 whales in 1995, the population declined by 17% to 81 whales in 2001 (-2.9% per year) before another slight increase to 84 whales in 2003 (Ford et al. 2000; Carretta et al. 2005). The population grew to 90 whales in 2006, although it declined to 87 in 2007 (NMFS 2008a). The most recent population abundance estimate of 87 Southern Residents consists of 25 whales in J pod, 19 whales in K pod, and 43 whales in L pod (NMFS 2008a).

Threats

The recent decline, unstable population status, and population structure (e.g., few reproductive age males and non-calving adult females) continue to be causes for concern. Moreover, it is unclear whether the recent increasing trend will continue. The relatively low number of individuals in this population makes it difficult to resist/recover from natural spikes in mortality, including disease and fluctuations in prey availability (NMFS 2008a). Although disease outbreaks have not been identified in this population, increased contaminant load (see below) may increase the susceptibility of individuals to disease.

Numerous threats to the continued survival of Southern Resident killer whales have been identified (see NMFS 2008a for a review). Many of these are human in origin. The primary prey of killer whales, salmon, has been severely reduced due to habitat loss and overfishing of salmon along the West Coast (NRC 1995; Slaney et al. 1996; Gregory and Bisson 1997; Lichatowich 1999; Lackey 2003; Pess et al. 2003; Schoonmaker et al. 2003). Several salmon species are currently protected under the ESA, and are generally well below their former numbers.

Puget Sound also serves as a major port and drainage for thousands of square miles of land. Contaminants entering Puget Sound and its surrounding waters accumulate in water, benthic sediments, and the organisms that live and eat here. As the top marine predator, Southern Resident killer whales bioaccumulate these toxins in their tissues, potentially leading to numerous physiological changes such as skeletal deformity, lowered disease resistance, and enzyme disruption. Presently, the greatest contaminant threats are organochlorines, which include PCBs, pesticides, dioxins, furans, other industrial products, and the popularized chemical DDT (Ross et al. 2000; CBD 2001; Krahn et al. 2002). These chemicals tend to bioaccumulate in fatty tissues, such as whale blubber, persist over long periods in the environment, and can be transmitted from mother to offspring. A similar, but separate concern is the growth of the petroleum industry in Puget Sound, which has the low potential to create a catastrophic oil spill, or more likely, small but chronic releases of petrochemicals.

Vessel activity also has been identified as a threat. This includes physical harm or behavioral modifications as well as habitat degradation/loss from U.S. naval vessel sonar activities, ship strike, and heavy and continuous presence by whale-watching vessels. In 2005, a U.S. vessel participating in sonar exercises apparently caused significant behavior changes in killer whale activity in the area, such that the whales vacated the area (NMFS 2005a). Although such activities are now receiving close scrutiny, the potential remains for these disruptions to occur, or as in other areas, the potential for auditory trauma, stranding, and death. The increase in “background noise” resulting from vessel traffic and coastal development activities, although not directly traumatic, has the potential to influence or disrupt the acoustic system that Southern Resident killer whales use to navigate, communicate, and forage (Bain and Dahlheim 1994; Gordon and Moscrop 1996; Erbe 2002; Williams et al. 2002a, b; NMFS 2008a). Commercial whale-watching in the region focuses primarily on Southern Resident killer whales and has increased dramatically in the recent years (Osborne et al.1999; Baird 2001; Erbe 2002; MMMP2002; Koski 2004, 2006, 2007). Although mechanisms are in place to regulate the industry, concerns remain over persistent exposure to vessel noise, proximity to whales, which can cause behavioral changes, stress, or potentially the loss of habitat (Kruse 1991; Kriete 2002; Williams et al. 2002a, b; Foote et al. 2004; Bain et al. 2006; Wiley et al. 2008; NMFS 2008a).

Critical Habitat

Critical habitat for the DPS of Southern Resident killer whales was designated on November 29, 2006 (71 FR 69054). Three specific areas were designated; (1) the Summer Core Area in Haro Strait and waters around the San Juan Islands; (2) Puget Sound; and (3) the Strait of Juan de Fuca, which comprise approximately 2,560 square miles of marine habitat. Three essential factors exist in these areas: water quality to support growth and development, prey species of sufficient quantity, quality and availability to support individual growth, reproduction and development, as well as overall population growth, and passage conditions to allow for migration, resting, and foraging. Water quality has declined in recent years due to agricultural run-off, urban development resulting in additional treated water discharge, industrial development, oil spills. The primary prey of southern residents, salmon, has also declined due to overfishing and reproductive impairment associated with loss of spawning habitat. The constant presence of whale-watching vessels and growing anthropogenic noise has raised concerns about the health of areas of growth and reproduction as well.

Sei Whale

The sei whale occurs in all oceans of the world except the Artic Ocean and is listed as endangered throughout its range. The migratory pattern of this species is thought to encompass long distances from high-latitude feeding areas in summer to low-latitude breeding areas in winter; however, the location of winter areas remains largely unknown (Perry et al. 1999). Sei whales are often associated with deeper waters and areas along the continental shelf edge (Hain et al. 1985). This general offshore pattern of sei whale distribution is disrupted during occasional incursions into more shallow and inshore waters (Waring et al. 2004). The species appears to lack a well-defined social structure and individuals are usually found alone or in small groups of up to six whales (Perry et al. 1999). When on feeding grounds, larger groupings have been observed (Gambell 1985b).

The population structure of sei whales remains unknown and populations herein follow IWC recommendations. In the North Atlantic, the IWC groups sei whales into three stocks for management purposes: the Nova Scotia, Iceland-Denmark Strait, and Northeast Atlantic stocks, noting that identification of sei whale population structure is difficult and remains a major research problem (Donovan 1991; Perry et al. 1999). The official IWC boundaries of the Nova Scotia stock extend from the U.S. East Coast to Cape Breton, Nova Scotia, and from there east to longitude 42° W (Waring et al. 2004).

In the North Pacific, the IWC groups all sei whales into one management stock (Donovan 1991). However, some mark-recapture, catch distribution, and morphological research indicate more than one population may exist – one between 175° W and 155° W longitude, and another east of 155° W longitude (Masaki 1976 *in* Perry et al. 1999; Masaki 1977). In the Southern Hemisphere, the IWC has divided the Southern Ocean into six baleen whale feeding areas – designated at 60° S latitude and longitude as follows: 120° W to 60° W (Area I), 60° W to 0° (Area II), 0° to 70° E (Area III), 70° E to 130° E (Area IV), 130° E to 170° W (Area V) and 170°W to 120°W (Area VI). There is little information on the population structure of sei whales in the Antarctic, although some degree of isolation appears to exist between IWC Areas I through VI (IWC 1980; Donovan 1991). Insufficient information exists to validate these management stock designations; however, links between some regions were found using tag data – for example, between (1) the Brazilian coast and the western half of Area II, (2) the Natal Coast of South Africa with the eastern half of Area III and the western half of Area IV, and (3) western and southeastern Australia with Area IV (Perry et al. 1999). This information suggests that sei whale stocks are dynamic and that individuals are immigrating and emigrating be between stocks. Consequently, until further information is available to suggest otherwise, we consider sei whales as forming "open" populations that are connected through the movement of individuals.

In the western North Atlantic, a major portion of the sei whale population occurs from northern waters, potentially including the Scotian Shelf, along Labrador and Nova Scotia, south into the U.S. EEZ, including the Gulf of Maine and Georges Bank (Mitchell and Chapman 1977, Waring et al. 2004). These whales summer in northern areas before migrating south to waters along Florida, in the Gulf of Mexico, and the northern Caribbean Sea (Mead 1977; Gambell 1985b). Sei whales may range as far south as North Carolina. In the U.S. EEZ, the greatest abundance of this species occurs during spring, with most sightings on the eastern edge of Georges Bank, in the Northeast Channel, and along the southwestern edge of Georges Bank in Hydrographer Canyon (CeTAP 1982). In 1999, 2000, and 2001, NMFS aerial surveys found sei whales concentrated along the northern edge of Georges Bank during spring; and surveys in 2001 found sei whales south of Nantucket along the continental shelf edge (Waring et al. 2004). During years of greater prey abundance (e.g., copepods), sei whales are found in more inshore waters, such as the Great South Channel (in 1987 and 1989), Stellwagen Bank (in 1986), and the Gulf of Maine (Payne et al. 1990; Schilling et al. 1992). In the eastern Atlantic, sei whales occur in the Norwegian Sea, occasionally occurring as far north as Spitsbergen Island, and migrate south to Spain, Portugal, and northwest Africa (Jonsgård and Darling 1977; Gambell 1985b).

In the North Pacific Ocean, sei whales have been reported primarily south of the Aleutian Islands, in Shelikof Strait and waters surrounding Kodiak Island, in the Gulf of Alaska, and inside waters of southeast Alaska and south to California to the east and Japan and Korea to the west (Nasu 1974; Leatherwood et al. 1982). Sei whales have been occasionally reported from the Bering Sea and in low numbers on the central Bering Sea shelf (Hill and DeMaster 1998). Masaki (1977) reported sei whales concentrating in the northern and western Bering Sea from July through September, although other researchers question these observations because no other surveys have ever reported sei whales in the northern and western Bering Sea. Horwood (1987) evaluated the Japanese sighting data and concluded that sei whales rarely occur in the Bering Sea. Horwood (1987) reported that 75 to 85% of the total North Pacific population of sei whales resides east of 180° longitude. During winter, sei whales are found from 20°-23° N (Masaki 1977; Gambell 1985b). Horwood (1987) reported that 75% to 85% of the North Pacific population of sei whales resides east of 180° longitude. Sei whales occur throughout the Southern Ocean during austral summer, although they do not migrate as far south to feed as blue or fin whales. During the austral winter, sei whales occur off Brazil and the western and eastern coasts of southern Africa and Australia.

The age structure of sei whale populations is unknown, and little information is available on natural mortality. Reproductive activities for sei whales occur primarily in winter. Gestation is about 12.7 months, calves are weaned at six to nine months of age, and the calving interval is about 3 years (Rice 1977). Sei whales become sexually mature at about age 10 (Rice 1977). Sei whales are primarily planktivorous, feeding mainly on euphausiids and copepods, although the species is also known to consume fish (Waring et al. 2006). In the Northern Hemisphere, sei whales consume small schooling fish such as anchovies, sardines, and mackerel when locally abundant (Mizroch et al 1984; Gambell 1985b). Sei whales in the North Pacific feed on euphausiids and copepods, which make up about 95% of their diets (Calkins 1986a). The balance of their diet consists of squid and schooling fish, including smelt, sand lance, Arctic cod, rockfish, pollack, capelin, and Atka mackerel (Nemoto and Kawamura 1977). In the Southern Ocean, analysis of stomach contents indicates sei whales consume *Calanus* spp. and small-sized euphasiids with prey composition showing latitudinal trends (Kawamura 1974). Evidence indicates that sei whales in the Southern Hemisphere reduce direct interspecific competition with blue and fin whales by consuming a wider variety of prey and by arriving later to the feeding grounds (Kirkwood 1992). Rice (1977) suggested that the diverse diet of sei whales may allow them greater opportunity to take advantage of variable prey resources, but may also increase their potential for competition with commercial fisheries.

Status and Trends

The sei whale was originally listed as endangered in 1970 (35 FR 18319), and this status remained since the inception of the ESA in 1973. Globally, Braham (1991) compiled available regional estimates and reported a pre-exploitation abundance for sei whales of more than 105,000 individuals worldwide; the estimate for 1991 indicated a global sei whale abundance of 25,000 (Braham 1991). In the North Atlantic, there is no information on sei whale abundance prior to commercial whaling (Perry et al. 1999). In 1974, the North Atlantic population was estimated to number about 2,078 individuals, including 965 whales in the Labrador Sea group and 870 whales in the Nova Scotia group (Mitchell and Chapman 1977). The most current estimate for the North Atlantic is a low-precision estimate of over 4,000 sei whales (Braham 1991). Estimates do exist for portions of the North Atlantic, however. In the northwest Atlantic, Mitchell and Chapman (1977) estimated the Nova Scotia, Canada, stock of sei whales to contain between 1,393 and 2,248 whales; and an aerial survey program conducted from 1978 to 1982 on the continental shelf and edge between Cape Hatteras, North Carolina, and Nova Scotia generated an estimate of 280 sei whales (CeTAP 1982). These two estimates are more than 20 years out of date and likely do not reflect the current true abundance; in addition, the Cetacean and Turtle Assessment Program (CeTAP) estimate has a high degree of uncertainty and is considered statistically unreliable (Perry et al. 1999; Waring et al. 1999, 2004). Based on an aerial survey conducted in August 2006, NMFS estimated the current abundance of the Nova Scotia stock at 207 individuals, with a minimum population estimate of 128 (Waring et al. 2008). The total number of sei whales in the U.S. Atlantic EEZ remains unknown (Waring et al. 2006). In the eastern North Atlantic, the most recent abundance estimates for the Iceland/Denmark Strait stock are 1,290 and 1,590 whales, based on sighting data from surveys in 1987 and 1989, respectively (Cattanach et al. 1993).

Prior to commercial whaling, sei whales in the North Pacific are estimated to have numbered 42,000 individuals (Tillman 1977), although Ohsumi and Fukuda (1975) estimated that sei whales in the north Pacific numbered about 49,000 whales in 1963, had been reduced to 37,000 or 38,000 whales by 1967, and reduced again to 20,600 to 23,700 whales by 1973. Japanese and Soviet catches of sei whales in the North Pacific and Bering Sea increased from 260 whales in 1962 to over 4,500 in 1968 and 1969, after which the sei whale population declined rapidly (Mizroch et al. 1984). When commercial whaling for sei whales ended in 1974, the population of sei whales in the North Pacific had been reduced to between 7,260 and 12,620 animals (Tillman 1977). There have been no direct estimates of sei whale populations for the eastern Pacific Ocean (or the entire Pacific). Between 1991 and 2001, during aerial surveys, there were two confirmed sightings of sei whales along the U.S. Pacific Coast. The minimum population estimate based on transect surveys of 300 nautical miles between 1996 and 2001 was 35, although the actual population along the U.S. Pacific Coast was estimated to be 56 (Carretta et al. 2006). About 50 sei whales are estimated to occur in the North Pacific stock with another 77 sei whales in the Hawaiian stock (Lowry et al. 2007).

Threats

Sei whales appear to compete with blue, fin, and right whales for prey and that competition may limit the total abundance of each of the species (Rice 1974; Scarff 1986). As discussed previously in the narratives for fin and right whales, the foraging areas of right and sei whales in the western North Atlantic Ocean overlap and both whales feed preferentially on copepods (Mitchell 1975).

Andrews (1916) suggested that killer whales attacked sei whales less frequently than fin and blue whales in the same areas. Sei whales engage in a flight responses to evade killer whales, which involves high energetic output, but show little resistance if overtaken (Ford and Reeves 2008). Endoparasitic helminths (worms) are commonly found in sei whales and can result in pathogenic effects when infestations occur in the liver and kidneys (Rice 1977). Rice (1977) estimated total annual mortality for adult females as 0.088 and adult males as 0.103.

Human activities known to threaten sei whales include whaling, commercial fishing, and maritime vessel traffic. Historically, whaling represented the greatest threat to every population of sei whales and was ultimately responsible for listing sei whales as an endangered species.

From 1910 to 1975, approximately 74,215 sei whales were caught in the entire North Pacific Ocean (Horwood 1987; Perry et al. 1999). From the early 1900s, Japanese whaling operations consisted of a large proportion of sei whales: 300 to 600 sei whales were killed per year from 1911 to 1955. The sei whale catch peaked in 1959, when 1,340 sei whales were killed. In 1971, after a decade of high sei whale catch numbers, sei whales were scarce in Japanese waters. Sei whales are thought to not be widely hunted, although harvest for scientific whaling or illegal harvesting may occur in some areas.

In the North Atlantic Ocean, sei whales were hunted from land stations in Norway and Iceland in the early- to mid-1880s, when blue whales started to become scarcer. In the late 1890s, whalers began hunting sei whales in Davis Strait and off the coasts of Newfoundland. In the early 1900s, whalers from land stations on the Outer Hebrides and Shetland Islands started to hunt sei whales. Between 1966 and 1972, whalers from land stations on the east coast of Nova Scotia engaged in extensive hunts of sei whales on the Nova Scotia shelf, killing about 825 sei whales (Mitchell and Chapman 1977).

Sei whales are occasionally killed in collisions with vessels. Of three sei whales that stranded along the Atlantic Coast of the U.S. between 1975 and 1996, two showed evidence of collisions with ships (Laist et al. 2001). Between 1999 and 2005, there were three reports of sei whales being struck by vessels along the Atlantic Coast of the U.S. and the Maritime Provinces of Canada (Cole et al. 2005; Nelson et al. 2007). Two of these ship strikes were reported as having resulted in the death of the sei whale. One sei whale was killed in a collision with a vessel off the coast of Washington in 2003 (Waring et al. 2008). Proposed rules for seasonal (June through December) slowing of vessel traffic in the Bay of Fundy to 10 knots or changing shipping lanes by less than one nautical mile to avoid the greatest concentrations of right whales are predicted to be capable of reducing ship strike mortality by 17% for sei whales.

Sei whales are known to carry body burdens of DDT, DDE, and PCBs (Henry and Best 1983; Borrell and Aquilar 1987; Borrell 1993). Males carry larger burdens than females, as gestation and lactation transfer these toxins from mother to offspring.

Critical Habitat

NMFS has not designated critical habitat for sei whales.

Sperm Whale

Sperm whales are distributed in all of the world’s oceans, from equatorial to polar waters, and are highly migratory (furthest from the equator in summer, closest in winter). Mature males range as widely as latitude 70ºN in the North Atlantic and latitude 70ºS in the Southern Ocean, whereas mature females and immature individuals of both sexes are seldom found higher than latitudes 50ºN and 50ºS (Reeves and Whitehead 1997; Perry et al. 1999). Sperm whales inhabit deep pelagic waters along continental shelf edges and further offshore and are rarely found in waters less than 1,000 feet deep. They are often concentrated around oceanic islands in areas of upwelling, and along the outer continental shelf and mid-ocean waters. However, significant numbers of sightings have occurred in shallow continental shelf waters south of New England and over the Nova Scotian shelf (CeTAP 1982; Scott and Sadove 1997).

There is no clear understanding of the global population structure of sperm whales (Dufault et al. 1999). One study found moderate, but statistically significant, differences in sperm whale mitochondrial DNA (mtDNA) between oceans, but it is generally accepted that sperm whales worldwide are genetically homogeneous (Lyrholm and Gyllensten 1998; Whitehead 2003). For management purposes, the IWC recognizes one population in the North Atlantic (Donovan 1991), while NMFS recognizes six stocks under the MMPA: three in the Atlantic/Gulf of Mexico and three in the Pacific (Alaska, California-Oregon-Washington, and Hawaii; Perry et al. 1999; Waring et al. 2004). Nevertheless, genetic studies indicate that movements of both sexes through expanses of ocean basins are common, and that males, but not females, often breed in different ocean basins than the one in which they were born (Whitehead 2003). Sperm whale populations appear to be structured socially, at the level of the social unit or clan, rather than geographically (Whitehead 2003; Whitehead et al. 2008).

Sperm whales primarily occur in waters off the east coast of the U.S. from New England south to North Carolina (Perry et al. 1999). The northern distributional limit of female/immature pods is probably around Georges Bank or the Nova Scotian shelf (Whitehead et al. 1991). Seasonal aerial surveys confirm that sperm whales are present in the northern Gulf of Mexico in all seasons (Mullin et al. 1994; Hansen et al. 1996). Sperm whales are distributed in a distinct seasonal cycle, concentrated east-northeast of Cape Hatteras in winter and shifting northward in spring when whales are found throughout the Mid-Atlantic Bight. Distribution extends further northward to areas north of Georges Bank and the Northeast Channel region in summer and then south of New England in fall, back to the Mid-Atlantic Bight. In the eastern Atlantic, mature male sperm whales have been recorded as far north as Spitsbergen (Øien 1990). Recent observations of sperm whales and stranding events involving sperm whales from the eastern North Atlantic suggest that solitary and paired mature male sperm whales predominantly occur in waters off Iceland, the Faroe Islands, and the Norwegian Sea (Gunnlaugsson and Sigurjónsson 1990; Øien 1990; Christensen et al. 1992a).

Sperm whales are found throughout the North Pacific and are distributed broadly in tropical and temperate waters to the Bering Sea as far north as Cape Navarin. Sperm whales are found year-round in Californian and Hawaiian waters, but they reach peak abundance from April through mid-June and from the end of August through mid-November (Rice 1960a; Rice 1974; Shallenberger 1981; Dohl et al. 1983; Lee 1993; Barlow 1995; Forney et al. 1995; Mobley et al. 2000). They are seen in every season except winter (December-February) in Washington and Oregon (Green et al. 1992). Summer/fall surveys in the eastern tropical Pacific (Wade and Gerrodette 1993) show that although sperm whales are widely distributed in the tropics, their relative abundance tapers off markedly towards the middle of the tropical Pacific and northward towards the tip of Baja California (Caretta et al. 2006).

In the Mediterranean, sperm whales are found from the Alboran Sea to the Levant Basin, primarily over steep slope and deep offshore waters. Sperm whales are rarely sighted in the Sicilian Channel, and are vagrants to the northern Adriatic and Aegean Seas (Notarbartolo di Sciara and Demma 1997). In Italian seas, sperm whales are more frequently associated with the continental slope off western Liguria, western Sardinia, northern and eastern Sicily, and both coasts of Calabria. All sperm whales of the southern hemisphere are treated as a single population with nine divisions, although this designation has little biological basis and is more in line with whaling records (Donovan 1991). However, sperm whales that occur off the Galapagos Islands, mainland Ecuador, and northern Peru may be distinct from other sperm whales in the Southern Hemisphere (Rice 1977; Wade and Gerrodette 1993; Dufault and Whitehead 1995).

Movement patterns of Pacific female and immature male groups appear to follow prey distribution and, although not random, movements are difficult to anticipate and are likely associated with feeding success, perception of the environment, and memory of optimal foraging areas (Whitehead et al. 2008). However, no sperm whale in the Pacific has been known to travel to points over 3,100 miles apart and only rarely have been known to move over 2,500 miles within a time frame of several years. This means that although sperm whales do not appear to cross from eastern to western sides of the Pacific (or vice-versa), significant mixing occurs that can maintain genetic exchange. Movements of several hundred miles are common, though (i.e. between the Galapagos Islands and the Pacific coastal Americas). Movements appear to be group or clan specific, with some groups traveling straighter courses than others over the course of several days. However, general transit speed averages about 2.5 miles per hour. Sperm whales in the Caribbean region appear to be much more restricted in their movements, with individuals repeatedly sighted within less than 100 miles of previous sightings.

Sperm whales have a strong preference for the 3,280-foot depth contour and seaward. Berzin (1971) reported that they are restricted to waters deeper than 1,000 feet, while others have reported that they are usually not found in waters less than 3,300 feet deep (Watkins 1977; Reeves and Whitehead 1997). While deep water is their typical habitat, sperm whales have been observed near Long Island, New York, in water between 135 and 180 feet (Scott and Sadove 1997). When they are found relatively close to shore, sperm whales are usually associated with sharp increases in bottom depth where upwelling occurs and biological production is high, implying the presence of a good food supply (Clarke 1956).

The age distributions of sperm whale populations are unknown, but sperm whales are believed to live at least 60 years (Rice 1978b). Female sperm whales become sexually mature at an average of 9 years of age when they reach a length of 27 to 29 feet (Kasuya 1991). Males reach a length of 33 to 39 feet at sexual maturity. Male sperm whales take between nine and 20 years to become sexually mature, but will require another 10 years to become large enough to successfully breed (Kasuya 1991). Adult females give birth after roughly 15 months of gestation and nurse their calves for 2 to 3 years. The calving interval is estimated to be about 4 to 6 years between the ages of 12 and 40 (Kasuya 1991; Whitehead et al. 2008). The peak breeding season for sperm whales in the North Atlantic occurs during spring (March and April to May), with some mating activity taking place earlier or later, from December to August. In the North Pacific, female sperm whales and their calves are usually found in tropical and temperate waters year-round, while it is generally understood that males move north in the summer to feed in the Gulf of Alaska, Bering Sea, and waters off of the Aleutian Islands (Kasuya and Miyashita 1988). It has been suggested that some mature males may not migrate to breeding grounds annually during winter, and instead may remain in higher latitude feeding grounds for more than 1 year at a time (Whitehead and Arnbom 1987).

Sperm whales are deep and prolonged divers and therefore, can use the entire water column, even in very deep areas. However, they seem to forage mainly on or near the bottom, often ingesting stones, sand, sponges, and other non-food items (Rice 1989). As far as is known, sperm whales feed regularly throughout the year. Lockyer (1981) estimated that they consumed about 3.0 to 3.5% of their body weight per day.

A large proportion of the sperm whale's diet consists of low-fat, ammoniacal, luminescent squids (Clarke 1980, 1996; Martin and Clarke 1986). While sperm whales feed primarily on large and medium-sized squids, the list of documented food items is fairly long and diverse. Prey items include other cephalopods, such as octopuses, and medium- and large-sized demersal fishes, such as rays, sharks, and many teleosts (Berzin 1972; Clarke 1977, 1980; Rice 1989). The diet of large males in some areas, especially in high northern latitudes, is dominated by fish (Rice 1989). In some areas of the North Atlantic, however, males prey heavily on the oil-rich squid *Gonatus fabricii*, a species also frequently eaten by northern bottlenose whales (*Hyperoodon ampullatus*; Clarke 1997 *in* NMFS 2006b).

Sperm whales are probably the deepest and longest diving mammalian species, with dives to nearly two miles down and durations in excess of two hours (Clarke 1976; Watkins et al. 1985; Watkins et al. 1993). However, foraging dives normally last about 40 minutes and one-quarter mile (Gordon 1987; Papastavrou et al. 1989). Differences in night and day diving patterns are not known for this species, but, like most diving air-breathers for which there are data (e.g. rorqual whales, fur seals, chinstrap penguins), sperm whales probably make relatively shallow dives at night when prey are closer to the surface.

Status and Trends

Sperm whales were originally listed as endangered in 1970 (35 FR 18319), and this status remained with the inception of the ESA in 1973. Past abundance estimates have largely relied on historic whaling data, which the IWC considers unreliable (Perry et al. 1999). Using modern visual survey research, Whitehead (2002) estimated that prior to whaling, sperm whales numbered around 1.1 million individuals and that the current global abundance of sperm whales is around 360,000 whales.

The total number of sperm whales in the western North Atlantic is unknown (Waring et al. 2008). The best available current abundance estimate for western North Atlantic sperm whales is 4,804 based on data from 2004. The best available current abundance estimate for Northern Gulf of Mexico sperm whales is 1,665, based on data from 2003 and 2004. There is insufficient data to determine population trends (Waring et al. 2008).

There are approximately 76,803 sperm whales in the eastern tropical Pacific, eastern North Pacific, Hawaii, and western North Pacific (Whitehead 2002). Minimum population estimates in the eastern North Pacific are 1,719 individuals and 5,531 in the Hawaiian Islands (Carretta et al. 2007). Caretta et al. (2005) concluded that the most precise estimate of sperm whale abundance off the coasts of California, Oregon, and Washington was 1,233 and their best estimate of sperm whale abundance in Hawaii was 7,082 sperm whales. The tropical Pacific is home to approximately 26,053 sperm whales and the western North Pacific has a population of approximately 29,674 (Whitehead 2002). There are only two estimates for local population trends, one in the Antarctic Ocean and one near the Galapagos Islands. There was no change in Antarctic population size between 1978 and 1992 but a dramatic decline in females around the Galapagos Islands between 1985 and 1999, likely due to migration to nearshore waters of South and Central America (Whitehead 2003).

The information available on the status and trend of sperm whales do not allow us to make definitive statement about the extinction risks facing sperm whales as a species or as populations. However, sperm whale populations probably are undergoing the dynamics of small population sizes, which is a threat in and of itself. In particular, the loss of sperm whales to directed Soviet takes likely inhibits recovery due to the loss of adult females and their calves, leaving sizeable gaps to demographic and age structuring of the remaining population (Whitehead 2003).

Threats

Sperm whales are known to be at least occasionally predated upon by killer whales and harassed by pilot whales (Arnbom et al. 1987; Rice 1989; Jefferson et al. 1991; Whitehead 1995; Palacios and Mate 1996; Weller et al. 1996; Pitman et al. 2001). Strandings are also relatively common events, with one to dozens of individuals generally beaching themselves and dying during any single event. Although several hypotheses have been proposed, direct widespread causes remain unclear (Goold et al. 2002; Wright 2005). Calcivirus and papillomavirus are known pathogens of this species (Smith and Latham 1978; Lambertsen et al. 1987).

Sperm whales historically faced severe depletion from commercial whaling operations. From 1800 to 1900, the IWC estimated that nearly 250,000 sperm whales were killed by whalers, with another 700,000 from 1910 to 1982 (IWC Statistics 1959-1983). However, other estimates have included 436,000 individuals taken between 1800 and 1987 (Caretta et al. 2005). Hill and DeMaster (1999) concluded that about 258,000 sperm whales were harvested in the North Pacific between 1947 and 1987. Takes in the Southern Hemisphere averaged roughly 20,000 whales between 1956 and 1976 (Perry et al. 1999). However, all of these estimates likely underestimated due to illegal and inaccurate takes by Soviet whaling fleets between 1947 and 1973. In the Southern Hemisphere, these whalers killed an estimated 100,000 whales that they did not report to the IWC, with smaller takes in the Northern Hemisphere, primarily the North Pacific that extirpated sperm whales from large areas (Yablokov et al. 1998; Yablokov and Zemsky 2000). Additionally, Soviet whalers disproportionately killed adult females in any reproductive condition (pregnant or lactating) as well as immature sperm whales of either gender.

Although the IWC instituted an international ban on the harvesting of sperm whales in 1981, Japanese whalers continued to hunt sperm whales in the North Pacific until 1988 (Reeves and Whitehead 1997). In 2000, the Japanese Whaling Association announced plans to kill 10 sperm whales in the Pacific Ocean for research, which was the first time sperm whales have been hunted since the international ban on commercial whaling. Although consequences of these deaths are unclear, the paucity of population data, uncertainly regarding recovery from whaling, and re-establishment of active programs for whale harvesting pose risks for the recovery and survival of this species. Sperm whales are also hunted for subsistence purposes by whalers from

Lamalera, Indonesia, where a traditional whaling industry has been reported to take up to 56 sperm whales per year.

Following the moratorium on whaling by the IWC, significant whaling pressures on sperm whales were eliminated. However, sperm whales are known to become entangled in commercial fishing gear with 17 individuals known to have been struck by vessels (Jensen and Silber 2004). Whale-watching vessels also influence sperm whale behavior (Richter et al. 2006). Sperm whales are taken incidentally by gill nets at a rate of roughly nine per year (data from 1991 to 1995) in U.S. waters in the Pacific Ocean (Barlow et al. 1997). While sperm whales are known to remove fish from longline fishing gear in the Gulf of Alaska, and entanglement has rarely been recorded (Rice 1989; Hill and DeMaster 1999, Sigler et al. 2008).

Contaminants have been identified in sperm whales, but vary widely in concentration based upon life history and geographic location, with northern hemisphere individuals generally carrying higher burdens (Evans et al. 2003). Contaminants include dieldrin, chlordane, DDT, DDE, PCBs, HCB and HCHs in a variety of body tissues (Aguilar 1983; Evans et al. 2004), as well as several heavy metals (Law et al. 1996). However, unlike other marine mammals, females appear to bioaccumulate these toxins at greater levels than males, which may be related to possible dietary differences between females who remain at relatively low latitudes compared to more migratory males (Aguilar 1983).

Critical Habitat

NMFS has not designated critical habitat for sperm whales.

<u>Steller Sea Lion</u>

Steller sea lions are distributed along the rim of the North Pacific Ocean from San Miguel Island (Channel Islands) off Southern California to northern Hokkaido, Japan (Loughlin et al. 1984; Nowak 2003). Their centers of abundance and distribution are in Gulf of Alaska and the Aleutian Islands, respectively (NMFS 1992). In the Bering Sea, the northernmost major rookery is on Walrus Island in the Pribilof Island group. The northernmost major haul-out is on Hall Island off the northwestern tip of St. Matthew Island. Their distribution also extends northward from the western end of the Aleutian chain to sites along the eastern shore of the Kamchatka Peninsula. For management purposes, two stocks have been designated, but which represent a single population.

Female Steller sea lions reach sexual maturity and first breed between 3 and 8 years of age and the average age of reproducing females (generation time) is about 10 years (Pitcher and Calkins 1981; Calkins and Pitcher 1982; York 1994). They give birth to a single pup from May through July and then breed about 11 days after giving birth. Females normally ovulate and breed annually after maturity although there is a high rate of reproductive failures. The gestation period is believed to be about 50 to 51 weeks (Pitcher and Calkins 1981). The available literature indicates an overall reproductive (birth) rate on the order of 55% to 70% or greater (Pike and Maxwell 1958; Gentry 1970; Pitcher and Calkins 1981).

Males reach sexual maturity at about the same time as females (3 to 7 years of age, reported in Loughlin et al. 1987), but generally do not reach physical maturity and participate in breeding until about 8 to 10 years of age (Pitcher and Calkins 1981). The sex ratio of pups at birth is assumed to be about 1:1 or biased toward slightly greater production of males, but non-pups are biased towards females (Pike and Maxwell 1958; Calkins and Pitcher 1982; Trites and Larkin 1992; NMFS 1992; York 1994).

Mothers with newborn pups will make their first foraging trip about a week after giving birth, but trips are short in duration and distance at first, then increase as the pup gets older (Merrick and Loughlin 1997; Milette 1999; Pitcher et al. 2001; Milette and Trites 2003; Maniscalco et al. 2006). Females attending pups tend to stay within 20 nm of the rookery (Calkins 1996; Merrick and Loughlin 1997). Newborn pups are wholly dependent upon their mother for milk during at least their first 3 months of life, and observations suggest they continue to be highly dependent upon their mother through their first winter (Scheffer 1946; Porter 1997; Trites et al. 2006). Generally, female Steller sea lion will nurse their offspring until they are 1 to 2 years old (Gentry 1970; Sandegren 1970; Pitcher and Calkins 1981; Calkins and Pitcher 1982; Trites et al. 2006).

Estimated annual mortality is 0.22 for ages 0 to 2, dropping to 0.07 at age 3, then increasing gradually to 0.15 by age 10 and 0.20 by age 20 (York 1994). Population modeling suggested that decreased juvenile survival likely played a major role in the decline of sea lions in the central Gulf of Alaska during 1975-1985 (Pascual and Adkison 1994; York 1994; Holmes and York 2003).

Most adult Steller sea lions occupy rookeries during the pupping and breeding season and exhibit a high level of site fidelity. During the breeding season, some juveniles and non-breeding adults occur at or near the rookeries, but most are on haulouts (sites that provide regular retreat from the water on exposed rocky shoreline, gravel beaches, and wave-cut platforms or ice; Rice 1998; Ban 2005; Call and Loughlin 2005). Adult males may disperse widely after the breeding season. Males that breed in California move north after the breeding season and are rarely seen in California or Oregon except from May through August (Mate 1973). During fall and winter many sea lions disperse from rookeries and increase use of haulouts, particularly on terrestrial sites but also on sea ice in the Bering Sea.

Steller sea lions are not known to make regular migrations but do move considerable distances. Adult males may disperse hundreds of miles after the breeding season (Calkins and Pitcher 1982; Calkins 1986; Loughlin 1997). Adult females may travel far out to sea into water greater than 3,300 feet deep (Merrick and Loughlin 1997). Studies on immature Steller sea lions indicate three types of movements: long-range trips (greater than 9.3 miles and greater than 20 hours), short-range trips (less than 9.3 miles and less than 20 hours), and transits to other sites (NMFS 2007a). Long-range trips started around 9 months of age and likely occur most frequently around the time of weaning, while short-range trips happen almost daily. Young individuals generally remain within 300 miles of rookeries their first year before moving further away in subsequent years (Raum-Suryan et al. 2002). Many animals also use traditional rafting sites, which are places where they rest on the ocean surface in a tightly packed group (Bigg 1985; NMFS unpublished data).

Steller sea lions are generalist predators that eat various fish (arrowtooth flounder, rockfish, hake, flatfish, Pacific salmon, Pacific herring, Pacific cod, sand lance, skates, cusk eel, lamprey, walleye, Atka mackerel), squids, and octopus and occasionally birds and marine mammals (Jones 1981; Pitcher and Fay 1982; Calkins and Goodwin 1988; Olesiuk et al. 1990b; Daniel and Schneeweis 1992; NMFS 2000a; Brown et al. 2002; Sinclair and Zeppelin 2002; McKenzie and Wynne 2008). Diet is likely strongly influenced by local and temporal changes in prey distribution and abundance (McKenzie and Wynne 2008).

Diving activity is highly variable by sex and season. During the breeding season, when both males and females occupy rookeries, adult breeding males rarely, if ever, leave the beach (Loughlin 2002). However, females tend to feed at night on 1-2 day trips and return to nurse pups (NRC 2003). Female foraging trips during winter are longer (80 miles) and dives are deeper (frequently greater than 820 feet). Summer foraging dives, however, are closer to shore (about 10 miles) and shallower (330 to 820 feet; Merrick and Loughlin 1997; Loughlin 2002). As pups mature and start foraging for themselves, they develop greater diving ability until roughly 10 years of age (Pitcher et al. 2005). Juveniles usually make shallow dives to just over 50 feet, but much deeper dives in excess of 1,000 feet are known (Loughlin et al. 2003). Young animals also tend to stay in shallower water less than 330 feet deep and within a dozen miles from shore (Fadely et al. 2005).

Status and Trends

Steller sea lions were originally listed as threatened under the ESA on November 26, 1990 (55 FR 49204), following a decline in the U.S. of about 64% over previous three decades. In 1997, the species was split into two separate populations based on demographic and genetic differences (Bickham et al. 1996; Loughlin 1997), and the western population was reclassified to endangered (62 FR 24345) while the eastern population remained threatened (62 FR 30772). The Steller sea lion is also listed as endangered on the 2007 IUCN Red List (Seal Specialist Group 1996).

Loughlin et al. (1984) estimated the worldwide population of Steller sea lions was between 245,000 and 290,000 animals (including pups) in the late 1970s. Though the genetic differences between the eastern and western DPSs were not known at the time, Loughlin et al. (1984) noted that 90% of the worldwide population of Steller sea lions was in the western DPS in the early 1980s (75% in the U.S. and 15% in Russia) and 10% in the eastern DPS. Loughlin et al. (1984) concluded that the total worldwide population size (both DPSs) was not significantly different from that estimated by Kenyon and Rice (1961) for the years 1959 and 1960, though the distribution of animals had changed. Steller sea lions collected in the Gulf of Alaska during the early 1980s showed evidence of reproductive failure and reduced rates of body growth that were consistent with nutritional limitation (Calkins and Goodwin 1988; Pitcher et al. 1998; Calkins et al. 1998). After conducting a range-wide survey in 1989, Loughlin et al. (1992) noted that the worldwide Steller sea lion population had declined by over 50% in the 1980s, to approximately 116,000 animals, with the entire decline occurring in the range of the western DPS.

<u>Eastern Steller Sea Lion</u>

The eastern DPS of Steller sea lions includes animals east of Cape Suckling, Alaska (144°W) south to California waters (55 FR 49204).

Status and Trends

Trend counts in Oregon were relatively stable in the 1980s, showing a gradual increase in numbers since 1976 (NMFS 2005b). Numbers in California, however, have declined to less than 2,000 non-pups, from counts between 1927 and 1947 that were as high as 7,000 non-pups (NMFS 2005b). The count from Central California in 2000, reached the second lowest count of 349 non-pups (in 1992 the count was as low as 276 non-pups). In Southeast Alaska, counts of non-pups at trend sites increased by 56% from 1979 to 2002 from 6,376 animals to 9,951 (Merrick et al. 1992; Sease et al. 2001; NMFS 2005b). Counts of non-pups at British Columbia trend sites increased nearly 260% between 1982 and 2002 (NMFS 2005b).

NMFS considers this population stable, and multiplies pup counts by a factor of 4.5 (based on Calkins and Pitcher 1982) or 5.1 (Trites and Larkin 1996) to estimate the total population size (Angliss and Outlaw 2008). Pup count data from 2002 through 2005 from across the range of the eastern population, multiplied by a factor of 4.5 or 5.1 results in a population estimate of 48,519 or 54,989 animals. In 2005, 5,510 pups were counted in Alaska, 3,318 pups were counted in British Columbia in 2002, 1,136 pups were counted in Oregon in 2002, and 818 counted in California in 2004. The current minimum population estimate is 44,584 animals. NMFS calculates this estimate by adding non-pup counts taken in 2002 in Southeast Alaska, to counts of animals in Washington in 2002 as well as counts of pups and non-pups in Canada in 1998, Oregon in 2002, California in 2004, and southeastern Alaska in 2005 (Angliss and Outlaw 2008).

Threats

Killer whale predation, particularly on the western DPS under reduced population size, may cause significant reductions in the stock (NMFS 2008b). Steller sea lions have tested positive for several pathogens, but disease levels are unknown (FOC 2008). Similarly, parasites in this species are common, but mortality resulting from infestation is unknown. However, significant negative effects of these factors may occur in combination with stress, which reduces immune capability to resist infections and infestations. If other factors, such as disturbance, injury, or difficulty feeding occur, it is more likely that disease and parasitism can play a greater role in population reduction.

Steller sea lions were historically and recently subjected to substantial mortality by humans, primarily due to commercial exploitation and both sanctioned and unsanctioned predator control, (Bonnot 1928; Rowley 1929; Scheffer 1945; Bonnot and Ripley 1948; Scheffer 1950; Pearson and Verts 1970; Bigg 1988; Atkinson et al. 2008; NMFS 2008b). Several dozen individuals may become entangled and drown in commercial fishing gear (Atkinson et al. 2008; NMFS 2008b). Several hundred individuals are removed by subsistence hunters annually in controlled and authorized takes. Occasional takes occur in Canada (FOC 2008). Additional mortality (362 from 1990 to 2003) has occurred from shooting of sea lions interfering in aquaculture operations along British Columbia (FOC 2008). Marine debris is also concerning for the health of Steller sea lion populations. It is estimated that 0.2% of Steller sea lions have marine debris around their necks (0.07%), or are hooked by fishing gear (FOC 2008).

Significant concern also exists regarding competition between commercial fisheries and Steller sea lions for the same resource: stocks of pollock, Pacific cod, and Atka mackerel. Significant evidence exists that supports the western DPS declining as a result of change in diet and resulting declines in growth, birth rates, and survival (Calkins and Goodwin 1988; Calkins et al. 1998; Pitcher et al. 1998; Trites and Donnelly 2003; Atkinson et al. 2008). As a result, limitations on fishing grounds, duration of fishing season, and monitoring have been established to prevent Steller sea lion nutritional deficiencies as a result of inadequate prey availability.

Behavioral disruption occurs as a result of human disturbance (FOC 2008). Research efforts to collect scats, count and weigh pups, and other human activities on or near rookeries can lead to stampedes into the water. Mortality can occur directly due to pup trampling, separating from mothers, or drowning. If disturbance is too frequent, haulouts may be completely abandoned. Although habituation to some activities, such as boating, can occur, unusual activities and sounds, such as blasting or demolition, can remotely trigger stampedes.

Contaminants are a considerable issue for Steller sea lions. Roughly 30 individuals died as a result of the Exxon *Valdez* oil spill and contained particularly high levels of PAH contaminants, presumable as a result of the spill. Blood testing confirmed hydrocarbon exposure. Subsequently, premature birth rates increased and pup survival decreased (Calkins et al. 1994b; Loughlin et al. 1996). Organochlorines, including PCBs and DDT (including its metabolites), have been identified in Steller sea lions in greater concentrations than any other pinniped during the 1980s, although levels appear to be declining (Barron et al. 2003; Hoshino et al. 2006). The levels of PCBs have been found to have twice the burden in individuals from Russia than from western Alaska (4.3 ng/g wet weight versus 2.1 ng/g wet weight; Myers et al. 2008). Levels of DDT in Russian pups were also on average twice that in western Alaska pups (3.3 ng/g wet weight blood versus 1.6 ng/g wet weight). The source of contamination is likely from pollack, which have been found to contain organochlorines throughout the Gulf of Alaska, but higher in regions occupied by the eastern DPS of Steller sea lions (Heinz et al. 2006; NMFS 2008b). Heavy metals, including mercury, zinc, copper, metallothionien, and butyltin have been identified in Steller sea lion tissues, but are in concentrations lower than other pinnipeds (Noda et al. 1995; Kim et al. 1996; Castellini 1999; Beckmen et al. 2002; NMFS 2008b). However, contaminants leading to mortality in Steller sea lions have not been identified (NMFS 2008b). Contaminant burdens are lower in females than males, because contaminants are transferred to the fetus *in utero* as well as through lactation (Lee et al. 1996; Myers et al. 2008). However, this means that new generations tend to start with higher levels of contaminants than their parents originally had. Concerns over Steller sea lion contaminants are of additional concerns because contaminants in the body tend to be mobilized as fat reserves are used, such as when prey availability is low.

Critical Habitat

Critical habitat was designated on August 27, 1993 for both eastern and western DPS Steller sea lions in California, Oregon, and Alaska (58 FR 45269). Steller sea lion critical habitat includes all major rookeries in California, Oregon, and Alaska and major haulouts in Alaska. Essential features of Steller sea lion critical habitat include the physical and biological habitat features that support reproduction, foraging, rest, and refuge, and include terrestrial, air and aquatic areas. Specific terrestrial areas include rookeries and haul-outs where breading, pupping, refuge and resting occurs. More than 100 major haulouts are documented. The principal, essential aquatic areas are the nearshore waters around rookeries and haulouts, their forage resources and habitats, and traditional rafting sites. Air zones around terrestrial and aquatic habitats are also designated as critical habitat to reduce disturbance in these essential areas. Specific activities that occur within the habitat that may disrupt the essential life functions that occur there include: (1) wildlife viewing, (2) boat and airplane traffic, (3) research activities, (4) timber harvest, (5) hard mineral extraction, (6) oil and gas exploration, (7) coastal development and pollutant discharge, and others.

In addition, British Columbia has established protective areas in which Steller sea lion rookeries occur at Triangle Island and Cape St. James (FOC 2008). Several other haul-out sites occur within Canadian national and provincial parks. Further, the Canadian government is moving to establish a marine wildlife area for the Scott Islands, where Steller sea lions haul-out and breed.

Marine Turtles

Green Sea Turtle

Green sea turtles, although designated as endangered or threatened based upon their nesting populations, are physically indistinguishable from one another and generally share many life history characteristics. Threatened green sea turtles have a circumglobal distribution, occurring throughout tropical, subtropical waters, and, to a lesser extent, temperate waters. Endangered green sea turtles nest in Florida in all coastal counties except those in the Big Bend area. The highest nesting densities are located along the southeast coast from Brevard to Palm Beach Counties (FFWCC 2007a). Green sea turtles nesting in Florida move to foraging areas located throughout the Florida Keys and include the Bahamas, Barbados, Cuba, Puerto Rico, southeastern U.S., and Venezuela (Lahanas et al. 1998; Luke et al. 2004; Bass et al. 2006; Moncada et al. 2006; Bolker et al. 2007; Diez and van Dam 2007). Several protected neritic habitats along the east coast of Florida have been identified as important areas for green sea turtles, including Mosquito and Indian River Lagoons, Port Canaveral, St. Lucie Inlet, and Biscayne Bay (Schmid 1995; Redfoot and Ehrhart 2000; Cantillo et al. 2000; Bresette et al. 2002; Bagley 2003; Kubis et al. 2003).

Green turtle nesting occurs sporadically along much of the Pacific coast of Mexico from the state of Sinaloa south to Chiapas, and near the tip of the Baja California Peninsula (Seminoff 1994; Tiburcios-Pintos in press). The primary nesting sites include the beaches of Colola and Maruata in Michoacán as well as Clarion and Socorro Islands in the Revillagigedos Archipelago). The primary foraging areas for these green sea turtles stretch from the U.S.-Mexico border to the Guatemala-Mexico border, although some turtles from Michoacán have been found as far south as Colombia (Alvarado and Figueroa 1992).

Through examining green sea turtle nesting in the context of oceanography, it is clear that environmental periodicity is a major determinant in the timing of green sea turtle reproduction (Limpus and Nichols 1988; Chaloupka 2001; Solow et al. 2002). It is also apparent that during years of heavy nesting activity, density dependent factors (e.g. beach crowding, digging up of eggs by nesting females) may impact nesting activity and hatchling production (Tiwari et al. 2005, 2006). Green sea turtles often return to the same foraging areas following nesting migrations, and once there, they move within specific areas, or home ranges, where they routinely visit specific localities to forage and rest (Seminoff et al. 2002a; Godley et al. 2002, 2003; Broderick et al. 2006; Makowski et al. 2006; Seminoff and Jones 2006; Taquet et al. 2006). However, it is also apparent that some green sea turtles remain in pelagic habitats for extended periods; perhaps never recruiting to coastal foraging sites (Pelletier et al. 2003).

Green sea turtles exhibit variable growth rates that largely depend upon diet quality and foraging season duration (Green 1993; McDonald-Dutton and Dutton 1998; Bjorndal et al. 2000; Seminoff et al. 2002b; Balazs and Chaloupka 2004b; Chaloupka et al. 2004b). In general, there is a tendency for green sea turtles to exhibit monotonic growth (declining growth rate with size) in the Atlantic and non-monotonic growth (growth spurt in mid size classes) in the Pacific, although this is not always the case (Chaloupka and Musick 1997; Seminoff et al. 2002b; Balazs and Chaloupka 2004b). Growth ranges from 0.55 inches in length per year to 3.14 inches per year (Zug and Glor 1998; Bresette and Gorham 2001; McMichael et al. 2006). Consistent with slow growth, age-to-maturity for green sea turtles appears to be the longest of any sea turtle species (Chaloupka and Musick 1997; Hirth 1997). Estimates indicate that age-to-maturity ranges from perhaps less than 20 years to 40 years or more (Limpus and Chaloupka 1997; Zug and Glor 1998; Seminoff et al. 2002b; Zug et al. 2002, Chaloupka et al. 2004b). Estimates of reproductive longevity range from 17 to 23 years (Carr et al. 1978; Fitzsimmons et al. 1995; Chaloupka et al. 2004b; Vera 2007). Considering that the mean interval between nesting seasons for Florida turtles is 2 years, a reproductive life span of this duration would result in a female nesting during 11 to 12 seasons over the course of her life (Bjorndal et al. 1983; Witherington and Ehrhart 1989). Florida green sea turtles nest three to four times per season and deposit a mean of 136 eggs per nest (Witherington and Ehrhart 1989; Johnson 1994). Thus, a female may produce 33 to 48 nests, or about 4,500 to 6,500 eggs, during her lifetime. For endangered green sea turtles, the mean duration between females returning to nest ranges from 2 to 5 years, these reproductive longevity estimates suggest that a female may nest three to 11 seasons over the course of her life (Hirth 1997). Based on the reasonable means of three nests per season and 100 eggs per nest, a female may deposit nine to 33 clutches, or about 900 to 3,300 eggs, during her lifetime (Hirth 1997).

Based on growth data from the Gulf of California, green sea turtles require from 9 to 21 years to reach sexual maturity after settling into this neritic foraging area (Seminoff et al. 2002b). Females nesting in Michoacán are substantially smaller than those nesting in the Revillagigedos (Alvarado and Figueroa 1990; Juarez-Ceron et al. 2003). The nesting season in Michoacán runs from September through January, with females nesting every 3 years and depositing a mean of 3.1 nests per season with roughly 65.1 eggs per nest (Alvarado and Figueroa 1990; Alvarado-Diaz et al. 2003). In the Revillagigedos Islands, nesting occurs from March through November with a peak in April/May, and although mean clutch frequency is unknown, there are substantially more eggs per nest (mean = 95 eggs; Brattstrom 1982; Awbrey et al. 1984; Juarez-Ceron et al. 2003).

In general, survivorship tends to be lower for juveniles and subadults than for adults. Adult survivorship has been calculated to range from 0.82 to 0.97 versus 0.58 to 0.89 for juveniles

(Seminoff et al. 2003; Chaloupka and Limpus 2005; Troëng and Chaloupka 2007), with lower values coinciding with areas of human impact on green sea turtles and their habitat (Bjorndal et al. 2003; Campbell and Lagueux 2005).

Green sea turtles undertake complex movements and migrations through geographically disparate habitats during their lifetimes (Musick and Limpus 1997; Plotkin 2003). The periodic migration between nesting sites and foraging areas by adults is a prominent feature of their life history. After departing as hatchlings and residing in a variety of marine habitats for up to 40 or more years (Limpus and Chaloupka 1997), green sea turtles make their way back to the same beach from which they hatched (Carr et al. 1978; Meylan et al. 1990). Upon leaving the nesting beach, hatchlings begin an oceanic phase, perhaps floating passively in major current systems (gyres) that serve as open-ocean developmental grounds. This early oceanic phase remains one of the most poorly understood aspects of green turtle life history. However, green sea turtles in the western Atlantic shift from this pelagic phase and recruit to neritic developmental areas at 5 to 6 years of age (Zug and Glor 1998). These new arrivals recruit to protected lagoons and open coastal areas rich in sea grass and marine algae and this first stop in their developmental migration may last for up to 6 years, after which time turtles may shift to other sites as larger juveniles/subadults (Musick and Limpus 1997; Zug and Glor 1998; Seminoff et al. 2002a, 2006; Lopez-Mendilaharsu et al. 2005; Bresette et al. 2006). While in coastal habitats, green sea turtles exhibit site fidelity to specific areas or home ranges, and it is clear that they can home in on these sites if displaced (Bresette et al. 1998; McMichael et al. 2003; Makowski et al. 2006).

Green turtles appear to prefer waters that usually remain around 68º F in the coldest month, but may be found considerably north of these regions during warm-water events, such as El Niño. Stinson (1984) found green turtles to appear most frequently in U.S. coastal waters with temperatures exceeding 64.4º F. Further, green sea turtles seem to occur preferentially in drift lines or surface current convergences, probably because of the prevalence of cover and higher prey densities that associate with flotsam. For example, in the western Atlantic Ocean, drift lines commonly containing floating *Sargassum* spp. are capable of providing juveniles with shelter and sufficient buoyancy to raft upon (NMFS and USFWS 1998). Underwater resting sites include coral recesses, the underside of ledges, and sand bottom areas that are relatively free of strong currents and disturbance. Available information indicates that green turtle resting areas are near feeding areas (Bjorndal and Bolten 2000).

Green sea turtles nesting in Michoacán, Mexico follow a coastal migratory corridor, usually within 66 miles of the mainland coast as they depart to the north and south (Nichols 2003a). Green turtles nesting in the Revillagigedos traverse oceanic regions as they move to coastal foraging areas along mainland Mexico and the Baja California Peninsula, and turtles moving north of the border to San Diego Bay, U.S., follow a coastal trajectory as soon as they reach the Baja Peninsula (P. Dutton, unpublished data in NMFS and USFWS 2007). Green sea turtles in the eastern Pacific Ocean, particularly those in foraging habitats of northwestern Mexico, have a more varied diet than green turtles in other areas of the world (Bjorndal 1997). Based on genetic differences, two distinct regional clades of green sea turtles are thought to exist in the Pacific: (1) western Pacific and South Pacific islands, and (2) eastern Pacific and central Pacific, including the rookery at French Frigate Shoals, Hawaii. In the eastern Pacific, green turtles forage from San Diego Bay, California to Mejillones, Chile. Individuals along the southern foraging area originate from Galapagos Islands nesting beaches, while those in the Gulf of California originate primarily from Michoacán. Green turtles foraging in San Diego Bay and along the Pacific coast of Baja California originate primarily from rookeries of the Islas Revillagigedos (Dutton 2003).

While offshore and sometimes while in coastal habitats, green sea turtles are not obligate plant-eating as widely believed, and instead consume invertebrates such as jellyfish, sponges, sea pens, and pelagic prey (Godley et al. 1998; Heithaus et al. 2002; Seminoff et al. 2002c, Hatase et al. 2006; Parker and Balazs in press). However, green sea turtles spend the majority of their lives in coastal foraging grounds. These areas include both open coastline and protected bays and lagoons. While in these areas, green sea turtles rely on marine algae and seagrass as their primary diet constituents, although some populations also forage heavily on invertebrates.

Based on the behavior of post-hatchlings and juvenile green turtles raised in captivity, it is presumed that those in pelagic habitats live and feed at or near the ocean surface, and that their dives do not normally exceed 33 to 100 feet while resting (NMFS and USFWS 1998; Hochscheid et al. 1999; Hays et al. 2000). The maximum recorded dive depth for an adult green turtle is just over 350 feet, while subadults routinely dive to 66 feet for 9 to 23 minutes, with a maximum recorded dive of over one hour (Berkson 1967 in Lutcavage and Lutz 1997; Brill et al. 1995 in Lutcavage and Lutz 1997).

Status and Trends

Federal listing of the green sea turtle occurred on July 28, 1978, with all populations listed as threatened except for the Florida and Pacific coast of Mexico breeding populations, which are endangered (43 FR 32800). Recently, NMFS and USFWS (2007) reviewed the endangered breeding populations' status and found that the nesting population of Florida appears to be increasing based on 18 years of index nesting data from throughout the state. Data for the largest nesting concentration in Pacific Mexico where nesting beach monitoring has been ongoing every year since the 1981 to 1982 nesting season shows an increase in nesting (Chaloupka et al. 2007).

Nesting data collected from 2000 to 2006 show that a mean of approximately 5,600 nests are laid each year in Florida. During this period, the counties with the greatest level of nesting activity were Brevard County, with a mean of 2,582 nests per year, and Palm Beach County, with a mean of 1,407 nests per year (FFWCC 2007a). There are no reliable estimates of the number of immature green sea turtles that inhabit coastal areas (where they come to forage) of the southeastern U.S. However, information on incidental captures of immature green sea turtles at the St. Lucie Power Plant in St. Lucie County, Florida (on the Atlantic coast of Florida) show that the annual number of immature green sea turtles captured has increased significantly in the past 26 years, with an average 215 green sea turtle captures per year since 1977.

It is likely that immature green sea turtles foraging in the southeastern U.S. come from multiple genetic stocks. Therefore, the status of immature green sea turtles in the southeastern U.S. might also be assessed from trends at all of the main regional nesting beaches, principally Florida, Yucatán, and Tortuguero. Trends in nesting at Yucatán beaches cannot be assessed because of a lack of consistent beach surveys over time. Trends at Tortuguero (20,000 to 50,000 nests/year) showed a significant increase in nesting during 1971-1996, and more recent information continues to show increasing nest counts (Bjorndal et al. 1999; Troëng and Rankin 2005). Therefore, it seems reasonable that there is an increase in immature green sea turtles inhabiting coastal areas of the southeastern U.S.; however, the magnitude of this increase is unknown.

There is one primary nesting concentration (Colola - Michoacán) and three lesser nesting sites (Maruata, Michoacán; Clarion Island, Revillagigedos Archipelago; and Socorro Island, Revillagigedos Archipelago) in Pacific Mexico. Based on nesting beach monitoring efforts, roughly 6,050 nests are deposited each year in Pacific Mexico. Based on the 25-year trend, green turtle nesting has increased since the population's low point in the mid-1980s to mid-1990s. The initial upward turn in annual nesting was seen in 1996, about 17 years after the initiation of a nesting beach protection program (Cliffton et al. 1982; Alvarado et al. 2001).

Current nesting abundance is known for 43 threatened nesting sites worldwide. These include both large and small rookeries and are believed to be representative of the overall trends for their respective regions. Based on the mean annual reproductive effort, 108,761 to 150,521 females nest each year among the 46 sites. Overall, of the 23 sites for which data enable an assessment of current trends, 10 nesting populations are increasing, 9 are stable, and 4 are decreasing (NMFS and USFWS 2007). Long-term continuous datasets of greater than 20 years are available for 11 sites, all of which are either increasing or stable. Despite the apparent global increase in numbers, the positive overall trend should be viewed cautiously because trend data are available for just over half of all sites examined and very few data sets span a full green sea turtle generation (Seminoff 2004). Nesting populations are doing relatively well in the western Atlantic and central Atlantic Ocean. In contrast, populations are doing relatively poorly in southeast Asia, eastern Indian Ocean, and perhaps the Mediterranean.

No trend data is available for almost half of the important nesting sites, where numbers are based on recent trends and do not span a full green sea turtle generation, and impacts occurring over four decades ago that caused a change in juvenile recruitment rates may have yet to be manifested as a change in nesting abundance. Additionally, these numbers are not compared to larger historical numbers. The numbers also only reflect one segment of the population (nesting females who are the only segment of the population for which reasonably good data are available and are cautiously used as one measure of the possible trend of populations).

Green turtles are thought to be declining throughout the Pacific Ocean, with the exception of Hawaii, from a combination of overexploitation and habitat loss (Eckert 1993; Seminoff et al. 2002a). In the western Pacific, the only major populations (>2,000 nesting females) of green turtles occur in Australia and Malaysia, with smaller colonies throughout the area. Indonesia has a widespread distribution of green turtles, but has experienced large declines over the past 50 years. Hawaii green turtles are genetically distinct and geographically isolated, and the population appears to be increasing in size despite the prevalence of fibropapillomatosis and spirochidiasis (Aguirre et al. 1998).

Threats

Hatchlings are preyed upon by herons, gulls, dogfish, and sharks. Adults face predation primarily by sharks and to a lesser extent by killer whales. All sea turtles except leatherbacks can undergo “cold stunning” if water temperatures drop below a threshold level, which can be lethal.

For unknown reasons, the frequency of a disease called fibropapillomatosis is much higher in green sea turtles than in other species and threatens a large number of existing subpopulations. Extremely high incidence has been reported in Florida, where the affliction rate reaches 62% in some areas (Schroeder et al. 1998). The fact that 22% of the 6,027 green sea turtles stranded in Florida from 1980 to 2005 had external fibropapillomatosis tumors suggests serious consequences for population stability (Singel et al. 2003; FFWCC 2007a). Extremely high incidence has been reported in Hawaii, where affliction rates peaked at 47% to 69% in some foraging areas (Murakawa et al. 2000). However, no incidences of fibropapillomatosis have been reported in Mexico.

Green sea turtles face threats from humans in several ways. Impacts of development that reduce nesting habitat along Florida include the construction of buildings and pilings, beach armoring and renourishment, and sand extraction (Lutcavage et al. 1997; Bouchard et al. 1998; Mosier 1998; Mosier and Witherington 2002; Leong et al. 2003; Roberts and Ehrhart 2003). These factors may directly, through loss of beach habitat, or indirectly, through changing thermal profiles and increasing erosion, serve to decrease the amount of nesting area available to nesting females, and may evoke a change in the natural behaviors of adults and hatchlings (Ackerman 1997; Witherington et al. 2003, 2007). Mexican coastal development constitutes a major threat in several areas, perhaps none more so than in northwest Mexico where the development of a large marina network (Escallera Nautica) is planned for at least five major foraging areas (Nichols 2003b). Several of the lesser green turtle nesting beaches in Mexico suffer from coastal development, a problem that is especially acute at Maruata, a tourist site with tourist activity and heavy foot traffic during the nesting season (Seminoff 1994). The presence of lights on or adjacent to nesting beaches in Florida and Mexico alters the behavior of nesting adults and is often fatal to emerging hatchlings, as they are attracted to light sources and drawn away from the water (Witherington and Bjorndal 1991; Witherington 1992; Nelson-Sella et al. 2006).

Three of the biggest threats to threatened green sea turtles result from harvest for commercial and subsistence use. These include egg harvest, the harvest of females on nesting beaches, and directed hunting of green sea turtles in foraging areas. These factors have led to the precipitous declines in worldwide green sea turtles previously described. Directed harvests are a major problem in American Samoa, Guam, Palau, Commonwealth of the Northern Mariana Islands, Federated States of Micronesia, Republic of the Marshall Islands, and the Unincorporated Islands (Wake, Johnston, Kingman, Palmyra, Jarvis, Howland, Baker, and Midway). In the Atlantic, green sea turtles are captured and killed in turtle fisheries in Colombia, Grenada, the Lesser Antilles, Nicaragua, St. Vincent and the Grenadines; the turtle fishery along the Caribbean coast of Nicaragua, by itself, has captured more than 11,000 green turtles annually over the past decade (Bräutigam and Eckert 2006; Lagueux 1998). While these threats have been largely eliminated in Florida due to successful conservation measures, the hunting of juvenile and adult turtles continues both legally and illegally in many foraging areas where turtles originating from Florida are known to occur (Fleming 2001; Chacon 2002). At the largest green sea turtle nesting beach along the Pacific Coast of Mexico, nearly all eggs were harvested for at least several decades prior to 1978 (Cliffton et al. 1982). Ongoing harvest of nesting adults has been documented in Michoacán (Alvarado-Diaz et al. 2001). Turtles are hunted in many areas of northwest Mexico despite legal protection (Nichols et al. 2002; Seminoff et al. 2003).

Other significant impacts on nesting beach habitat include disturbances from feral and domestic animals (Figueroa et al. 1993; Seminoff 1994). Contamination from herbicides, pesticides, oil spills, and other chemicals, as well as structural degradation from excessive boat anchoring and dredging is also a problem (Francour et al. 1999; Lee Long et al. 2000; Waycott et al. 2005). In addition to impacting the terrestrial zone, anthropogenic disturbances also threaten coastal marine habitats, particularly areas rich in seagrass and marine algae. Further, the introduction of alien algae species threatens the stability of some coastal ecosystems and may lead to the elimination of preferred dietary species of green sea turtles (De Weede 1996). Sea level rise may have significant impacts upon green turtle nesting on Pacific atolls. These low-lying, isolated locations could likely be inundated by rising water-levels associated with global warming, potentially eliminating nesting habitat (Baker et al. 2006).

Green sea turtles have been found to contain the organochlorines chlordane, lindane, endrin, endosulfan, dieldrin, DDT and PCB in a variety of tissues and may affect susceptibility to fibropapillomas (Miao et al. 2001; Gardner et al. 2003). These contaminants have the potential to cause deficiencies in endocrine, developmental, and reproductive health, and are known to depress immune function in loggerhead sea turtles (Keller et al. 2006; Storelli et al. 2007). However, studies of DDE and embryonic sex determination have not identified correlations (Podreka et al. 1998). PCB concentrations have been measured to be 45ng/g to 58 ng/g dry weight in liver tissue and 73 ng/g to 665 ng/g dry weight in adipose tissue, with hexachlorobiphenyls being dominant (Miao et al. 2001). DDE has not been found to influence sex determination at levels below cytotoxicity (Podreka et al. 1998; Keller and McClellan-Green 2004). To date, no tie has been found between pesticide concentration and susceptibility to fibropapillomatosis, although degraded habitat and pollution have been tied to the incidence of the disease and habitats impacted by agricultural, industrial, and urban development (Aguirre et al. 1994; Herbst and Klein 1995; Foley et al. 2005). Flame retardants have been measured at 3.70 ng/g in whole blood from healthy individuals (Hermanussen et al. 2008). Arthur et al. (2008) suspects that exposure to tumor-promoting compounds produced by the cyanobacteria *Lyngbya majuscule* may promote the development of fibropapillomatosis. Others suspect that dinoflagellates of the genus *Prorocentrum* that produce the tumorogenic compound okadoic acid may influence the development of fibropapillomatosis, although okadoic acid has not been detected in green turtle tissues (Landsberg et al. 1999; Takahashi et al. 2008). Takahashi et al. (2008) estimated that the total daily intake of okadoic acid by an adult turtle consuming 4.4 pounds of seagrass per day would be 920 ng.

Metal concentrations are generally similar to those found in loggerhead sea turtles. Arsenic in the form of arsenobetaine has been identified from green sea turtle tissues and is highest in muscle, followed by kidney and liver (Saeki et al. 2000; Fujihara et al. 2003). Cadmium, zinc, and copper have been measured in liver (4.26 mug/g, 34.5 mug/g, and 32.8 mug/g, respectively) and kidney tissues (5.06 mug/g to 5.89 mug/g, 26.39 mug/g, and 8.2mug/g, respectively; Godley et al. 1999; Storelli et al. 2008). Levels of copper and silver in the liver and cadmium in the kidney are very high (Anan et al. 2001). Zinc has also been measured in adipose tissue at 51.3 mug/g wet weight (Sakai et al. 2000). Mercury in the liver has been found at 0.55 mug/g dry weight (Godley et al. 1999). Additional metals identified in green sea turtles include chromium, silver, barium, and lead (Anan et al. 2001). Cadmium, selenium, and zinc concentrations in kidney tend to decrease with age, while zinc in liver tends to increase (Gordon et al. 1998; Sakai et al. 2000; Anan et al. 2001). These metals likely originate from plants in the green sea turtle diet and seem to have high transfer coefficients (Anan et al. 2001; Celik et al. 2006; Talavera-Saenz et al. 2007). Metal concentrations in eggs have not been found to be high (Celik et al. 2006). However, concentrations of calcium and magnesium are positively correlated with nesting success (Yalcin-Ozdilek et al. 2006).

Critical Habitat

On September 2, 1998, critical habitat for green sea turtles was designated in coastal waters surrounding Culebra Island, Puerto Rico (63 FR 46693). Aspects of this area that is important for green sea turtle survival and recovery include important natal development habitat, refuge from predation, shelter between foraging periods, and food for green sea turtle prey. Although specific issues with habitat degradation have not been noted for the designated critical habitat, concerns exist regarding infrastructure for sewage discharge in Puerto Rico. It is not uncommon for raw sewage to be discharged directly to coastal waters, although the occurrence of this on Culebra Island is unknown. Tourism in the area has also grown, but the effects on critical habitat have not been specifically addressed. NMFS has not designated critical habitat for Florida or Mexico breeding stocks of green sea turtles.

Leatherback Sea Turtle

The leatherback ranges farther than any other sea turtle species, having evolved physiological and anatomical adaptations that allow them to exploit waters far colder than any other sea turtle species (Frair et al. 1972; Greer et al. 1973; NMFS and USFWS 1995). In the Atlantic Ocean, leatherbacks have been recorded as far north as North Sea, Barents Sea, Newfoundland, and Labrador, and as far south as Argentina and the Cape of Good Hope, South Africa (Threlfall 1978; Goff and Lien 1988; Marquez 1990; Hughes et al. 1998; Luschi et al. 2003, 2006; James et al. 2005a). In the Pacific Ocean, they range as far north as Alaska and as far south as Chile and New Zealand (Marquez 1990; Gill 1997; Brito 1998; Hodge and Wing 2000). They also occur throughout the Indian Ocean (Hamann et al. 2006). Although leatherbacks occur in Mediterranean waters, no nesting is known to take place in this region (Casale et al. 2003).

Data suggest that leatherbacks in the western North Atlantic may not reach maturity until 29 years of age, not 2 to 14 years as previously thought (Pritchard and Trebbau 1984; Rhodin 1985; Zug and Parham 1996; Dutton et al. 2005; Avens and Goshe 2007). Survival is extremely low in early life, but greatly increases with age. Spotila et al. (1996) estimated survival in the first year to be 0.0625. For the St. Croix population, the average annual juvenile survival rate was estimated 0.63 (Eguchi et al. 2006a). The annual survival rate for leatherbacks that nested at Playa Grande, Costa Rica, was estimated to be 0.65 (Spotila et al. 2000). Rivalan et al. (2005) estimated the mean annual survival rate of leatherbacks in French Guiana to be 0.91. An examination of available strandings and in-water sighting data from the U.S. Atlantic and Gulf of Mexico coasts indicates that 60% of individuals were female. James et al. (2007) found the size distribution to consist mainly of large sub-adult and adults and a significant female biased sex ratio (1.86:1).

Leatherbacks are currently broken down into four main populations in the Pacific, Atlantic, and Indian Oceans, and the Caribbean Sea. These populations are further divided into nesting aggregations. Leatherback nesting aggregations occur widely in the Pacific, including in Mexico and Costa Rica (eastern Pacific), Malaysia, Indonesia, Australia, the Solomon Islands, Papua New Guinea, Thailand, and Fiji (western Pacific; Limpus 2002; Dutton et al. 2007). Scattered nesting also occurs along the Central American coast (Marquez 1990). In the Atlantic Ocean, leatherback nesting aggregations have been documented in Gabon, Sao Tome and Principe, French Guiana, Suriname, and Florida (Marquez 1990; Spotila et al. 1996; Bräutigam and Eckert 2006). Widely dispersed but fairly regular nesting also occurs between Mauritania in the north and Angola in the south (Fretey et al. 2007a). In the U.S., nesting commences in March and continues into July. Females can deposit up to seven nests during a season and return to nest about every 2 to 3 years. They can produce 100 or more eggs, although this varies geographically, and some eggs in each clutch are infertile. Many sizeable populations (perhaps up to 20,000 females annually) of leatherbacks are known to nest in West Africa (Fretey 2001). In the Caribbean, leatherbacks nest in the U.S. Virgin Islands and Puerto Rico as well as St. Croix, Puerto Rico, Costa Rica, Panama, Colombia, Trinidad and Tobago, Guyana, Suriname, and French Guiana (Marquez 1990; Spotila et al. 1996; Bräutigam and Eckert 2006). In the Indian Ocean, leatherback nesting aggregations are reported in South Africa, India, Sri Lanka, and the Andaman and Nicobar islands (Hamann et al. 2006).

Leatherback sea turtles are highly migratory animals that are found throughout convergence zones and upwelling areas in the open ocean, along continental margins, and in archipelagic waters (Morreale et al. 1994; Eckert 1998; Eckert 1999a). In a single year, a leatherback may swim more than 6,000 miles (Eckert 1998). Movements during and following nesting are widespread throughout oceans (Ferraroli et al. 2004; Hays et al. 2004; Eckert 2006b; Eckert et al. 2006; Sale et al. 2006; Benson et al. 2007).

Leatherback sea turtles may select foraging areas based on oceanic structures that tend to concentrate prey, including several types of invertebrates (Ferraroli et al. 2004; Eckert 2006). Leatherbacks are deep divers, with recorded dives to depths in excess of a half mile (Eckert et al. 1989). The North Pacific foraging grounds contain individuals from both the eastern and western Pacific rookeries, although leatherbacks from the eastern Pacific generally forage in the southern hemisphere along Peru and Chile (Dutton et al. 1998, 2000; Dutton 2005-2006). Mean primary productivity in all the foraging areas of western Atlantic females is significantly higher (150% greater) than those of the eastern Pacific females. This is coincident with the reproductive output of western Atlantic females was double that of eastern Pacific females (Saba et al. 2007). Leatherback turtles are pelagic and tend to forage in temperate waters except during the nesting season, when gravid females are nesting. Males do not generally occur near nesting areas. It is thought that leatherback sea turtles probably mate outside of tropical waters (Eckert and Eckert 1988). Distribution in temperate and boreal latitudes may be reflective of the location and abundance of their prey, which includes medusae, siphonophores, and salpae (Plotkin 1995).

Leatherback turtles are typically associated with both continental shelf and pelagic environments, and are sighted regularly in offshore waters in a variety of thermal regimes (45˚ to 80˚ F; CeTAP 1982). However, juvenile leatherbacks are generally found in water warmer than 70˚ F, indicating that the first part of a leatherback's life is spent in tropical waters (Eckert 2002). There appears to be some fidelity to breeding sites by males and females, who show some degree of natal homing (James et al. 2005b).

Leatherbacks are some of the deepest-diving sea turtles, with maximum recorded depths of 1,500 to 3,000 feet (Lutcavage and Lutz 1997). However, dives are more typically 164 to 275 feet; 75% to 90% of the time the leatherback turtles were at depths less than 260 feet (Standora et al. 1984 in Southwood et al. 1999). Dive durations are also impressive, with a maximum duration of 42 minutes and routine dives of 1 to 14 minutes (Eckert et al. 1989, 1996; Harvey et al. 2006). Most of this time is spent traveling to and from maximum depths (Eckert et al. 1989). Overall, leatherbacks appear to dive continuously (Southwood et al. 1999).

Status and Trends

The leatherback sea turtle was listed as endangered on June 2, 1970 (35 FR 8491). Recent declines have been seen in leatherbacks nesting worldwide. Initial estimates of the worldwide leatherback population between 29,000 and 40,000 breeding females were later refined to approximately 115,000 adult females globally (Pritchard 1971, 1982). An estimate of 34,500 females (26,200 to 42,900) was made by Spotila et al. (1996), along with a claim that the species as a whole was declining and local populations were in danger of extinction (NMFS 2001).

Leatherbacks have experienced major declines at all major Pacific basin rookeries, including Mexico, Costa Rica, Malaysia, India, Sri Lanka, Thailand, Trinidad, Tobago, and Papua New Guinea. At Mexiquillo, Michoacán, Mexico, Sarti et al. (1996) reported an average annual decline in nesting of about 23% from 1984-1996. The total number of females nesting on Mexico's Pacific coast during 1995-1996 was estimated at fewer than 1,000. Less than 700 females are estimated for Central America (Spotila et al. 2000). In the western Pacific, the decline is equally severe. Current nesting at Terengganu, Malaysia represent 1% of the levels recorded in 1950s (Chan and Liew 1996). South China Sea and East Pacific nesting colonies have undergone catastrophic collapse. Pacific populations are in a critical state of decline. Once estimated at 81,000 individuals, they are now estimated at less than 3,000 total adults and subadults (Spotila et al. 2000). This tremendous collapse likely stems from drastic overharvesting of eggs and significant mortality from fishing (Sarti et al. 1996; Eckert 1997).

Recent analysis suggests that seven stocks exist in the Atlantic including Florida, northern Caribbean, western Caribbean, southern Caribbean-Guyana Shield-Trinidad, West Africa, South Africa, and Brazil (TEWG 2007). Except for the Western Caribbean, these stocks appeared to be increasing (TEWG 2007). However, caution should be taken as these trend estimates were based only on information from nesting females (one segment of the population). The largest leatherback nesting aggregation in the western North Atlantic occurs along the northern coast of South America in French Guiana and Suriname. Adult leatherbacks of the North Atlantic are believed to number 34,000 to 94,000 individuals (TEWG 2007). Western Atlantic nesting females are reported to number 18,800, while the Eastern Atlantic population is approximately 4,700. However, these data do not consider the number or origin of leatherbacks in specific foraging areas, nor do they provide an estimate of subadult abundance.

Threats

Sea turtles face predation primarily by sharks and to a lesser extent by killer whales (Pitman and Dutton 2004). Hatchlings are preyed upon by herons, gulls, dogfish, and sharks. Unlike other sea turtles, leatherbacks do not undergo "cold stunning" if water temperatures drop below a threshold level, which can be lethal to other sea turtle species.

There are increasing impacts to the nesting and marine environments of leatherbacks. Leatherback nesting beaches are affected by development and tourism in several countries (e.g., Maison 2006; Hamann et al. 2006a; Santidrian-Tomillo et al. 2007; Hernandez et al. 2007). Structural impacts to nesting habitat include the construction of buildings and pilings, beach armoring and renourishment, and sand extraction (Lutcavage et al. 1997; Bouchard et al. 1998). In addition, accumulation of timber and marine debris on the beach, as well as sand mining, can have a negative impact on available nesting habitat in some areas (Chacón-Chaverri 1999; Formia et al. 2003; Laurance et al. 2008). The presence of lights on or adjacent to nesting beaches alters the behavior of nesting adults and is often fatal to emerging hatchlings as they are attracted to light sources and drawn away from the water (Witherington and Bjorndal 1991; Witherington 1992; Cowan et al. 2002; Deem et al. 2007). Global warming is expected to expand foraging habitats into higher latitude waters (James et al. 2006; McMahon and Hays 2006), and there is some concern that increasing temperatures may increase feminization of nests (Mrosovsky et al. 1984; Hawkes et al. 2007). Egg collection occurs in many countries around the world and has been attributed to catastrophic declines such as in Malaysia. Harvest of females still remains a matter of concern on many beaches.

Commercial and artisanal fishing may severely inhibit leatherback recovery. Lewison et al. (2004) estimated that more than 50,000 leatherbacks were likely taken as pelagic longline bycatch in 2000. Lee Lum (2006) estimated that more than 3,000 leatherbacks were entangled by coastal gillnets off Trinidad in the Southern Caribbean annually, with a 30% mortality. Gillnets are probably a major source of leatherback decline along French Guiana (Chevalier et al. 1999). Elsewhere in the Atlantic, leatherback entanglements are also common. In Canadian waters, 70% of leatherbacks had entanglements in some form, including salmon net, herring net, gillnet, trawl line, and crab pot line (Goff and Lien 1988). Shrimp trawling in the Gulf of Mexico capture the largest number of leatherback sea turtles, with roughly 3,000 individuals captured, but only about 80 of those dying. Along the eastern seaboard, the NMFS estimates about 800 leatherbacks are captured in pelagic longline fisheries, bottom longline and drift gillnet fisheries as well as lobster, deep-sea red crab, Jonah crab, mahi mahi, wahoo, and Pamlico Sound gillnet fisheries. Of these, about 40% are estimated to be killed.

Little is known about the effects contaminants have on leatherback sea turtles. Amongst heavy metals, arsenic, cadmium, copper, mercury, selenium, and zinc are known to bioaccumulate, with cadmium being higher in concentration (30.3 mu g/kg dry weight) in leatherbacks than in any other marine vertebrate (Gordon et al. 1998; Caurant et al. 1999). This is likely due to a diet of primarily jellyfish, which have high cadmium concentrations (Caurant et al. 1999). The pancreas of leatherbacks seems to accumulate metals in greater concentrations than any other tissue (Caurant et al. 1999). Arsenobetaine, arsenate, and arsenocholine are major bioaccumulative congeners of arsenic (Gordon et al. 1998). Chlorobiphenyls have been identified in the range of 47 mu g/kg to 178 mu g/kg wet weight, with the highest levels in adipose tissues (McKenzie et al. 1999). Organochlorine pesticides have also been measured in this species (McKenzie et al. 1999). Baseline blood values have been established for leatherbacks (Deem et al. 2006). Concentrations of PCBs are reportedly equivalent to those in some marine mammals (Davenport et al. 1990).

Critical Habitat

On March 23, 1979, critical habitat for the leatherback was identified in waters adjacent to Sandy Point, St. Croix, U.S. Virgin Islands, up to and inclusive of the waters from 600 feet water depth shoreward to the level of the mean high tide with boundaries at 17° 42’12” N and 65°50’00” W (44 FR 17710). This habitat is critical for leatherback sea turtle nesting and reproduction. Since 1979, tourism to St. Croix has increased significantly and could bring nesting habitat for sea turtles and people into close proximity more often. However, specific studies do not currently support significant deterioration of critical habitat. In January 2010, there was a proposed rule to revise critical habitat designations for the leatherback turtles from Cape Flattery, Washington to the Umpqua River (Winchester Bay), Oregon east of a line approximating the 2,000 meter depth contour (75 FR 319). The PCEs of the proposed revised critical habitats for leatherback turtles include water quality, prey species, and passage conditions.

Loggerhead Sea Turtle

Loggerheads are circumglobal, occurring throughout the temperate and tropical regions of the Atlantic, Pacific, and Indian Oceans. Loggerheads are the most abundant species of sea turtle found in U.S. coastal waters. Loggerhead sea turtles, are divided into five groupings that represent major oceans or seas: Atlantic, Pacific, and Indian oceans, as well as Caribbean and Mediterranean seas. As with other sea turtles, populations are frequently divided by nesting aggregation (Hutchinson and Dutton 2007). In the eastern Atlantic, five rookeries are known from Cape Verde, Greece, Libya, Turkey, and the western Africa coast. Western Atlantic nesting occurs principally from southern Virginia to Florida, on Dry Tortugas (Florida), along the Gulf Coast from northwestern Florida to Texas, on Cay Sal Bank (Bahamas), at Quintana Roo (Mexico’s Yucatan Peninsula), along Brazil’s shores, and at additional rookeries in Caribbean Central America, Bahamian Archipelago, Cuba, Colombia, Venezuela, and eastern Caribbean Islands that have not been classified. Loggerheads are known to nest along the Indian Ocean in Oman, Yemen, Sri Lanka, Madagascar, South Africa, and possibly Mozambique. Pacific Ocean rookeries are limited to the western portion of the basin. These sites include Australia, New Caledonia, New Zealand, Indonesia, Japan, and the Solomon islands.

The life cycle of loggerhead sea turtles can be divided into seven stages: eggs and hatchlings, small juveniles, large juveniles, subadults, novice breeders, first year emigrants, and mature breeders (Crouse et al. 1987). Hatchling loggerheads migrate to the ocean where they are generally believed to lead a pelagic existence for as long as seven to 12 years. Loggerheads hatched on U.S. beaches migrate offshore and become associated with *Sargassum* habitats, driftlines, and other convergence zones (Carr 1986). After 14 to 32 years of age, they shift to a benthic habitat, where immature individuals forage in the open ocean and coastal areas along continental shelves, bays, lagoons, and estuaries (NMFS 2001). In the western North Atlantic, loggerheads move into continental shelf waters from Cape Cod Bay south through Florida, The

Bahamas, Cuba, and the Gulf of Mexico. Estuarine waters, including areas such as Long Island Sound, Chesapeake Bay, Pamlico and Core Sounds, Mosquito and Indian River Lagoons, Biscayne Bay, Florida Bay, and numerous embayments fringing the Gulf of Mexico, comprise important inshore habitat. Along the Atlantic and Gulf of Mexico shoreline, essentially all continental shelf waters are inhabited by loggerheads. Habitat preferences of non-nesting adult loggerheads in the neritic zone differ from the juvenile stage. Areas such as Pamlico Sound and the Indian River Lagoon, regularly used by juveniles, are only rarely frequented by adult loggerheads. Estuarine areas with more open ocean access, such as Chesapeake Bay in the northeast U.S., are more frequently used by adults, primarily during warmer seasons. Offshore, adults primarily inhabit continental shelf waters, from New York south through Florida, The Bahamas, Cuba, and the Gulf of Mexico. Continental shelf waters along the west Florida coast, The Bahamas, Cuba, and the Yucatán Peninsula have been identified as important resident areas for South Florida Nesting Subpopulation adult female loggerheads (Foley et al. in press). At 20 to 38 years of age, loggerhead sea turtles become sexually mature, although the age at which they reach maturity varies widely among populations (Frazer and Ehrhart 1985; NMFS 2001). Adult loggerheads are known to make considerable migrations between foraging areas and nesting beaches (TEWG 1998). However, recent studies suggest that not all loggerhead sea turtles completely circumnavigate the North Atlantic Gyre as pelagic immatures. Some of these turtles may either remain in the pelagic habitat in the North Atlantic longer or move between pelagic and coastal habitats (Witzell 2002).

Loggerhead diving behavior varies based upon habitat, with longer surface stays in deeper habitats than in coastal ones. The maximum recorded dive depth for a post-nesting female was over 760 feet, although most dives are far shallower (30 to 70 feet). Routine dive durations for a post-nesting female were between 15 and 30 minutes, with subadults diving somewhat longer (19 to 30 minutes; Sakamoto et al. 1990 *in* Lutcavage and Lutz 1997). Loggerheads tagged in the Pacific over the course of five months showed that about 70% of dives are very shallow (less than 20 feet) and 40% of their time was spent within 3 feet of the surface (Polovina et al. 2003). During these dives, there were also several strong surface temperature fronts individuals were associated with, one of 68° F at 28° N latitude and another of 63° F at 32° N latitude.

Status and Trends

Loggerhead sea turtles were listed as threatened under the ESA of 1973 on July 28, 1978 (43 FR 32800). However, NMFS recently determined that a petition to reclassify loggerhead turtles in the western North Atlantic Ocean as endangered may be warranted due to the substantial scientific and commercial information presented. Consequently, NMFS has initiated a review of the status of the species and is currently soliciting additional information on the species status and ecology, as well as areas that may qualify as critical habitat (73 FR 11849; March 5, 2008).

There is general agreement that the number of nesting females provides a useful index of the species' population size and stability at this life stage, even though there are doubts about the ability to estimate the overall population size. The nesting trend for the northern subpopulation of loggerheads appears to be stable or declining (TEWG 1998; NMFS 2001). An important caveat for population trends analysis based on nesting beach data is that this may reflect trends in adult nesting females, but it may not reflect overall population growth rates well. Adult nesting females often account for less than 1% of total population numbers.

Western Atlantic nesting locations include The Bahamas, Brazil, and numerous locations from the Yucatán Peninsula to North Carolina (Addison and Morford 1996; Addison 1997; Marcovaldi and Chaloupka 2007). In this region, it is estimated that between 53,000 and 92,000 nests are laid per year in the southeastern U.S. and the Gulf of Mexico, and estimated the total number of nesting females at 32,000 to 56,000. This group comprises five nesting subpopulations: the Northern Nesting Subpopulation, South Florida Nesting Subpopulation, Dry Tortugas Nesting Subpopulation, Florida Panhandle Nesting Subpopulation, and the Yucatán Nesting Subpopulation. All of these are currently in decline or data are insufficient to access trends. Loggerheads from western North Atlantic nesting aggregations may or may not feed in the same regions from which they hatch. Loggerhead sea turtles from the northern nesting aggregation, which represents about 9% of the loggerhead nests in the western North Atlantic, comprise between 25% and 59% of individuals foraging from Georgia up to the northeast U.S. (Sears 1994; Sears et al. 1995; Norrgard 1995; Rankin-Baransky 1997; Bass et al. 1998). However, loggerheads associated with the South Florida nesting aggregation occur in higher frequencies in the Gulf of Mexico (where they represent about 10% of the loggerhead sea turtles captured) and the Mediterranean Sea (where they represent about 45% of the loggerhead sea turtles captured). It has been estimated that about 4,000 nests per year are laid along the Brazilian coast (Ehrhart et al. 2003).

The South Florida population increased at 5.3% to 5.4% per year from 1978 to 1990, and was initially increasing at 3.9% to 4.2% after 1990. However, an analysis of nesting data from the Index Nesting Beach Survey Program from 1989 to 2005, a period encompassing index surveys that are more consistent and more accurate than surveys in previous years, has shown no detectable trend and, more recently (1998 through 2005), has shown evidence of a declining trend of approximately 22.3% (FFWCC 2007b). Nesting data from the Archie Carr Refuge (one of the most important nesting locations in southeast Florida) over the last 6 years shows a decline in the number of nests from approximately 17,629 in 1998 to 7,599 in 2004. While this is a long period of decline relative to the past observed nesting pattern at this location (a record high followed by a variable period of declines, followed by another record high), aberrant ocean surface temperatures complicate the analysis and interpretation of this data. Although one must be cautious in interpreting the decreasing nesting trend given inherent annual fluctuations in nesting and the short time period over which the decline has been noted, the recent nesting decline at this nesting beach is reason for concern. Based upon the small sizes of almost all nesting aggregations in the Atlantic, the large numbers of individuals killed in fisheries, and the decline of the only large nesting aggregation, we suspect that the extinction probabilities of loggerhead sea turtle populations in the Atlantic are only slightly lower than those of populations in the Pacific.

In the eastern Atlantic, the Cape Verde Islands support the only known loggerhead nesting assemblage, and it is of at least intermediate size (Fretey 2001). Annual data from monitoring projects in Cyprus, Greece, Israel, Tunisia, and Turkey reveal total annual nesting in the Mediterranean ranging from 3,375 to 7,085 nests per season (Margaritoulis et al. 2003). Libya and the West African coast host genetically-unique breeding populations of loggerhead sea turtles as well (Hutchinson and Dutton 2007).

Pacific nesting is limited to two major locations, Australia and Japan. Eastern Australia supported one of the major global loggerhead nesting assemblages until recently (Limpus 1985). Now, less than 500 females nest annually, an 86% reduction in the size of the annual nesting population in 23 years (Limpus and Limpus 2003). The status of loggerhead nesting colonies in southern Japan and the surrounding region is uncertain, but approximately 1,000 female loggerhead turtles may nest there; a 50% to 90% decline compared to historical estimates (Dodd 1988; Bolton et al. 1996; Sea Turtle Association of Japan 2002; Kamezaki et al. 2003; Kamezaki et al. 2003). In addition, loggerheads are not commonly found in U.S. Pacific waters, and there have been no documented strandings of loggerheads off the Hawaiian Islands in nearly 20 years (1982-1999 stranding data). There are very few records of loggerheads nesting on any of the many islands of the central Pacific, and the species is considered rare or vagrant on islands in this region (NMFS and USFWS 1998).

The largest known nesting aggregation occurs on Masirah and Kuria Muria Islands in Oman (Ross and Barwani 1982). Extrapolations resulting from partial surveys and tagging in 1977 to 1978 provided broad estimates of 19,000 to 60,000 females nesting annually at Masirah Island, while a more recent partial survey in 1991 provided an estimate of 23,000 nesting females (Ross 1979, 1998; Ross and Barwani 1982; Baldwin 1992). Over 3,000 nests per year have been recorded on the Al-Halaniyat Islands, while along the Oman mainland of the Arabian Sea; about 2,000 nests are deposited per year (Salm 1991; Salm et al. 1993). Based upon genetic analyses, additional populations have been identified as nesting in Yemen, Sri Lanka, and Madagascar (Hutchinson and Dutton 2007). In the southwestern Indian Ocean, the highest concentration of nesting occurs on the coast of Tongaland, South Africa (Baldwin et al. 2003). The total number of females nesting annually in South Africa is estimated to be between 500 and 2,000 (Baldwin et al. 2003). An estimated 800 to 1,500 loggerheads nest annually on Dirk Hartog Island beaches along Western Australia (Baldwin et al. 2003).

Threats

Sea turtles face predation primarily by sharks and to a lesser extent by killer whales. All sea turtles except leatherbacks can undergo "cold stunning" if water temperatures drop below a threshold level, which can pose lethal effects. Eggs are commonly eaten by raccoons and ghost crabs along the eastern U.S. (Barton and Roth 2008). In the water, hatchlings are hunted by predators like herons, gulls, dogfish, and sharks. Adult loggerhead sea turtles also face predation by sharks and killer whales.

Anthropogenic threats impacting loggerhead nesting habitat are numerous: coastal development and construction, placement of erosion control structures, beachfront lighting, vehicular and pedestrian traffic, sand extraction, beach erosion, beach nourishment, beach pollution, removal of native vegetation, and planting of non-native vegetation (Baldwin 1992, NMFS and FWS 1998, Margaritoulis et al. 2003). Loggerhead sea turtles face numerous threats in the marine environment as well, including oil and gas exploration, marine pollution, trawl, purse seine, hook and line, gill net, pound net, longline, and trap fisheries; underwater explosions; dredging, offshore artificial lighting; power plant entrapment; entanglement in debris; ingestion of marine debris; marina and dock construction and operation; boat collisions; and poaching. The major factors inhibiting their recovery include mortalities caused by fishery interactions and degradation of the beaches on which they nest. Shrimp trawl fisheries account for the highest number of loggerhead sea turtles that are captured and killed. Along the Atlantic coast of the U.S., the NMFS estimated that almost 163,000 loggerhead sea turtles are captured in shrimp trawl fisheries each year in the Gulf of Mexico, of which 3,948 are killed. Each year, about 2,000 loggerhead sea turtles are captured in various fisheries in Pamlico Sound, of which almost 700 die. Offshore longline tuna and swordfish longline fisheries are also a serious concern for the survival and recovery of loggerhead sea turtles (Bolten et al. 1994; Aguilar et al. 1995; Crouse 1999). Deliberate hunting of loggerheads for their meat, shells, and eggs is reduced from previous exploitation levels, but still exists and hampers recovery efforts.

Climate change may also have significant implications on loggerhead populations worldwide. In addition to potential loss of nesting habitat due to sea level rise, loggerhead sea turtles are very sensitive to temperature as a determinant of sex while incubating. Ambient temperature increase by just 1.8º to 3.6º F can potentially change hatchling sex ratios to all or nearly all female in tropical and subtropical areas (Hawkes et al. 2007). Over time, this can reduce genetic diversity, or even population viability, if males become a small proportion of populations. Increasing ocean temperatures may also lead to reduced primary productivity and eventual food availability. This has been proposed as partial support for reduced nesting abundance for loggerhead sea turtles in Japan; a finding that could have broader implications for other populations in the future if individuals do not shift feeding habitat (Chaloupka et al. 2008).

Loggerhead sea turtles have been found to contain the organochlorines chlordanes, lindane, endrin, endosulfan, dieldrin, PFOS, PFOA, DDT and PCB in a variety of tissues (Rybitski et al. 1995; Corsolini et al. 2000; Gardner et al. 2003; Keller et al. 2004a, b, 2005; Alava et al. 2006; Storelli et al. 2007). PCB concentrations in studied tissue compartments include 52.3 ng/g to 119 ng/g wet weight in liver, 19.0 ng/g in kidney, 12.75 ng/g in lung, and 4.65 ng/g to 15 ng/g in muscle, and 334 ng/g to 459.6 ng/g in fat (Corsolini et al. 2000; Perugini et al. 2006; Storelli et al. 2007). DDT concentrations have been measured at 18.3 ng/g in liver, 5.7 ng/g in kidney, 3.76 ng/g in lung, and 1.45 ng/g in muscle (Storelli et al. 2007). Chlorobiphenyls have been measured in various tissue compartments, but are highest in adipose tissue, ranging from 775 mu g/kg to 893 mu g/kg wet weight (McKenzie et al. 1999). It appears that levels of organochlorines have the potential to suppress the immune system of loggerhead sea turtles and may affect metabolic regulation (Keller et al. 2004b; Keller et al. 2006). These contaminants have the potential to cause deficiencies in endocrine, developmental and reproductive health (Storelli et al. 2007). It is likely that the omnivorous nature of loggerheads makes them more prone to bioaccumulating toxins than other sea turtle species (McKenzie et al. 1999). Blood may be used as a non-lethal sampling mechanism to test for organochlorine concentrations (Keller et al. 2004a, c). Loggerhead eggs have been found to contain DDD, DDE (0.034 ppm to 0.099 ppm), DDT (7.88 ng/g to 1340 ng/g; mean of 67.1), PCBs (7.11 ng/g to 3930 ng/g; mean of 65.0 ng/g), chlordane (4.04 ng/g to 685 ng/g; mean of 37.0 ng/g), dieldrin (1.69 ng/g to 44.0 ng/g; mean of 11.1 ng/g), and polycyclic aromatic hydrocarbons, 1,2,5,6-dibenzanthracene, 1-methyl naphthalene, and naphthalene (Fletemey 1980; Clark and Krynitsky 1985; Alam and Brim 2000; Alava et al. 2006). PCB concentrations have been found to be highest in the chorioallantoic membrane

(Cobb and Wood 1997). Along with Kemp's ridleys, loggerhead sea turtles have higher levels of PCB and DDT than leatherback and green sea turtles. The generally higher level of contaminants found in loggerhead sea turtles is likely due to this species tendency to feed higher on the food chain than other sea turtles (Godley et al. 1999; McKenzie et al. 1999). Females from sexual maturity through reproductive life should have lower levels of contaminants than males because contaminants are shared with progeny through egg formation.

Heavy metals, including cadmium, iron, nickel, copper, zinc, and manganese, have also been found in a variety of tissues in levels that increase with turtle size (Gardner et al. 2006). Arsenic in the form of arsenobetaine has been identified from green sea turtle tissues and is highest in muscle, followed by kidney and liver (Saeki et al. 2000; Fujihara et al. 2003). Cadmium, zinc, and copper have been measured in liver (4.26 mg/kg, 34.5 mg/kg, and 32.8 mg/kg, respectively) and kidney tissues (5.06 mg/kg to 5.89 mg/kg, 26.39 mg/kg, and 8.2mg/kg, respectively) (Godley et al. 1999; Storelli et al. 2008). Levels of copper and silver in the liver and cadmium in the kidney are very high (Anan et al. 2001). Zinc has also been measured in adipose tissue at 51.3 mg/kg wet weight (Sakai et al. 2000). Cadmium, selenium, and zinc concentrations in kidney tend to decrease with age, while zinc in liver tends to increase (Gordon et al. 1998; Sakai et al. 2000; Anan et al. 2001). These metals likely originate from plants in the green sea turtle diet and seem to have high transfer coefficients (Anan et al. 2001; Celik et al. 2006; Talavera-Saenz et al. 2007). Metal concentrations in eggs have not been found to be high (Celik et al. 2006). However, concentrations of calcium and magnesium are positively correlated with nesting success (Yalcin-Ozdilek et al. 2006).

Loggerhead sea turtles have higher mercury levels than any other sea turtle studied, but concentrations are an order of magnitude less than many toothed whales (Pugh and Becker 2001). Mercury in the liver has been found at 0.55 mg/kg dry weight (Godley et al. 1999). Additional metals identified in green sea turtles include chromium, silver, barium, and lead (Anan et al. 2001). Additionally, loggerhead eggs laid along the Atlantic U.S. coast have an order of magnitude higher level of mercury than what has been measured in the Mediterranean Sea or along Japan. Similarly, arsenic has been found to be several fold more concentrated in loggerhead sea turtles than marine mammals or seabirds.

Critical Habitat

NMFS has not designated critical habitat for loggerhead sea turtles. However, NMFS recently determined that a petition to reclassify loggerhead turtles in the western North Atlantic Ocean may be warranted. Consequently, NMFS has initiated a review of the status of the species and is currently soliciting information on the species status and population demographics, and areas that may qualify as critical habitat (73 FR 11849).

Olive Ridley Sea Turtle

Olive ridleys are globally distributed in tropical regions of the Pacific (southern California to Peru, and rarely in the Gulf of Alaska; Hodge and Wing 2000), Indian (eastern Africa and the Bay of Bengal), and Atlantic oceans (Grand Banks to Uruguay and Mauritania to South Africa; Fretey 1999; Foley et al. 2003; Fretey et al. 2005; Stokes and Epperly 2006). They are not known to move between or among ocean basins.

Olive ridleys are best known for their arribada behavior (Carr 1967; Hughes and Richard 1974). Hundreds to tens of thousands of ridleys may synchronously emerge in just a few days from June through December to nest in close proximity. However, many ridleys nest solitarily. It has been suggested that the smaller clutch sizes observed for solitary nesters might be due to energetic costs associated with undertaking internesting movements among multiple beaches (Plotkin and Bernardo 2003). A third mating system may also exist, where some females switch between solitary nesting and arribada nesting in a nesting season (Kalb 1999; Bernardo and Plotkin 2007).

Arribada nesting occurs in the eastern Pacific from Nicaragua to Panama, in the Indian Ocean in the Indian State of Orissa (Gahirmatha, Robert Island, and Rushikulya, which host the largest olive ridley arribadas worldwide), and in the western Atlantic from Suriname/French Guiana to Brazil (NMFS and USFWS 2007). Solitary nesting occurs from Guatemala to Columbia as well as Indonesia and Malaysia in the Pacific, throughout much of the western and northern Indian Ocean, Guyana, Suriname, and French Guiana in the western Atlantic, and from Gambia south to Angola in the eastern Atlantic (NMFS and USFWS 2007). The endangered stock of olive ridleys nest along much of the western Mexican coastline.

In general, individual olive ridleys may nest one to three times per season, but on average two clutches are produced annually, with approximately 100 to 110 eggs per clutch (Pritchard and Plotkin 1995; NMFS and USFWS 1998). Solitary nesters ovulate on 14-day cycles whereas arribada nesters ovulate approximately every 28 days (Pritchard 1969; Kalb and Owens 1994; Kalb 1999). In the western Pacific, females lay nests every 1.1 years on average. Survivorship is low on high-density arribada nesting beaches (Cornelius et al. 1991). The sheer number of nesting turtles (1,000-500,000) means that nests are frequently disturbed by subsequent nesters in the same or following arribada. On solitary nesting beaches, hatching rates are significantly higher, presumably due to reduced disturbance (Castro 1986; Gaos et al. 2006). It is believed that, like other sea turtles, olive ridleys experience high mortality in early life stages, but details of survivorship are poorly understood. Both juveniles and adults occupy offshore waters, where they forage on gelatinous prey such as jellyfish, salps, and tunicates as well as crustaceans and small fish. Olive ridley sexual maturity is attained at a median age of 13 years with a range of 10 to 18 years (Kopitsky et al. 2005; Zug et al. 2006).

Olive ridleys are highly migratory and may spend most of their non-breeding life cycle in deep ocean waters, but occupy the continental shelf region during the breeding season (Cornelius and Robinson 1986; Pitman 1991, 1993; Arenas and Hall 1991; Plotkin 1994; Plotkin et al. 1994, 1995; Beavers and Cassano 1996). Reproductively active males and females migrate toward the coast and aggregate at nearshore breeding grounds near nesting beaches (Pritchard 1969; Hughes and Richard 1974; Cornelius 1986; Plotkin et al. 1991, 1996, 1997; Kalb et al. 1995). However, some breeding also takes place far from shore (Pitman 1991; Kopitsky et al. 2000), and it is possible that some males and females may not migrate to nearshore breeding aggregations at all. Some males appear to remain in oceanic waters, are non-aggregated, and mate opportunistically as they intercept females *en route* to near shore breeding grounds and nesting beaches (Plotkin 1994; Plotkin et al. 1994, 1996; Kopitsky et al. 2000). Their migratory pathways vary annually (Plotkin 1994), there is no spatial and temporal overlap in migratory pathways among groups or cohorts of turtles (Plotkin et al. 1994, 1995), and no apparent migration corridors exist. Olive ridleys from different populations may occupy different oceanic habitats (Polovina et al. 2003, 2004). Unlike other marine turtles that migrate from a breeding ground to a single feeding area, where they reside until the next breeding season, olive ridleys are nomadic migrants that swim hundreds to thousands of miles over vast oceanic areas (Plotkin 1994; Plotkin et al. 1994, 1995). Olive ridleys may associate with flotsam, which could provide food, shelter, and/or orientation cues (Hall 1992).

Olive ridley turtle diving behavior remains somewhat of a mystery, but several studies have highlighted general insights. In the eastern tropical Pacific, diving rate is greater during daytime than at night (Beavers and Cassano 1996; Parker et al. 2003). During nighttime however, dives are longer (up to 95 minutes). Most dives are relatively less than 330 feet, but individuals can dive to roughly 1,000 feet (Polovina et al. 2003). The presence of a thermocline appears to influence diving behavior, likely due to its impact on prey availability (Parker et al. 2003).

Status and Trends

Except for the Mexico breeding stock, olive ridley sea turtles were listed as threatened under the ESA on July 28, 1978 (43 FR 32800). Olive ridley population trends vary in trajectory; arribada sites in Nicaragua, Costa Rica (Ostional Beach), and Brazil appear to be increasing. One arribada site in Costa Rica (Nancite Beach) seems to be in decline. All other beaches, including the largest sites along the Indian coastline, require further survey data to access trends. Most recent information regarding solitary nesting sites along Guatemala, El Salvador, Bangladesh, Myanmar, Malaysia, Pakistan, and southwest India indicate declines in these areas. However, solitary nesting in Indonesia may be increasing (Limpus 1995; Asrar 1999; Thorbjarnarson et al. 2000; Islam 2002; Dermawan 2002; Krishna 2005).

The olive ridley is the most abundant sea turtle in the world (Pritchard 1997). The eastern Pacific population is believed to number roughly 1.39 million (Eguchi et al. in preparation). Abundance estimates in recent years indicate that the Mismaloya and Moro Ayuta nesting populations appear to be stable and the nesting population at La Escobilla is increasing, although less than historical levels, which was roughly 10 million adults prior to 1950 (Cliffton et al. 1982; R. Briseño, BITMAR and A. Abreu, pers. comm. in NMFS and USFWS 2007). By 1969, after years of adult harvest, the estimate was just over one million (Cliffton et al. 1982). Olive ridley nesting at La Escobilla rebounded from approximately 50,000 nests in 1988 to over 700,000 nests in 1994, and more than a million nests by 2000 (Márquez-M. et al. 1996, 2005).

High levels of adult mortality due to harvesting are believed to be the reason why rapid and large nesting population declines occurred in Mexico (Cornelius et al. 2007). The nationwide ban on commercial sea turtles harvest in Mexico, enacted in 1990, has greatly aided olive ridley conservation, but the population is still seriously decremented and threatened with extinction (Groombridge 1982). Several solitary and arribada nesting beaches experience (although banned) egg harvesting, which is causing declines (Cornelius et al. 2007). Approximately 300,000-600,000 eggs were seized each year from 1995-1998 (Trinidad and Wilson 2000).

Threats

Sea turtles face predation primarily by sharks and to a lesser extent by killer whales. All sea turtles except leatherbacks can undergo "cold stunning" if water temperatures drop below a threshold level, which can pose lethal effects. Collection of eggs as well as adult turtles has historically led to species decline (NMFS and USFWS 2007). Harvests remain a concern for olive ridley recovery. In some locations, takes are now regulated or banned (with varying compliance), while harvests remain uncontrolled in other areas. Takes of adult turtles are now largely banned, except along African coasts.

There are additional impacts to the nesting and marine environment that affect olive ridleys. Structural impacts to nesting habitat include the construction of buildings and pilings, beach armoring and renourishment, and sand extraction (Lutcavage et al. 1997; Bouchard et al. 1998). The presence of lights on or adjacent to nesting beaches alters the behavior of nesting adults and is often fatal to emerging hatchlings as they are attracted to light sources and drawn away from the water (Witherington and Bjorndal 1991; Witherington 1992). At sea, there are numerous potential threats including marine pollution, oil and gas exploration, lost and discarded fishing gear, changes in prey abundance and distribution due to commercial fishing, habitat alteration and destruction caused by fishing gear and practices, agricultural runoff, and sewage discharge (Lutcavage et al. 1997; Frazier et al. 2007).

In India, uncontrolled mechanized fishing in areas of high sea turtle concentration, primarily illegally operated trawl fisheries, has resulted in large scale mortality of adult olive ridley turtles during the last two decades. Since 1993, more than 50,000 olive ridleys have stranded along the coast, at least partially because of near-shore shrimp fishing (Shanker and Mohanty 1999). Fishing in coastal waters off Gahirmatha was restricted in 1993 and completely banned in 1997 with the formation of a marine sanctuary around the rookery. However, mortality due to shrimp trawling reached a record high of 13,575 ridleys during the 1997 to 1998 season and none of the approximately 3,000 trawlers operating off the Orissa coast use turtle excluder devices in their nets despite mandatory requirements passed in 1997 (Pandav and Choudhury 1999).

Olive ridley sea turtles have been found to contain the organochlorines chlordanes, lindane, endrin, endosulfan, dieldrin, DDT and PCB in a variety of tissues (Gardner et al. 2003). These contaminants have the potential to cause deficiencies in endocrine, developmental and reproductive health (Storelli et al. 2007), and are known to depress immune function in loggerhead sea turtles (Keller et al. 2006). Heavy metals, including cadmium, iron, nickel, copper, zinc, and manganese, have been found in a variety of tissues in levels that increase with turtle size (Gardner et al. 2006). Females from sexual maturity through reproductive life should have lower levels of contaminants than males because contaminants are shared with progeny through egg formation. Eggs have been found to contain iron, zinc, lead, cobalt, chromium, copper, cadmium, and nickel, with the first three metals being of higher concentrations than the rest, but none in particularly high concentrations (Sahoo et al. 1996). Newly emerged hatchlings have higher concentrations than are present when laid, suggesting that metals may be accumulated during incubation from surrounding sands (Sahoo et al. 1996).

Critical Habitat

NMFS has not designated critical habitat for olive ridley sea turtles.

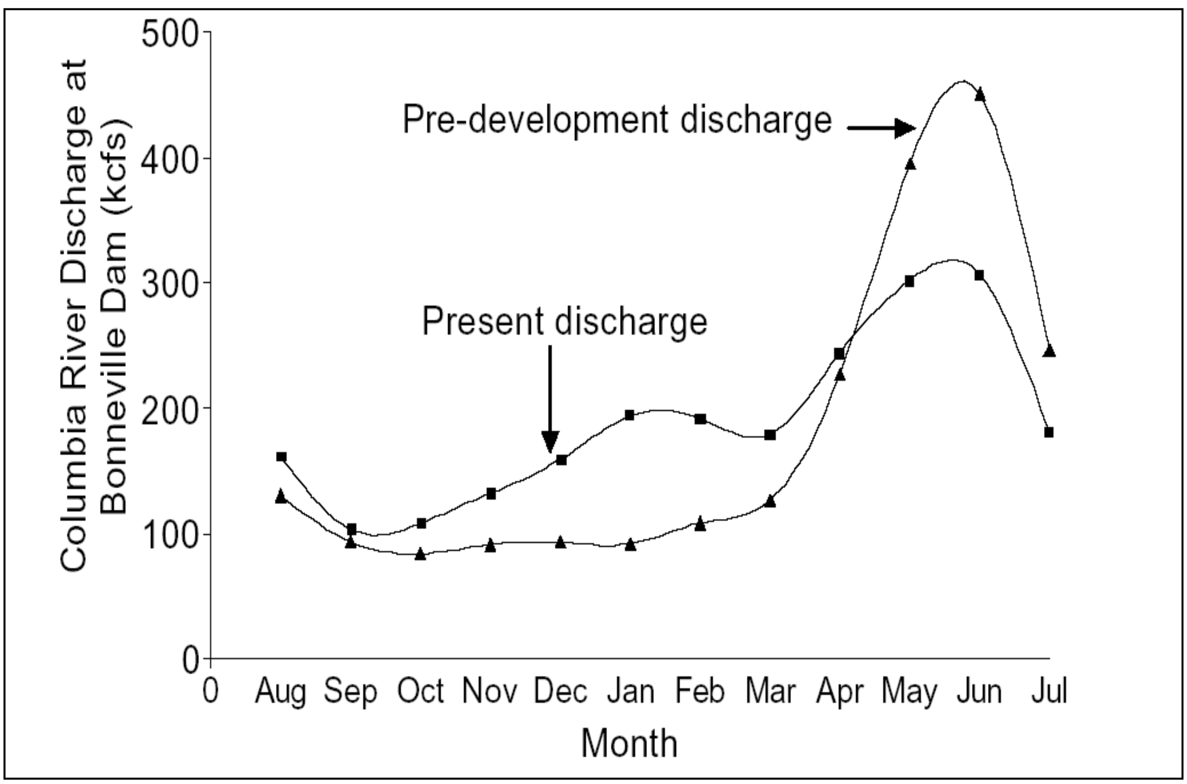
ENVIRONMENTAL BASELINE

The environmental baseline includes the past and present impacts of all Federal, State, or private actions and other human activities in the action area, the anticipated impacts of all proposed Federal projects in the action area that have already undergone formal or early section 7 consultation, and the impact of State or private actions which are contemporaneous with the consultation in process (50 CFR 402.02).

Overview

The Columbia River drains an area of 259,000 square miles and flows 1,243 miles from its headwaters in the Canadian Rockies of British Columbia, across the state of Washington, and along the border of Washington and Oregon to its mouth on the Pacific Ocean near Astoria, Oregon. The lower Columbia River extends from Bonneville Dam (RM 146) to the mouth of the Columbia River. Historically, unregulated discharges at the mouth ranged from 79,000 cubic feet per second (cfs) to over 1 million cfs, with average discharges of 273,000 cfs (Figure 39). Currently, discharge at the mouth of the river ranges from 100,000 to 500,000 cfs, with an average of about 260,000 cfs.

Figure 39. Annual Monthly River Discharge at Bonneville Dam under Current Operations as Compared to Historical River Discharge with No Mainstem Dams



Source: Corps Portland District

Highest discharges occur between December and March. Stream discharge in the lower Columbia River is influenced by snowmelt, winter rainstorms, and dam regulation. Stream discharge peaks generally occur during April through June. Local flooding in the lower Columbia River now begins when stream discharge reaches about 450,000 cfs, while the unregulated peak discharge would have been 602,000 cfs. Low stream flow generally occurs between August and October.

Discharge and sediment load have been altered by construction of 31 irrigation and hydropower dams, and 162 smaller dams, in the basin since 1890. Before 1890, the Columbia River estuary had extensive sand beds and variable river discharges. However, the construction of upriver hydroelectric dams has dramatically changed the nature of the estuary, as these dams have translated into different discharge rates and sediment discharges. Moreover, channel deepening, use of jetties and dredging to stabilize channels, development of perennial wetland areas, and isolation of remaining wetlands from the mainstem river have altered the physical character of the estuary; these changes have affected the biological systems supported by the estuary.

Physical Characteristics

The Columbia River estuarine environment extends from the mouth to approximately RM 38. The river varies from 2 to 5 miles wide throughout the estuary and is about 1 mile wide at RM 30. Tidal effect extends almost 150 miles upstream (Corps 1983), but the saltwater wedge is limited to approximately RM 20 (Corps 1999). The North and South jetties and Jetty A were constructed at the mouth to help stabilize the channel, reduce the need for dredging, and provide protection for ships. A series of pile dikes were also historically constructed for similar reasons. The navigation channel is currently maintained at authorized depths of 48-55 feet deep below MLLW and 0.5-mile wide from RM -3 to RM 3. River flows are controlled by upstream storage dams. A dredged material disposal site near the North Jetty was established in 1999 to protect the North Jetty from erosion. About 100,000 to 500,000 cubic yards of sand are placed there annually. The MCR Shallow Water Site (SWS), Deep Water Site (DWS), and Chinook Channel Area D Sites are also active disposal locations within the action area but offshore and upstream of MCR, respectively. Historic disposal sites no longer active within vicinity of the jetties include Site E located within the expanded SWS and sites A, B, and F, which are in deeper water but still shoreward of the active DWS.

The Corps regularly conducts operations and maintenance activities to maintain the jetty system and the authorized navigation channels and facilities. In the action area, there are several turning and mooring basins and federally authorized periodically dredged channels extending to various ports from the navigation channel. The Columbia River Channel Improvements Project was recently completed and deepened the navigation channel 3 feet from approximately RM 3-104.

Waves, Currents, and Morphology

The MCR is a high energy environment. The ocean entrance at the MCR is characterized by large waves and strong currents interacting with spatially variable bathymetry. The MCR is considered one of the world's most dangerous coastal inlets for navigation. Approximately 70% of all waves approaching the MCR are from the west-northwest. During winter storm conditions, the ocean offshore of the jettied river entrance is characterized by high swells approaching from the northwest to southwest combined with locally generated wind waves from the south to southwest. From October to April, average offshore wave height and period is 9 feet and 12 seconds, respectively. From May to September, average offshore wave height and period is 5 feet and 9 seconds, respectively, and waves approach mostly from the west-northwest. Occasional summer storms produce waves approaching MCR from the south-southwest with wave heights of 6.5 to 13 feet and wave periods of 7 to 12 seconds. Astronomical tides at MCR are mixed semi-diurnal with a diurnal range of 7.5 feet. The instantaneous flow rate of estuarine water through the MCR inlet during ebb tide can reach 1.8 million cfs. Tidally dominated currents within the MCR can exceed 8.2 feet per second. A large, clockwise-rotating eddy current has been observed to form between the North Jetty, the navigation channel, and Jetty A during ebb tide. A less pronounced counter-clockwise eddy forms in response to flood tide. Horizontal circulation in the estuary is generally clockwise (when viewed from above), with incoming ocean waters moving upstream in the northern portion of the estuary and river waters moving downstream in the southern portion. Vertical circulation is variable, reflecting the complex interaction of tides with river flows and bottom topography and roughness (Corps 1983). The North Jetty eddy has varying strength and direction (based on location and timing of tide) ranging from 0.3 to 3.3 feet per second.

As waves propagate shoreward toward the mouth of the Columbia River, the waves are modified (waves begin to shoal and refract) by the asymmetry of the mouth of the Columbia River underwater morphology. Nearshore currents and tidal currents are also modified by the jetties and the mouth of the Columbia River morphology. These modified currents interact with the shoaling waves to produce a complex and agitated wave environment within the mouth of the Columbia River. The asymmetric configuration of the mouth of the Columbia River and its morphology is characterized by the significant offshore extent of Peacock Spit on the north side of the North Jetty, southwesterly alignment of the North/South jetties and channel, and the absence of a large shoal on the south side of the mouth of the Columbia River. The asymmetry of the mouth of the Columbia River causes incoming waves to be focused onto areas which would not otherwise be exposed to direct wave action. An example of this wave-focusing effect is the area along the south side of the North Jetty. Upon initial inspection, it would appear that this area is most susceptible to wave action approaching the mouth of the Columbia River from the southwest. However, this is not the case; the opposite is what occurs. The area located between the North Jetty, the navigation channel, and Jetty A is affected by wave action during conditions when the offshore wave direction is from the west-northwest, because of the refractive nature of Peacock Spit. Waves passing over Peacock Spit (approaching from the northwest) are focused to enter the mouth of the Columbia River along the south side of the North Jetty. Conversely, large waves approaching the mouth of the Columbia River from the southwest are refracted/diffracted around the South Jetty and over Clatsop Spit, protecting the south side of the North Jetty from large southerly waves.

Channel stability at the mouth of the Columbia River is related to the jetties and the morphology of Peacock and Clatsop spits (Moritz et al. 2003). Because of phased jetty construction from 1885 to 1939 and the associated response of morphology, mouth of the Columbia River project features and the resultant morphology are now mutually dependent both in terms of structural integrity and project feature functional performance.

Foundation Conditions

The project has two main shoaling areas. The outer shoal extends from approximately RM -1.6 to RM -1.0. The inner shoal, Clatsop Shoal, extends from approximately RM 0.0 to RM 2.6, beginning on the south side and crossing the channel near RM 1.0. To maintain the channel's depth, dredging is conducted and materials dredged from the project are placed in one of two EPA Section 102 of the Marine Protection, Research, and Sanctuaries Act (MPRSA) Ocean Dredged Material Disposal Sites (ODMDS) -- the Deep Water Site (DWS) or the Shallow Water Site (SWS), or alternately in a Clean Water Act Section 404 North Jetty site (Corps 2008).

The MCR jetties were constructed on these underwater sand shoals which are considered to be crucial project elements. These shoals are currently receding, which could affect the sediment budget supplying the adjacent littoral zones north and south of the MCR. As morphology near the jetties experiences significant erosion, the jetties will be undermined by waves and currents.

Landforms

Near the Oregon shore of the estuary, Clatsop Spit is a coastal plain. On the Washington shore, Cape Disappointment is a narrow, rocky headland. Extensive accretion of land has occurred north of the North Jetty since its construction. This accreted land, however, is now in the process of recession as is evident by erosion at Benson Beach. The Corps is in the process of placing Columbia River sand back into the littoral drift cell north of the North Jetty at Benson Beach. Behind the headland is beach dune and swale. Wetlands occur on accreted land north of the North Jetty and on Clatsop Spit.

Wetlands near the North Jetty

Scouring has occurred on the north side of the North Jetty resulting in the formation of wetlands and a backwater lagoon within the approximately 16-acre wedge of land between the North Jetty and Jetty Road. Lagoons are characterized by shallow water and intermittent ocean connectivity and are often oriented parallel to the shoreline. Because of their interface location between land and sea, their exposure to rapidly changing physical and chemical influences, their short and varied water residence time, and their wind and weather dependent vertical and horizontal stratification, these lagoon features can be very dynamic and productive based on these natural constraints (Troussellier 2007). A recently repaired sand berm separates the western entrance of the North Jetty lagoon from tidal flows along the south end of Benson Beach. Thus, the North Jetty lagoon and wetlands are separated from direct ocean connectivity by the berm and the jetty itself. Fish access to and use of the lagoon is not likely. However, the lagoon is often inundated both by tidal waters that come through the jetty and by freshwater from wetlands that have formed in accreted lands north of Jetty Road and which drain through a culvert into the lagoon and its adjacent wetlands. The lagoon area and three wetland areas were delineated in this wedge of land and total approximately 6.5 acres of wetlands and waters of the United States.

Wetlands within and fringing the lagoon that are proposed to be filled are located between the North Jetty and the beach access road to the north and comprise a total of 1.78 acres. These wetlands were delineated by Tetra Tech (2007a, b) in accordance with the Corps' Wetlands Delineation Manual (Corps 1987). Three distinct wetlands were identified.

Wetland 1 (0.61 acre). These disjunct wetlands are classified as estuarine emergent, persistently regularly flooded. These patches of wetlands fringe the scoured-out tidal channel and are characterized by bighead sedge, American dune grass, Baltic rush, and tufted hairgrass. These fringe wetlands are ephemeral in nature in that they can be affected by moving sand. This was evident during a field visit in fall 2007 when a storm during the previous winter washed sand eastward covering nearly all of a patch of wetland that occurred near Benson Beach.

Wetland 2 (0.97 acre). This wetland is classified as palustrine emergent, persistently seasonally flooded and as palustrine scrub-shrub broad-leaved deciduous seasonally flooded. It occurs adjacent to the beach access road in drainage ditches. Three plant communities characterize this wetland: baltic rush-velvet grass emergent, slough sedge emergent, and willow shrub.

Wetland 3 (0.20 acre). This wetland is classified as palustrine scrub-shrub, broad-leaved deciduous, seasonally flooded. This bowl-shaped wetland occurs toward the west end of the area projected for filling and is characterized by a thick understory of slough sedge and an overstory mainly of alder. Pacific crabapple and Sitka spruce are also present.

Two of the three wetlands described above were rated by the Washington Department of Ecology and the Corps on November 16, 2007 in accordance with the Washington State Wetland Rating System (Hruby 2004). Wetland 1, the tidal fringe wetlands, was not rated by this system because they are considered estuarine wetlands. Because of lack of hydrologic connection, Wetland 2 (consisting of two ditches) was broken out into discrete wetlands for rating purposes (referred to here as Wetland 2a and Wetland 2b). Wetland 2a is between the east parking lot and beach access road and Wetland 2b is just west of Wetland 2a. Categories assigned by the rating system are: Category I (score ≥ 70), Category II (score 51-69), Category III (score 30-50), and Category IV (score < 30). All three wetlands rated are considered depressional wetlands and qualify as Category III wetlands. Scores for the wetlands are shown in Table 34.

Table 34. North Jetty Wetland Scores

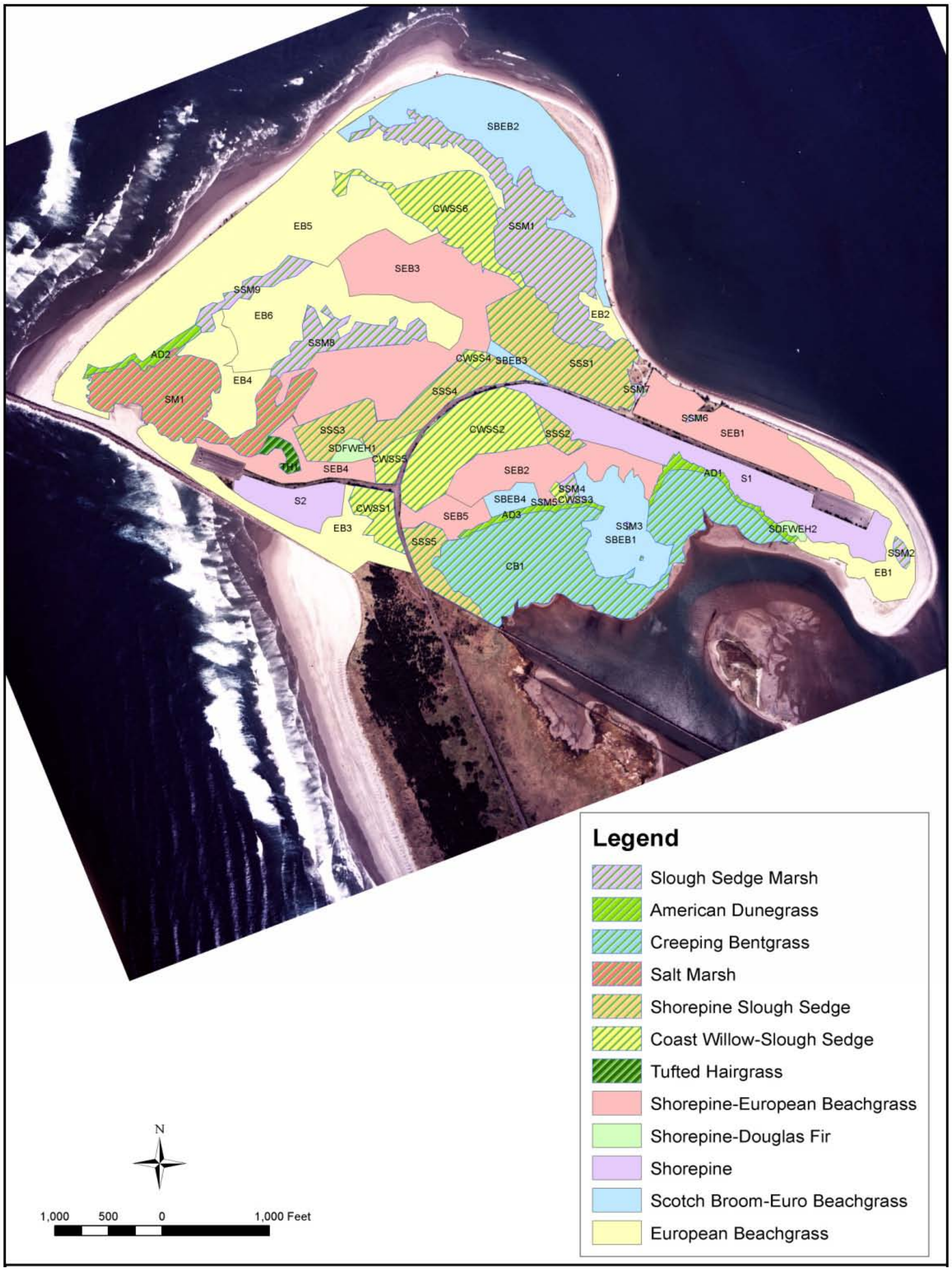
Function	Wetland		
	2a	2b	3
Water Quality Functions	12	20	12
Hydrologic Functions	5	10	12
Habitat Functions	13	13	15
Total Score	30	43	39

Note: Rating by Washington State Wetland Rating System.

Wetlands near the South Jetty (on Clatsop Spit)

Though official delineations have not yet been completed near the South Jetty, habitat surveys (Tetra Tech, 2007b) suggest that of the 600-acres of Clatsop Spit surveyed, there are likely 193-acres of wetlands. The topography of the area is complex with dunes and intertidal swales forming a mosaic of various vegetation communities, including: shorepine-slough sedge, slough sedge marsh, American dune grass, creeping bent grass, salt marsh, coast willow-slough sedge, tufted hair grass, shorepine-European beach grass, shorepine-Douglas fir, shorepine, Scotch broom-European beach grass, and European beach grass (Figure 40). At least three of these communities (shorepine-slough sedge, shorepine-Douglas fir, and coast willow-slough sedge) have been ranked globally and by the state for their rarity and vulnerability to extinction.

Figure 40. Clatsop Spit Vegetative Communities (Tetra Tech 2007b)



It is anticipated that the proposed actions will avoid most impacts to wetlands and waters of the United States in this area to the maximum degree feasible. The marsh wetlands at the South Jetty are also mostly isolated and separated from active direct ocean access by an existing dune that precludes regular connectivity, therefore regular anadromous fish use is not expected. However, fish monitoring surveys from the 2007 repairs did observe some stranding of threespine stickleback (*Gasterosteus aculeatus*), which was reported to NMFS. As mentioned, at the South Jetty fish salvage and exclusion have been proposed to avoid stranding listed species.

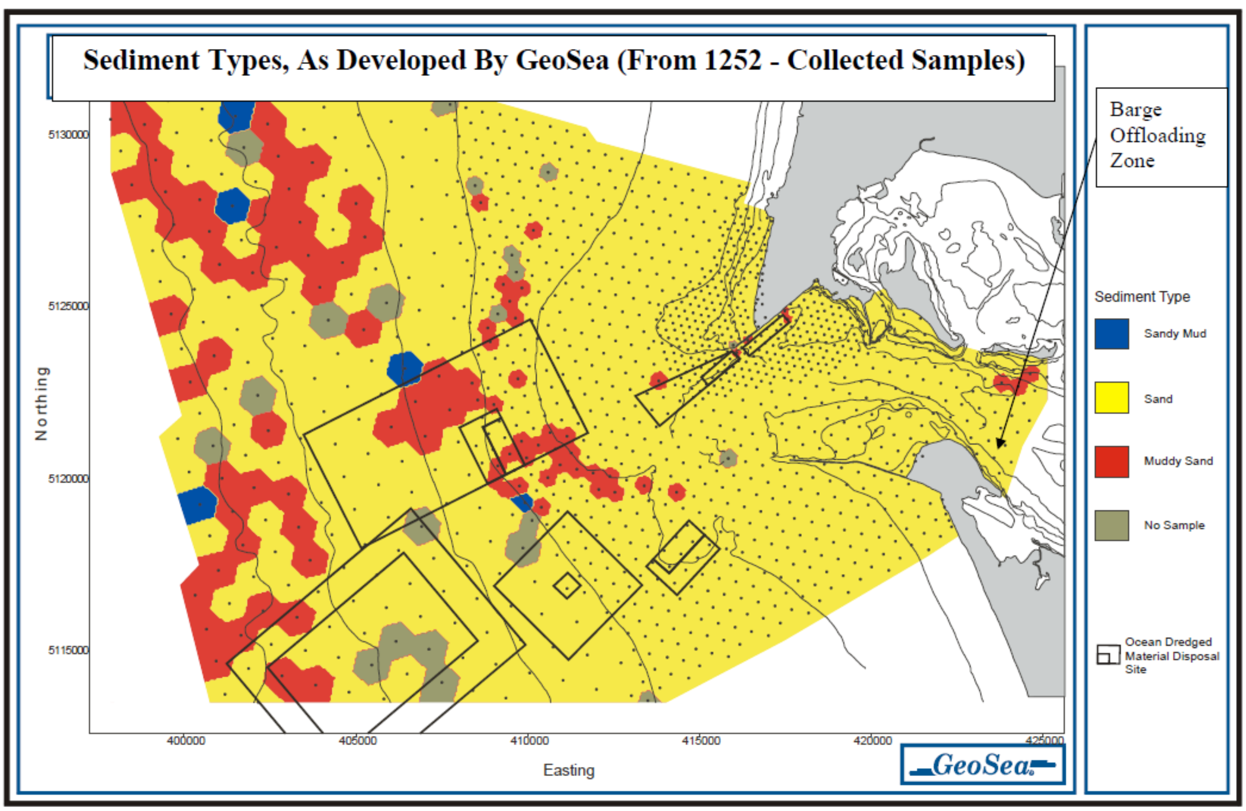
Wetlands near Jetty A

Land around the base of Jetty A received a cursory inspection on January 22, 2007 and on September 13, 2010. It is possible that sparse, perched wetlands composed of sedge and grassy fringe estuarine wetlands were present; no official wetland delineation was completed.

Sediment Quality

In 2000 a Sediment Trend Analysis (STA) was conducted by GeoSea Consulting, under contract to the Corps. Over twelve hundred (1,252) samples were collected in the MCR and surrounding off-shore locations (Figure 41). Physical analyses, of the samples surrounding the study area (6 samples selected), indicate the project area consists of >99 % sand. Select samples (10) from the GeoSea study in the MCR project were analyzed for physical and chemical contamination. These samples indicated no contaminates were detected at or near the DMEF screening levels. See http://www.nwp.usace.army.mil/ec/h/hr/Reports/Mcr/mouth00.pdf for the complete report on chemical results (Corps 2008).

Figure 41. Sediment Trend Analysis in MCR Area



In 2005 a Tier I evaluation was conducted near the proposed the South Jetty barge offloading site following procedures set forth in the Inland Testing Manual (ITM) and the Upland Testing Manual (UTM). The methodologies used were those adopted for use in the Dredge Material Evaluation Framework (DMEF) for the Lower Columbia River Management Area, November 1998, and its updated draft 2005 version, the Sediment Evaluation Framework (SEF). This Tier I evaluation of the proposed dredge material indicated that the material was acceptable for both unconfined in-water and upland placement. No significant, adverse ecological impacts in terms of sediment toxicity were expected from disposal (Corps 2005a).

In 2008 using USEPA's OSV Bold, ten Van Veen surface grab samples were collected from sites previously sampled during the September 2000 sediment evaluation study. Percent sand averaged 98.45% with a range of 99.3% to 97.0%. Percent silt and clay averaged 1.59% ranging from 3.0% to 0.7%. Per the Project Review Group approved SAP, no chemical analyses were conducted. Physical results for the 2000 and 2008 sampling events were compared. The mean percent sand for all samples in September 2000 was 98.11% for June 2008 it was 98.45%. Within both data sets, sediment towards the outer portion of the mouth is finer than sediments towards the center of the mouth (Corps 2008).

Other Activities and Conditions

Commercial and recreational fishing activities also have some influence on listed species and their prey items in the action area. The major fisheries are for bottom fish, salmon, crab, and other species of shellfish. Crab fishing occurs from December to September with the majority of the catch occurring early in the season. Most crab fishing occurs north of the Columbia River mouth at depths ranging from 25 to 250 feet mean sea level (MSL). Dungeness crab population numbers are subject to large cyclic fluctuations in abundance. Catch records for fishery are generally believed to represent actual population fluctuations. Modeling studies by Higgins and others (1997) show that small scale environmental changes, such as a short delay in the onshore currents in spring, can dramatically impact survival of young-of-the-year crab but have no effect on adults and older juveniles inshore. Bottom fishing by trawl for flatfish, rockfish, and pink shrimp occurs year-round throughout the entire offshore area, primarily at depths offshore from the jetties. Many of these species interact with listed species in a predator-prey relationship that, in some cases, can change over the course of each species' life history. Fisheries could have some effect on prey availability and species numbers in the action area.

EFFECTS OF THE ACTION

Effects of the action refers to the direct and indirect effects of an action on the species or critical habitat, together with the effects of other activities that are interrelated or interdependent with that action, that will be added to the environmental baseline (50 CFR 402.02). Indirect effects are those that are caused by the proposed action and are later in time, but still are reasonably certain to occur. Interrelated actions are those that are part of a larger action and depend on the larger action for their justification. Interdependent actions are those that have no independent utility apart from the action under consideration. The Corps has determined that the effects of the proposed action could occur from:

- Rock Transport
- Construction Access, Staging, Storage, And Rock Stockpiling
- Rock Placement
- Dredging
- Disposal
- Barge Offloading Facilities
- Pile Installation and Removal
- Lagoon And Wetland Fill And Culvert Replacement
- Dune Augmentation
- Water Quality
    - Suspended sediment
        - Dredging
        - Disposal
        - Pile Installation and Removal
    - Spills Leaks
    - Contamination
- Hydraulic and Hydrological Processes
    - Water Velocity
    - Salinity and Plume Dynamics
    - Bed Morphology
- Wetland Mitigation and Habitat Improvements

Rock Transport

As discussed, barge transport of stone from quarry sites is likely and would occur mostly during daylight hours along major navigation routes in existing harbors and navigation channels. The number of additional barge trips per year attributable to the proposed action is expected to be somewhere between 8 and 22 ships. This is small annual percentage increase relative to the current number of other commercial and recreational vessels already using any of these potential routes. MCR is the gateway to the Columbia-Snake River system, accommodating commercial traffic with an approximate annual value of $16 billion dollars a year. Loaded water-borne container traffic identified as foreign in- and outbound to/from Portland that would likely have crossed the MCR in 2008 totaled approximately 195,489 ships (Corps 2010). Traffic from the proposed action will also be limited mostly to summer months when fair weather allows safe passage. Though transport will occur on an annual basis, stone may or may not be delivered to one or more jetties seasonally. Due to the infrequency of these vessel trips, their geographic limitation to existing navigation channels, and their minimal duration in any particular area, the disturbance effects are expected to be discountable. The proposed action will not cause any meaningful increase (less than 1%) in annual vessel traffic along the routes or around the MCR jetty system.

Construction Access, Staging, Storage, and Rock Stockpiling

Construction activities will occur on an annual basis, could happen through-out the year, and may occur at one or more jetties simultaneously. Upland effects could include: repetitive disturbance; de-vegetation; residual rock side-cast; and soil compaction. Changes in soil structure and composition could also result in localized habitat conversion of the vegetative and biological communities. Invasive species are located in the vicinity of all three jetties, and chronic disturbance can increase the spread and establishment of such species. Changes in the plant communities can also cause trophic effects on the faunal communities that rely on these ecosystems for forage and habitat. However, the Corps expects effects to listed species from associated construction activities for staging, roadways, and stockpiles to be localized at all jetties, as the majority of these construction features are located in upland areas above mean high tide elevation. Species exposure is therefore highly unlikely. Avoidance and minimization measures have reduced the construction footprint where possible, and higher value habits like marsh wetlands and slough sedge communities have been preserved such that activities are limited to areas where previous disturbance and development have already occurred. Wetland fill effects from these activities are discussed in the wetland fill section. Whenever feasible, stabilizing dune vegetation is being preserved and little if any riparian or vegetative cover will be removed or disturbed. Furthermore, protective fencing, set-backs, and an Erosion and Sediment Control Plan or Stormwater Protection Plan will be implemented so that best management practices (BMPs) avoid stormwater erosion and run-off from disturbed areas. The topography in this area is flat, and proposed impact minimization measures for construction will reduce the likelihood for sediment to enter the Columbia River. When construction activities are suspended for the season, appropriate demobilization and site stabilization plans will limit the distribution and duration of any effects. No pollutants are expected to enter waterways. There may be some disturbance from equipment sounds and human presence, but these will be indirect and of low intensity, mostly during daylight hours and summer months. Therefore, disturbance effects from these activities are expected to be minimal and discountable.

Rock Placement

Rock placement will occur on an annual basis starting in the late spring through the late to early fall seasons. Placement may occur at more than one jetty per season and will occur regularly throughout the duration of the construction schedule. Some permanent habitat conversion and modification will occur as a result of stone placement for repair and rehabilitation of jetty features. Along specific portions of North and South jetties and along the entire length of Jetty A, substrate will be converted to rocky sub and intertidal habitat, and associated benthic communities will be covered. In addition, crane set-up pads and turnouts will require placement of rock that could extend slightly off the current centerline of the jetty trunk. However, this total area is a relatively small percentage of the existing jetty structures, and conversion is mostly limited to the spur groin locations. Generally, effects to in-water habitat could include the following sub-tidal and intertidal habitat conversion from sandy to rocky substrate and potential unforeseen indirect far-field effects from hydraulic influence (slight, localized changes to accretion, currents, velocities, etc). However, relatively little habitat conversion and footprint expansion will occur because a majority of the stone placement for construction of the jetty head, trunk, and root features will occur on existing relic jetty stone and within the existing structural prism. Moreover, species will experience limited exposure, since stone placement for cross-section repair and rehabilitation actions occurs mostly above the MHHW elevation. This is summarized below.

North Jetty

- About 58% of the overall stone placement on these portions of the jetty will be placed above mean higher high water (MHHW); about 25% of the volume will be placed between MHHW and MLLW; and about 18% of the volume placed will be below MLLW. Therefore, approximately 83% of the volume placed for trunk and root cross section repairs is above MLLW. There is no expected expansion of the footprint beyond the relic jetty stone or structure.
- A small percentage (about 0.1%) of the overall stone placement for spur groins will be above MHHW; about 4% will be placed between MHHW and MLLW; and about 95.9% will be placed below MLLW. Therefore, approximately 96% of the spur groin construction will be below MLLW, and this will cause 1.55 acres of habitat conversion from sandy to rocky substrate. Bottom topography and shallow water habitat will be altered in a limited geographical area, and benthic organisms will be covered. This is a small percentage relative to the existing acreage of the jetty structure and the available adjacent remaining shallow-water sand habitat in the vicinity of the action area. These structures are also relatively short, remaining close to the jetty trunk and root. Channel-side groins are submerged a minimum of 5 to 35 ft below MLLW.
- About 49% of the overall stone placement on the capping portions of the jetty will be placed above MHHW; about 24% of the volume will be placed between MHHW and MLLW; and about 27% of the volume placed will be below MLLW. Therefore, approximately 73% of the volume placed for head capping will remain above MLLW. This feature is not expected to expand beyond the footprint of the relic jetty stone.
- Stone placement for barge offloading facilities (additional effects discussed further elsewhere), turn-outs, and set-up pad facilities will cover and convert about 0.63 acres and will be confined within the same location as the stone placed for repairs. This is a small percentage relative to the existing acreage of the jetty structure and the available adjacent remaining shallow-water sand habitat in the vicinity of the action.

South Jetty

- About 68% of the overall stone placement on these portions of the jetty will be placed above mean higher high water (MHHW); about 19% of the volume will be placed between MHHW and MLLW; and about 13% of the volume placed will be below MLLW. Therefore, approximately 87% of the volume placed for trunk and root cross section repairs is above MLLW. There is no expected expansion of the footprint beyond the relic jetty stone or structure.

- A small percentage (about 0.1%) of the overall stone placement for spur groins will be above MHHW; about 12.3% will be placed between MHHW and MLLW; and about 87.6% will be placed below MLLW. Therefore, approximately 88% of the spur groin construction will be below MLLW, and this will cause 1.10 acres of habitat conversion from sandy to rocky substrate. This is a small percentage relative to the existing acreage of the jetty structure and the available adjacent remaining shallow-water sand habitat in the vicinity of the action area. These structures are also relatively short, remaining close to the jetty trunk and root.
- About 52% of the overall stone placement on the capping portions of the jetty will be placed above MHHW; about 25% of the volume will be placed between MHHW and MLLW; and about 23% of the volume placed will be below MLLW. Therefore, approximately 77% of the volume placed for head capping will remain above MLLW. This feature is not expected to expand beyond the footprint of the relic jetty stone or structure.
- Stone placement for barge offloading facilities, causeways, turn-out, and set-up pad facilities will cover and convert about 1.96 acres. This is a small percentage relative to the existing acreage of the jetty structure and the available adjacent remaining shallow-water sand habitat in the vicinity of the action.

Jetty A

- About 63% of the overall stone placement on these portions of the jetty will be placed above mean higher high water (MHHW); about 29% of the volume will be placed between MHHW and MLLW; and about 8% of the volume placed will be below MLLW. Therefore, approximately 92% of the volume placed for trunk and root cross section rehabilitation will remain above MLLW. There may be some expansion of the footprint beyond the relic jetty stone or structure. This is not expected to extend beyond 10-ft off the existing prism, which is a possible conversion of 1.2 acres from sandy to rocky substrate. This is a small percentage relative to the existing acreage of the jetty structure and the available adjacent remaining shallow-water sand habitat in the vicinity of the action.
- 100% of the spur groin construction will be below MLLW, and this will cause 0.61 acres of habitat conversion from sandy to rocky substrate. This is a small percentage relative to the existing acreage of the jetty structure and the available adjacent remaining shallow-water sand habitat in the vicinity of the action area. These structures are also relatively short, remaining close to the jetty trunk and root. Both groins are submerged a minimum of 5 below MLLW.
- About 44% of the overall stone placement on the capping portions of the jetty will be placed above MHHW; about 26% of the volume will be placed between MHHW and MLLW; and about 30% of the volume placed will be below MLLW. Therefore, approximately 70% of the volume placed for head capping will remain above MLLW.

This feature is not expected to expand beyond the footprint of the relic jetty stone or structure.
- Stone placement for barge offloading facilities, causeways, turn-out, and set-up pad facilities will cover and convert about 2.89 acres. This is a small percentage relative to the existing acreage of the jetty structure and the available adjacent remaining shallow-water sand habitat in the vicinity of the action.

Indirect disturbance effects due to placement activities will be localized and occur mostly during daylight hours in the summer months. Disturbance effects are expected to be of limited duration and minimal, since a majority of the placement is above MHHW and on existing relic stone. The Corps does not expect long-term negative effects from these actions.

Dredging

As previously described, dredging will for construction and maintenance of barge offloading facilities and is likely during early summer prior to rock delivery, but may not occur at all facilities annually. If all facilities were dredged, this would total about 16 acres near the jetties. However, it is likely only one or two facilities would be used seasonally for short durations and would be dredged on a periodic basis as needed.

The effects of dredging on physical habitat features include modification of bottom topography, which in the vicinity of the jetties is by nature extremely dynamic. Dredging may convert intertidal habitats to subtidal, or shallow subtidal habitats to deeper subtidal. Such conversions may affect plant and animal assemblages uniquely adapted to the particular site conditions these habitats offer. However, the dredged prisms are very small as a relative percentage of the ~19,575 acres of shallow-water habitat available within a 3-mile proximity to the MCR. The proposed dredging of the offloading facilities will affect bottom topography, but is unlikely to cause large-scale or long-term effects to habitat features. Dredging activities will also have some contribution to increased acoustic disturbance that could occur for a limited duration while dredging is underway. These effects are expected to attenuate rapidly such that they return to background levels within a short distance from the source.

The effects on water quality and suspended sediment are discussed further under the Water Quality section.

Disposal

Disposal is likely to occur on an annual basis originating from one or more of the offloading facilities. The duration of disposal will be limited and will likely occur earlier in the construction season prior to use of offloading facilities. As mentioned previously, all disposal of dredged material will be placed at previously evaluated and EPA-approved in-water ODMDS or Clean Water Act disposal sites. No new or different impacts to species or habitats than those previously evaluated by EPA for disposal approval are expected from these actions. Per EPA guidelines, all ocean dumping sites are required to have a site management and monitoring plan (SMMP) which is aimed at assuring that disposal activities will not unreasonably degrade or endanger the marine environment. This involves regulating the times, the quantity, and the physical/chemical characteristics of dredged material that is dumped at the site, establishing disposal controls, and monitoring the site environs to verify that unanticipated or significant adverse effects are not occurring from past or continued use of the disposal site and that permit terms are met. The relative quantities, characteristics, and effects of the proposed action area not expected to have different or significant negative impacts to these sites.

The effects of disposal on physical habitat features include modification of bottom topography. In some cases, disposal may result in the mounding of sediments on the bed of the disposal site. Such conversions may affect plant and animal assemblages uniquely adapted to the particular site conditions these habitats offer. However, the area impacted by disposal is relatively small and will likely occur in deeper habitat offshore, in the littoral cell or near the North Jetty vicinity. The proposed disposal is unlikely to cause large-scale or long-term effects to habitat features. The effects on suspended sediment are discussed further under the Water Quality section.

Barge Offloading Facilities

Installation of offloading facilities is likely to occur once, likely in the late spring or early summer prior to or during the first season of construction on the associated jetty. Subsequently, periodic maintenance may be required as facilities weather wave and current conditions at the MCR. Facilities may also occasionally be partially removed and reconstructed, which could slightly increase the frequency of disturbance. Depending on the specific facility and contemporary conditions at the time, removal would then occur at the end of the scheduled construction duration. Temporally, this limits the repetition of disturbance activities associated with the construction of these facilities. Use of the facilities may be annual with periodic breaks in between, depending on the construction schedule and conditions at the jetties. Annual use is likely at least one of the facilities and will be seasonally concentrated in the spring, summer, and fall. Though unlikely, occasional breaks in weather could allow offloading at other times of the year.

Stone placement for barge offloading facilities could have the same minimal effects and were described previously under rock placement. However, - with the exception of the facility at Parking Lot D on the Clatsop Spit - construction and maintenance of the facility and associated and piles would be equivalent to actions already occurring from jetty repair and stone placement, and would not cause a separate or cumulative increase in disturbance. Also as mentioned previously, chemically treated wood will not be used for decking material, as treated decking could leach toxic substances into the water. Therefore water quality is not expected to be negatively impacted by these facilities. Possible effects of the action to water quality are discussed under Water Quality. Offloading facilities will be areas of slightly increased activity and vessel traffic, but the intensity of use is expected to be low and seasonal in nature. Additional noise from vessel activities may increase disturbance, but acoustic effects are not expected to reach harmful levels and will be geographically and temporally limited. A return to background noise levels is likely near the source.

The effects from dredging and pile installation and removal for these facilities are discussed under their respective sections.

Pile Installation and Removal

Pile Installation and subsequent removal is likely to occur once, likely in the late spring or early summer prior to or during the first season of construction on the associated jetty. Subsequently, periodic maintenance may be required as piles weather barge use and wave and current conditions at the MCR. Pile may also occasionally be partially removed and installed, which could slightly increase the frequency of disturbance. Depending on the specific associated offloading facility and contemporary conditions at the time, removal would then occur at the end of the scheduled construction duration. Temporally, this limits the repetition of disturbance activities associated with the installation and removal of these structures.

As mentioned previously, for initial construction of all four facilities combined, up to approximately up to 96 Z- or H-piles could be installed as dolphins, and up to approximately 373 sections of Z or H piles installed to retain rock fill. However, it is unlikely that all facilities would be installed at the same time. Installation is likely to happen early in the construction season sometime between April and June, and is weather dependent. Piles will be located within 200-ft of the jetty and offloading structures. Vibratory drivers will be used and will dampen any acoustic effects to fish and other species. Because of the soft substrates in the lower Columbia River, vibratory drivers can be used effectively to install and remove piles. Sound wave form and intensity is not expected to reach harmful levels and are expected to return to background levels within a short distance from the source. Any acoustic impacts would be short duration and intermittent in frequency. Therefore, this action is not expected to have any significant direct effects.

The presence of piles at the offloading facilities could increase perching opportunities for piscivorous birds, especially cormorants and brown pelicans. However, piling caps will avoid any significant increase in new perch sites so that the effects are expected to be minimal and discountable. Furthermore, perching opportunities for these birds are abundant in the lower Columbia River and are not expected to increase cormorant and pelican use of this area.

Wetland and Lagoon Fill and Culvert Replacement

Wetland fills and culvert installations at all jetties will occur once, and could happen during anytime in the construction season depending on weather. Sequentially, these actions will be required prior to several of the other proposed action. Subsequent removal of construction related culverts is likely to occur once, and could also happen during anytime in the construction season depending on weather and construction need. Periodic culvert maintenance may be required during construction. Temporally, this limits the repetition of disturbance activities to single event and season on separate jetties.

Where possible, the Corps has planned the construction, access, and staging areas at all jetties so that the footprint minimizes impacts to wetlands and higher value habitat features. Protections will be implemented for the identified rare and ranked vegetative communities within this area. Strategic use of uplands and lower quality wetlands for rock storage will be done to the most practical extent in order to avoid and minimize these impacts. However, permanent and temporary wetland fill will occur as a result of construction staging, storage, and rock stockpiles at all three jetties. Fill to protect the North Jetty root will also affect wetlands. Long-term direct and indirect impacts to wetlands could include: permanent wetland fill; potential fragmentation of and between existing wetlands; soil compaction; loss of vegetation; altered hydrology; conversion to upland; and loss of ecosystem functions (water quality, flood storage, nitrogen cycling, habitat, etc.). However, the Corps further expects effects from wetland impacts and lagoon fill to be insignificant on river functions, as the wetlands are not within the channel prism of the Columbia River. Although these wetlands are connected hydrologically to the Columbia River, wetland fill impacts are not likely to negatively alter groundwater-stream exchange or hyporheic flow because wetlands are on accreted land that has formed on stabilized sand shoals behind the jetties. Wetland hydrology is mostly elevation and rainfall dependent, and fill impacts will be relatively insignificant to the Columbia channel. Culverts will be installed to maintain wetland hydrology and connectivity with permanent replacement at the North Jetty and when temporary construction roadways cross wetlands. See the Wetland Mitigation and Habitat Improvements sections for further information about actions that will offset any habitat and functional losses from wetland fill.

Dune Augmentation

Dune augmentation will occur once during a single season, and could happen likely in the late spring or early summer depending on weather. Sequentially, this actions will be required prior to several of the other proposed action. Periodic maintenance may be required, likely on a decadal scale. This is only proposed at the South Jetty. Therefore, temporally and geographically this limits the repetition of disturbance activities to single event and season on a single jetty.

Dune augmentation at the South Jetty will occur above mean high tide; therefore, actions will cause limited exposure to aquatic species. Though substrate modification will occur along the shoreline, the Corps does not expect any measurable changes from in-water habitat conversion below MHHW. This action is likely to be completed in a single season, and cobble replenishment would likely be on a decadal scale. Clean cobble material will be placed from an existing roadway, and delivery via beach access will be prohibited. Some equipment will be required to move materials around on the dry sand. There is little likelihood of having any direct or indirect negative impacts to water quality or intertidal species, and the amount of dry sand conversion is relatively small compared to the amount of similar adjacent habitat that is available. The effects of this conversion are discountable and species exposure is unlikely.

Water Quality

Effects of the proposed action to water quality could occur by: increasing suspended sediments; increasing the potential occurrence of spills and leaks, and; increasing the potential for contamination. However, the Corps does not expect these effects to be significant.

Placement of rock by heavy equipment, jetty access road construction, dredging, disposal, and pile installation and removal could all cause temporary and local increases in suspended sediment. This is expected to have minimal and limited effects on the environment. Previous tests have confirmed that material to be dredged will be primarily sand with little or no fines, which does not stay suspended in the water column for a significant length of time. During infrequent and limited duration dredging and disposal, suspended sediments may increase locally for a short time. However, light attenuation and water quality effects from increased suspended sediments are expected to be minimal and fleeting. Pile driving is also expected to occur in sand and therefore have similar transient and minimal effects to water quality. Jetty roads could also contribute suspended sediments that would create turbidity, but since they are above MHHW this will likely be an infrequent occurrence. Increases in turbidity from construction activities on the jetties will likely occur on a nearly daily basis but will be of limited extent and duration, as rock placement will involve clean fill. Wave and current conditions in the action area naturally contribute to higher background turbidity levels; and such conditions also preclude the effective use of isolating measures to minimize turbidity. However, other BMPs described in the proposed action will further reduce effects of turbidity from the proposed action. Effects from potential stormwater runoff were addressed in the Construction Staging and Stockpile section. Therefore, impact from suspended sediments should be insignificant.

The Corps will require the contractor to provide a spill prevention and management plan that will include measures to avoid and minimize the potential for spills and leaks and to respond quickly to minimize damages should spills occur. Good construction practices, proper equipment maintenance, appropriate staging set-backs, and use of a Wiggins fueling system would further reduce the likelihood of leak and spill potential and exposure extent and its associated effects.

Test results on dredge material described earlier further indicated that materials in the area are approved for unconfined in-water disposal and do not contain contaminants in concentrations harmful to organisms occupying the action area. The prohibition of treated wood will also avoid contamination from the migration of creosote and its components [e.g., copper and polynuclear aromatic hydrocarbons (PAHs)] from treated wood in the lotic environments.

Temporally, effects to water quality from suspended sediment and turbidity could occur on a daily basis, but are not expected to be continuous throughout the day. Turbidity levels and durations will be limited to conditions required in the State Water Quality Certifications which include exceedence windows that are protective of beneficial uses like salmonids and other aquatic life. Contamination, spill, or leaks are expected to be infrequent and unlikely. Though, temporally the repetition of disturbance could be greater, this is still expected to remain within safe ranges that do not have long-term or significant effects. Furthermore, effects are expected to be geographically limited, short term and minor.

Hydraulic and Hydrological Processes

As mentioned previously, over the years of project development, USGS and ERDC have conducted numerical modeling to evaluate changes in circulation and velocity, salinity, and sediment transport at the MCR for various rehabilitation design scenarios of the MCR jetty system. The purpose of the 2007 USGS evaluation was to assess the functional performance of the extended jetty system and to aid in the assessment of potential impacts to fish from the rebuilt lengths and spur groins. Except for the spur groins, modeling components including rebuilding jetty lengths is not proposed in this action. However, results under the larger build-out scenario are still relevant for comparing and evaluating previously estimated potential changes to the MCR system as a whole. Previous modeling work also remains somewhat valid for consideration because the current proposed action caps the jetties at their present location, which is essentially the same length as the original base conditions used for the previous models.

In 2007, modeling by USGS was done for two time periods, August-September and October-November. The model period of August-September was in existence from the 2005 Mega-Transect experiment (see below). The October-November run was established for engineering purposes as this time period represents extreme conditions at the MCR. A series of plots was produced to show existing and post-rehabilitation conditions for the following parameters: residual (average for all tides) velocity and current direction for bed and near surface, residual bed load transport, residual total load transport (bed load + suspended load), and mean salinity for bed and near surface. Rehabilitation components for USGS modeling included restoring the lengths of the North Jetty and Jetty A, and installing spur groins (Moritz and Moritz 2010; USGS 2007).

Existing conditions were established using August-September 2005 data collected from the Mega-Transect, a data collection system at the MCR. The Mega-Transect experiment was a 6-week field data collection effort to observe currents, suspended sediment, and salinity-temperature across the MCR. Data was collected concurrently at five fixed locations spanning 2 miles across the MCR during August-September of 2005. Instrumented tripods were placed at these five critical hydraulic-morphologic locations. Acquisition of prototype data describing the three-dimensional circulation within the MCR was intended to improve the hydrodynamic understanding and improve the ability to manage the sediment resources within the inlet/estuary (Moritz et al., undated).

The ERDC analyzed the impacts of the presence of spur groins at the MCR. This analysis was done independently of the modeling conducted by USGS and was conducted with the coastal modeling system (CMS) and other models that operate within the surface water modeling system (SMS). A regional circulation model (ADCIRC) provided the tidal and wind forcing for the boundaries of project-and local-scale wave, current, sediment transport, and morphology change calculated by the CMS. The half-plane version of the wave transformation model, STWAVE, was coupled with two-dimensional and three-dimensional versions of the CMS, which calculates current, sediment transport, and morphology change. These models were coupled to provide wave forcing and update calculated bathymetry used in both models at regular intervals (Connell and Rosati 2007).

Water Circulation and Velocity

The Columbia River estuary has a greater range between high and low tides and receives a larger river discharge than most other estuaries in the U.S. resulting in rapid and turbulent currents. The primary factors controlling circulation in the Columbia River estuary are river flow, tides, and currents resulting from the pressure gradient force. The variability in the above mentioned parameters result in large variability in velocity (see charts presented in Fox et al. 1984). Quinn (2005) notes that there is great spatial variation in estuaries and that and that physiochemical attributes of the water such as depth, salinity, temperature, turbidity, and velocity vary over complex temporal scales including seasonal, lunar, and tidal periods. The USGS modeling results, for example, showed that in near surface waters near the landward portions of the North Jetty, velocity naturally varies with tides to over 1 meter/second during August-September. Under the rebuild scenario, changes to bed and surface velocities and current directions predicted by the models were negligible, particularly with respect to fluctuations that already occur. Though spur groins remain a component, no length rebuild is proposed under the current action.

Therefore, any previously predicted effects to water circulation and velocity are even less likely under the current proposed action.

To further illustrate for the sake of comparison, previous model results quantified changes for the length rebuilds, which were negligible despite the larger scale action than what is currently proposed. When viewing the figures below, it is important to keep in mind they represent a previous action of a larger scope and scale. The representative original condition along with the spur groins is now more reflective of what the likely post-project conditions could entail.

For the August-September timeframe, an increase to residual bed layer velocity was predicted on the west side of the south portion of Jetty A to currents oriented in a south-southeast direction (Figure 42) but mean differences (existing to predicted) were less than 0.1 meter/second in this area. Smaller changes in residual velocities were predicted for near surface waters in the vicinity of Jetty A (Figure 43) (Moritz 2010, USGS 2007). These changes are small (10% or less) relative to the natural variation in this high energy environment. In these velocity charts, length of arrows indicates magnitude of velocity; red arrows indicate existing conditions and black arrows indicate predicted conditions resulting from implementation of the proposed project.

Under the length rebuild scenario, surface current direction for the August-September timeframe was predicted to change slightly toward the north as water flowed around Jetty A forming a more pronounced clockwise eddying effect west of Jetty A and tending to force water more directly toward the North Jetty. Residual velocities toward the North Jetty were predicted to decrease, however, and this effect would have protected the North Jetty. Predicted changes to current direction in the bed layer are less pronounced than in the surface layer (Figures 44 and 45). Changes to current direction and velocities are negligible in the vicinity of the South Jetty (Figure 45) (Moritz 2010, USGS 2007).

Figure 42. Residual Velocity Bed Layer for August/September Time Window

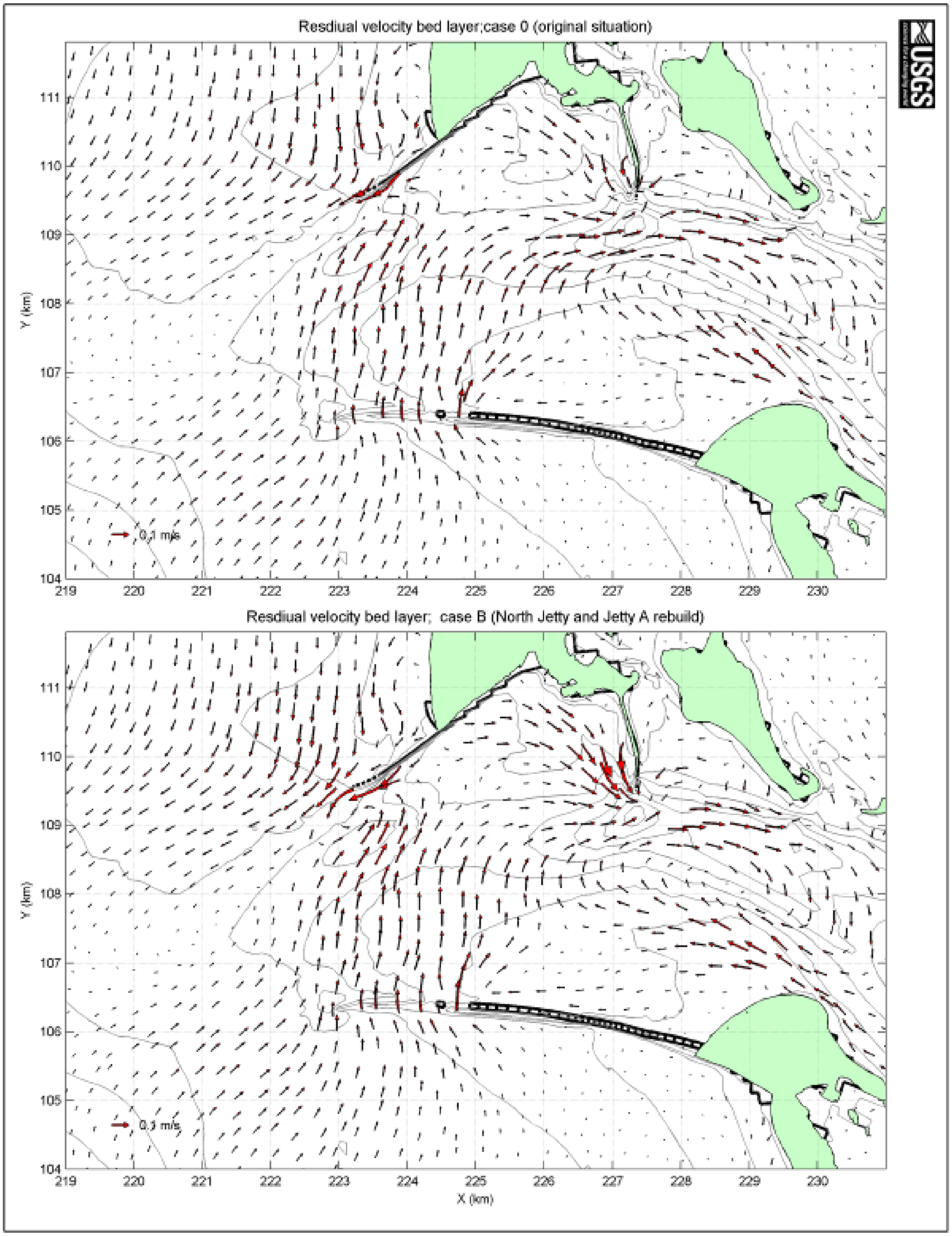


Figure 43. Residual Velocity Surface Layer for August/September Time Window

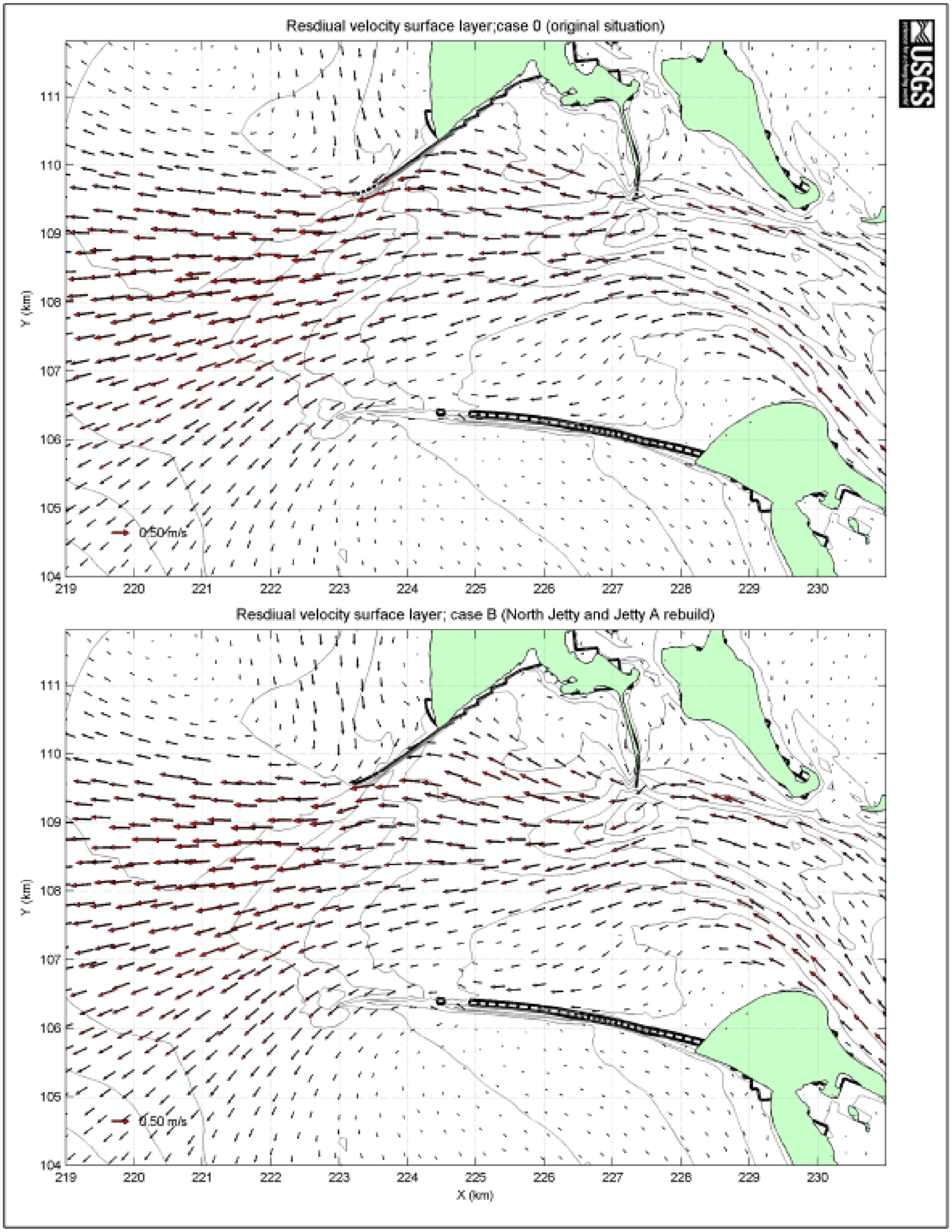


Figure 44. Residual Velocity near North Jetty and Jetty A for August/September Time Window

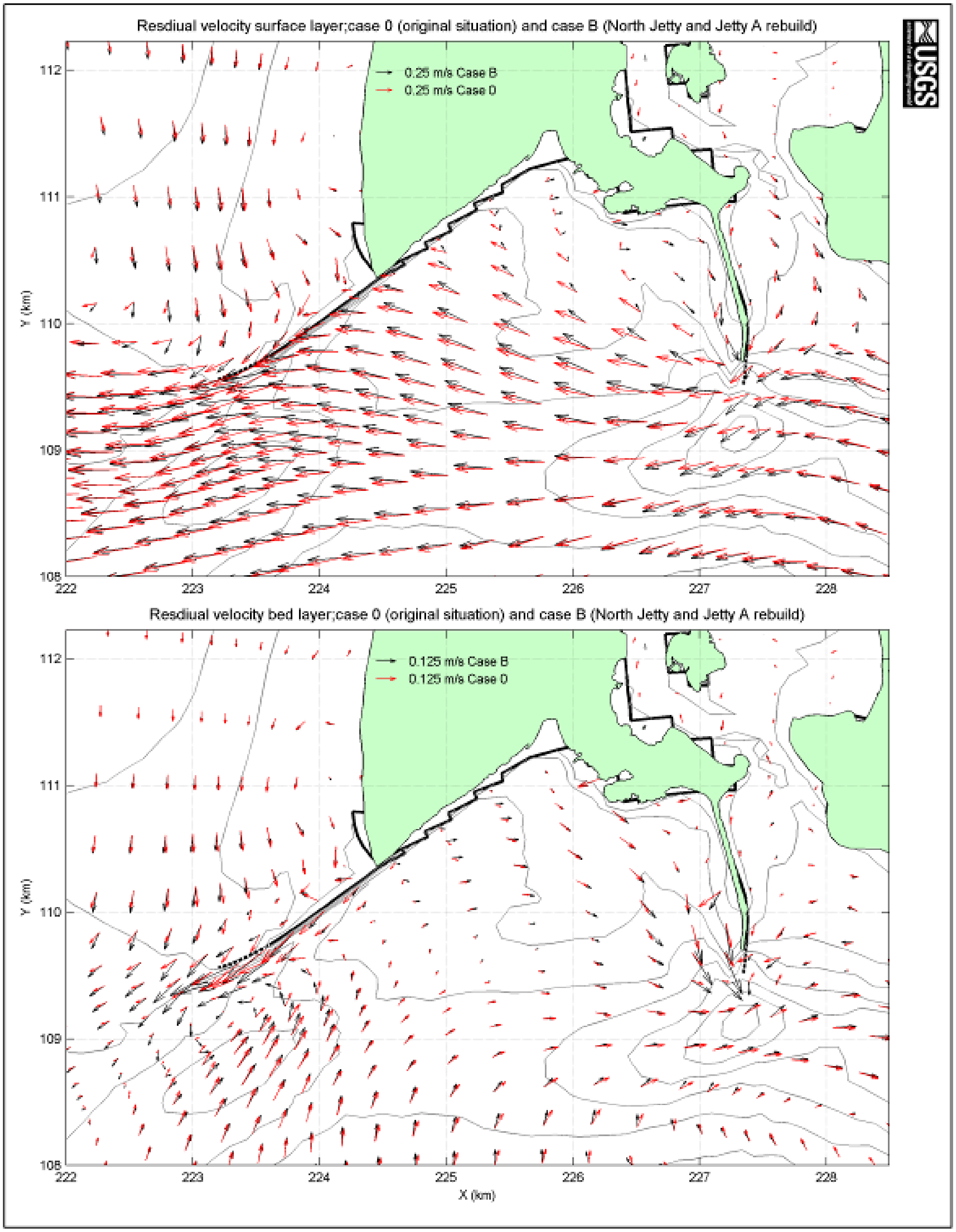
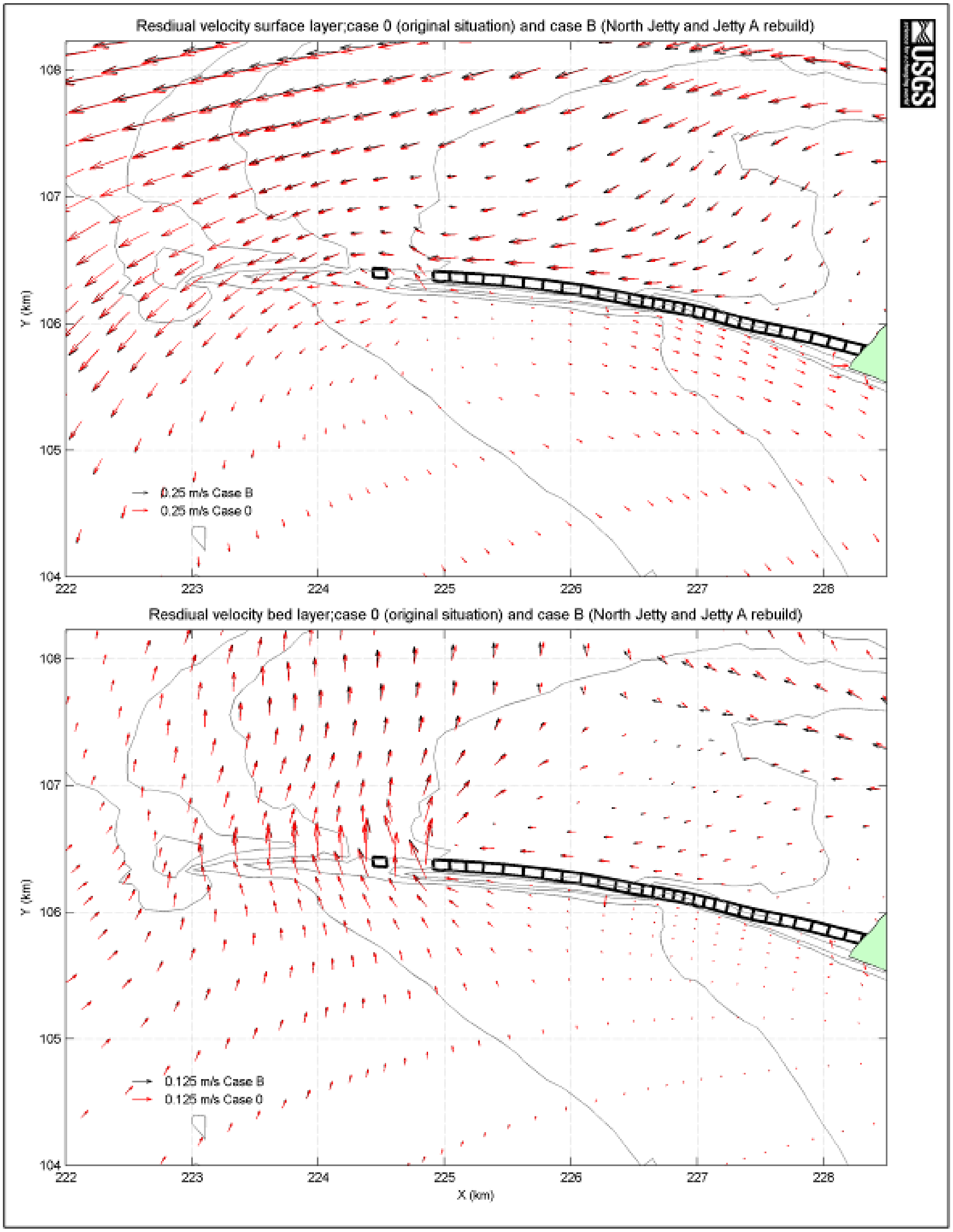


Figure 45. Residual Velocity near South Jetty for August/September Time Window



For the October-November timeframe, the situation was similar to the August-September timeframe in that a relatively large increase to residual bed layer velocity, compared to other areas in the MCR, was predicted on the west side of the south portion of Jetty A to currents oriented in a south-southeast direction (Figure 46) (Moritz 2010, USGS 2007). These changes, however, as with the August-September timeframe, were small as compared to natural variability.

For the October-November timeframe, current direction was predicted to change slightly toward the north as water flows around Jetty A forming a more pronounced clockwise eddying effect west of Jetty A and tending to force water more directly toward the North Jetty (Figure 47). Residual velocities toward the North Jetty are predicted to decrease, however, and this effect would act to protect the North Jetty, as is the case with the August-September timeframe (Moritz 2010, and USGS 2007). Such changes to velocities and currents are even less likely now since the current proposed action does not involve a length rebuild.

For the October-November timeframe, there also were predicted increases in bed layer velocity near the terminus of the North Jetty (Figure 47). Only small changes in residual velocities were predicted for near surface waters near the North Jetty terminus. Changes in surface current direction are similar to those described above for the August-September timeframe. Changes to velocities and current directions were predicted to be minimal for areas near the South Jetty (Figure 48), because these parameters at the South Jetty are essentially unaffected by alterations on the north side of the river (Moritz 2010, USGS 2007). As mentioned above, such changes are unlikely now since the current proposed action does not involve any length rebuild.

Figure 46. Residual Velocity Bed Layer for October/November Time Window

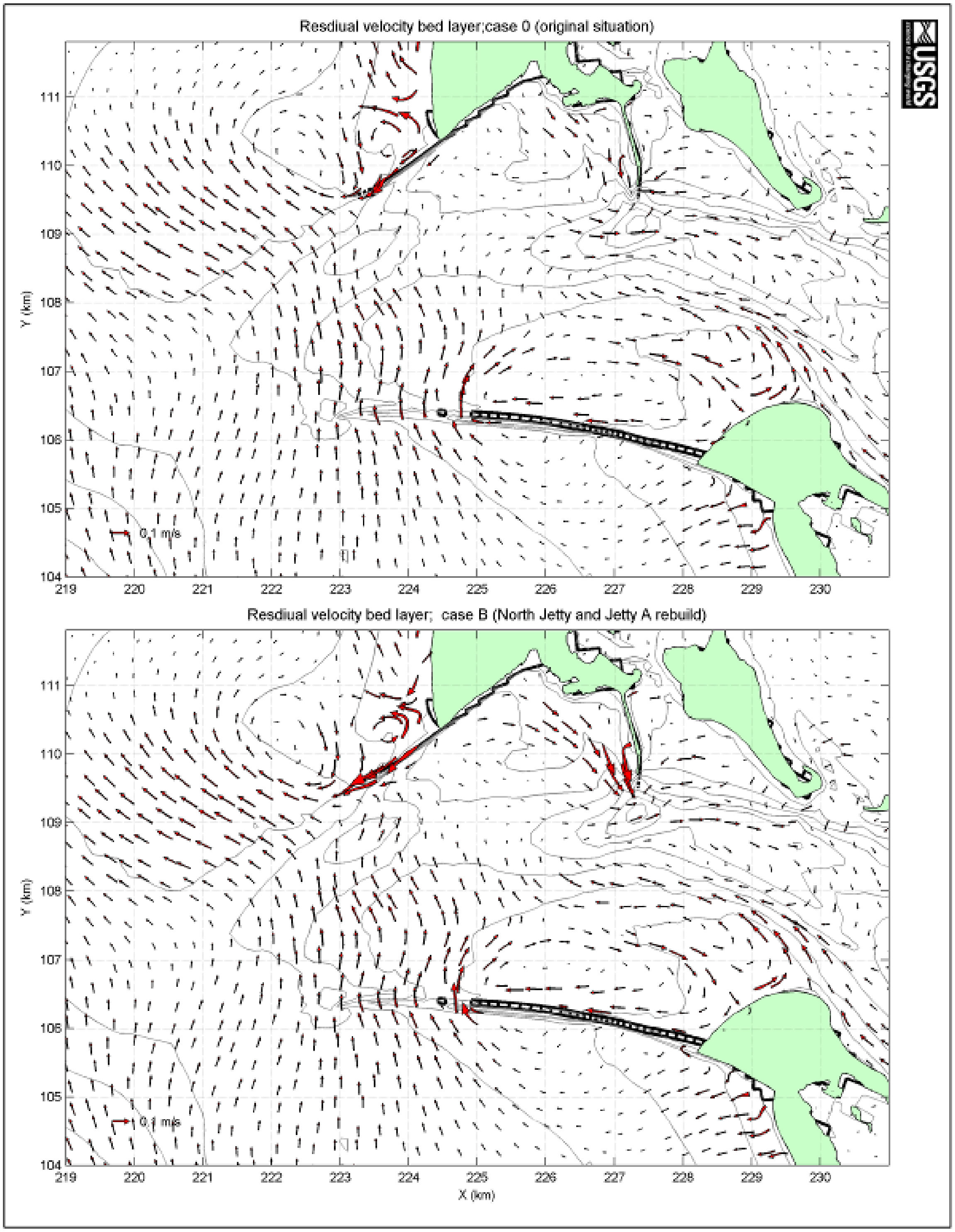


Figure 47. Residual Velocity near North Jetty and Jetty A for October/November Time Window

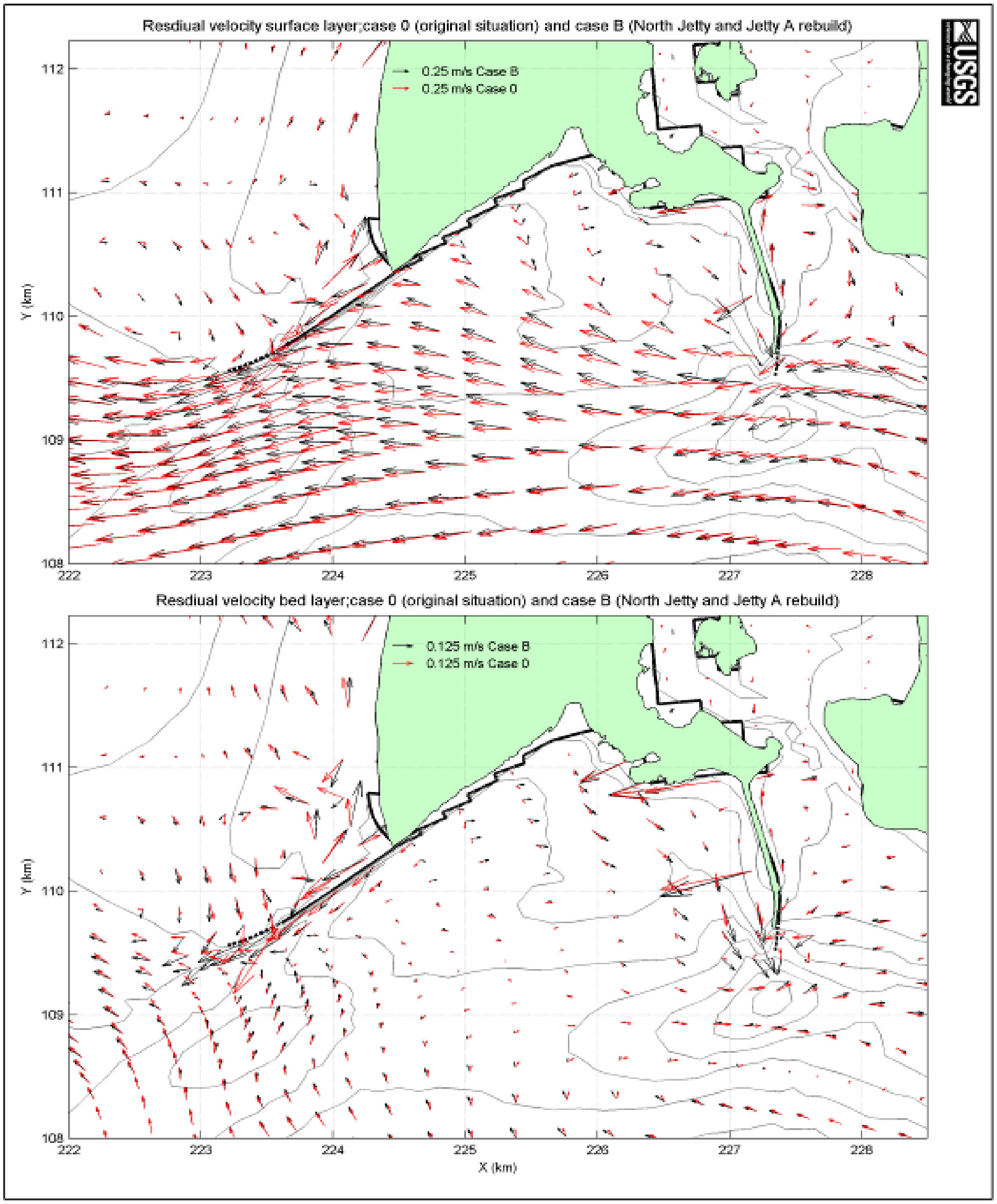
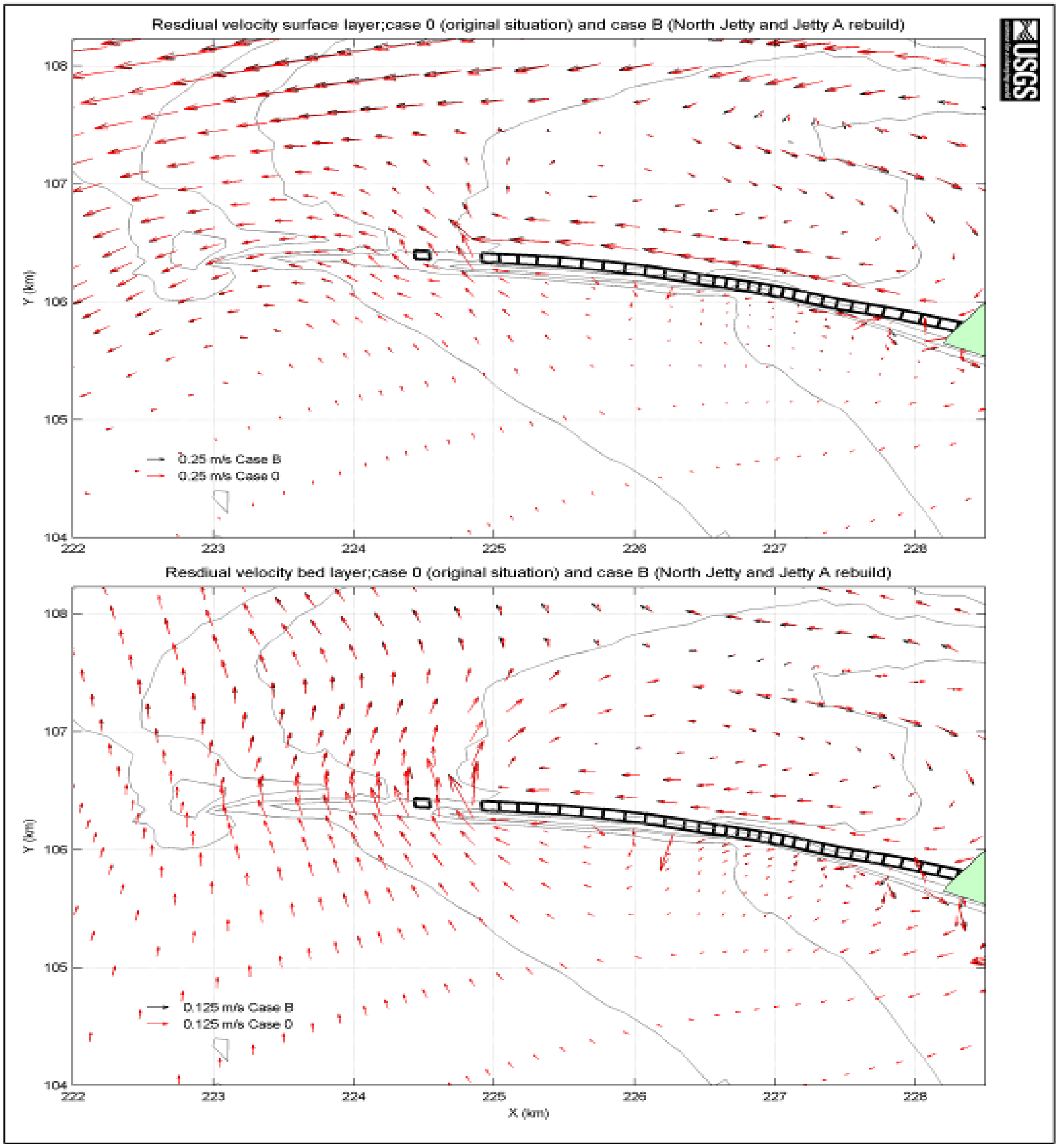


Figure 48. Residual Velocity near South Jetty for October/November Time Window



Salinity

As noted above, the primary factors controlling circulation in the Columbia River estuary are river flow, tides, and currents resulting from the pressure gradient force. Salinity distribution is, in turn, determined by the circulation patterns and the mixing process driven by tidal currents. The variability in the above mentioned parameters also result in large variability in salinity. The USGS modeling results, for example, showed that in near surface waters near the landward portions of the North Jetty, salinity naturally varies with tides to 20 parts per thousand (ppt) during October-November (Moritz 2010, USGS 2007).

As illustrated previously, earlier model results quantified changes to salinity for the length rebuild scenarios. Changes were again negligible despite the larger scale action than what is currently proposed. As before, figures represent changes predicted for action of a larger scope and scale. The representative original condition along with the spur groins is now more reflective of what the likely post-project conditions could entail.

Minor local changes to mean salinity was predicted as a result of implementation of the length rebuild proposed action. For the August-September timeframe, changes to bed layer salinity were predicted in waters between Jetty A and the North Jetty (Figure 49). An increase in mean salinity of 0-4 ppt from 26-28 ppt to 28-30 ppt was predicted to occur over some of this area (Moritz 2010, and USGS 2007) This could be calculated as up to ~ 15% change, but was still well under the 20 ppt (or up to 67%) change range of natural variability. A similar but less extensive salinity pattern was predicted for the near surface layer in waters between Jetty A and the North Jetty, where mean salinity was also predicted to increase 0-4 ppt from 18-20 ppt to 20-22 ppt (Figure 50). For the near surface layer, note that this increase in mean salinity included the area in close proximity to much of the landward portion of the North Jetty. For the near surface layer, a decrease in mean salinity of 0-4 ppt from 12-14 ppt to 14-16 ppt was predicted to occur over a relatively small area south of West Sand Island, which is located just east of Jetty A (Moritz 2010, USGS 2007).

For the October-November timeframe, small patterns of salinity change were also predicted. For the bed layer, a small-scale extrusion of higher salinity water was predicted for the main channel and along the South Jetty as a result of implementation of the proposed action (Figure 51). For example, for the existing condition, salinity in the range of 28-30 ppt occurs just upstream of Jetty A; whereas for the post-project condition, this zone of salinity ended directly south of Jetty A. Only small changes were predicted in the bed layer near the North Jetty. For the surface layer, extrusion of higher salinity water in the main channel was not predicted but was predicted for waters near the South Jetty (Figure 52). For the existing condition, salinity in the range of 24-26 ppt was predicted along the seaward 1/3 of the South Jetty, whereas for the post-project condition this area was predicted to support salinity in the range of 22-24 ppt. A minor reduction of lower salinity waters in the range of 18-20 ppt is predicted for along the landward half of the North Jetty (Moritz 2010, USGS 2007).

In summary, under the rebuild scenario minor local changes to mean salinity were predicted as a result of implementation of jetty build-outs. Even under a larger rebuild, the resulting changes to salinity were also negligible with respect to fluctuations that already occur. No rebuild is proposed under the current action, so any effects to water salinity and plume conditions are even more unlikely.

Figure 49. Mean Salinity for Bed Layer for August/September Time Window

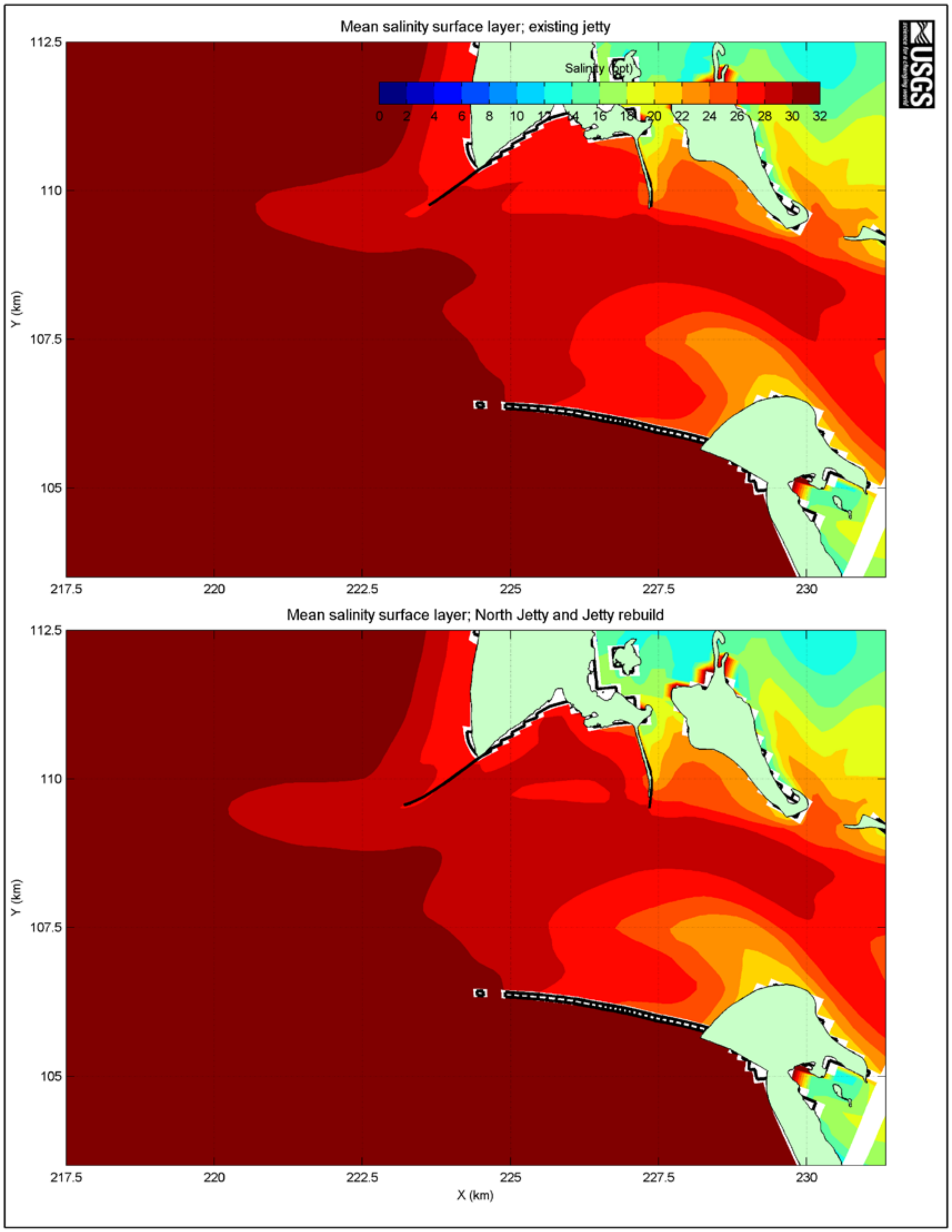


Figure 50. Mean Salinity for Surface Layer for August/September Time Window

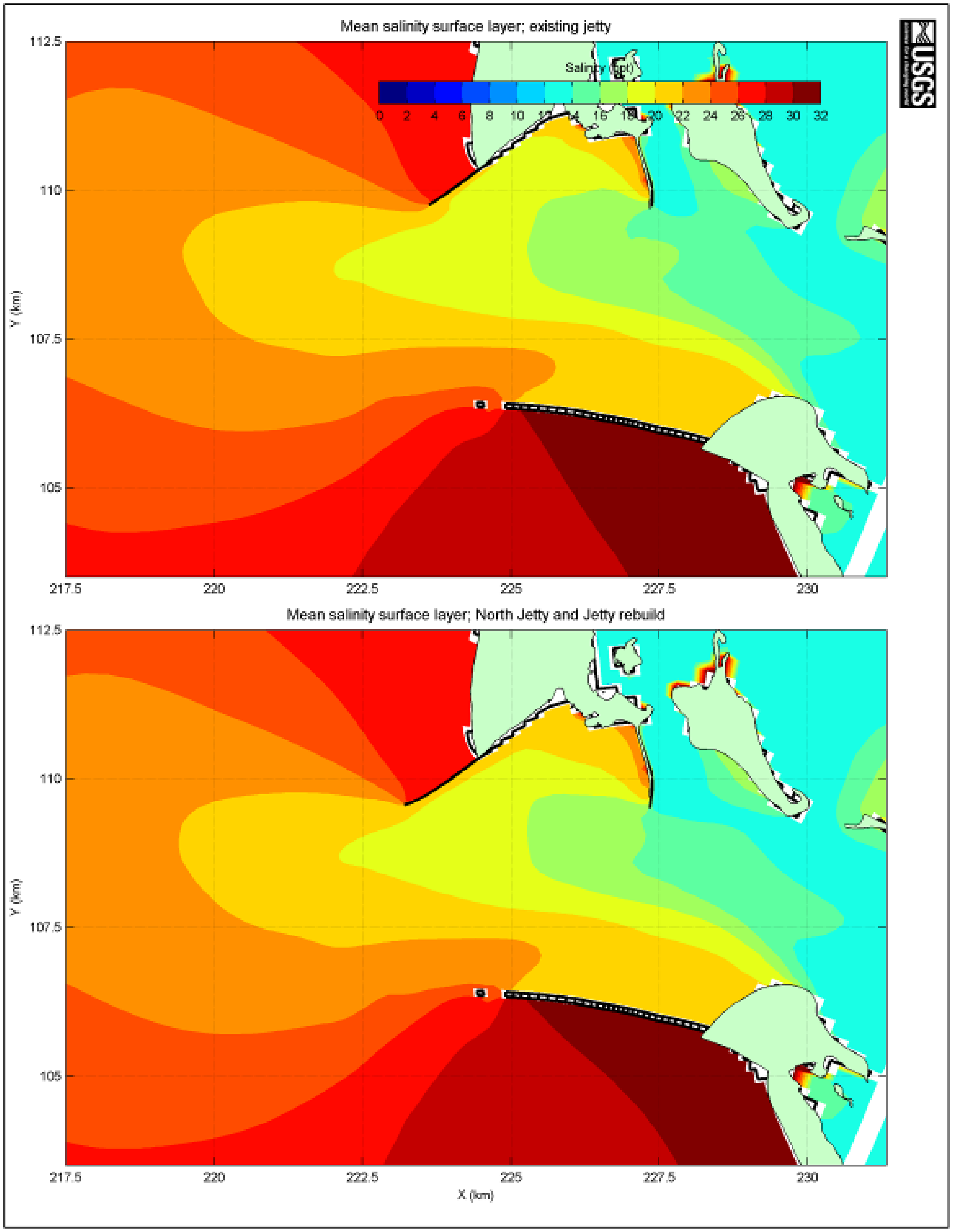


Figure 51. Mean Salinity for Surface Layer for October/November Time Window

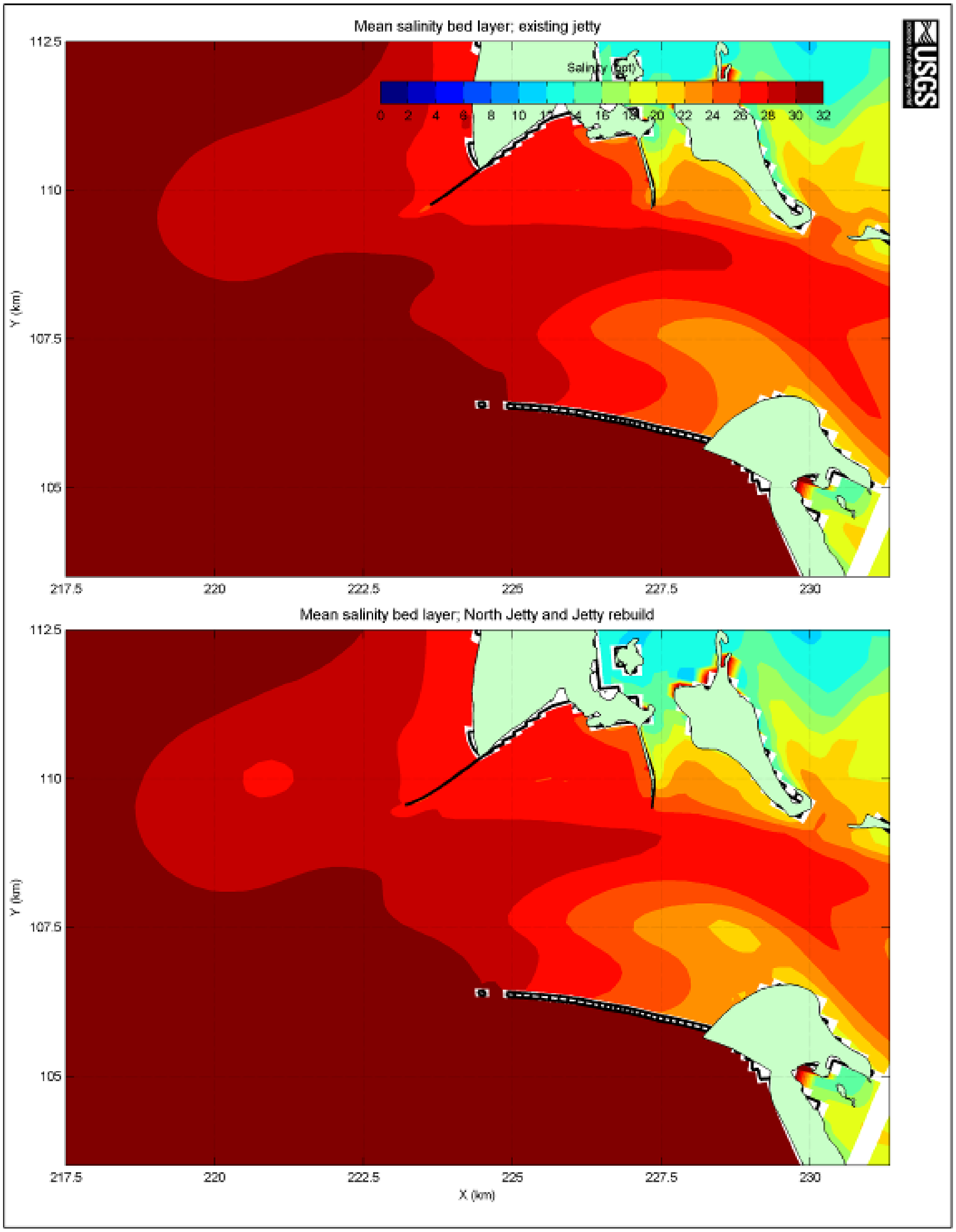
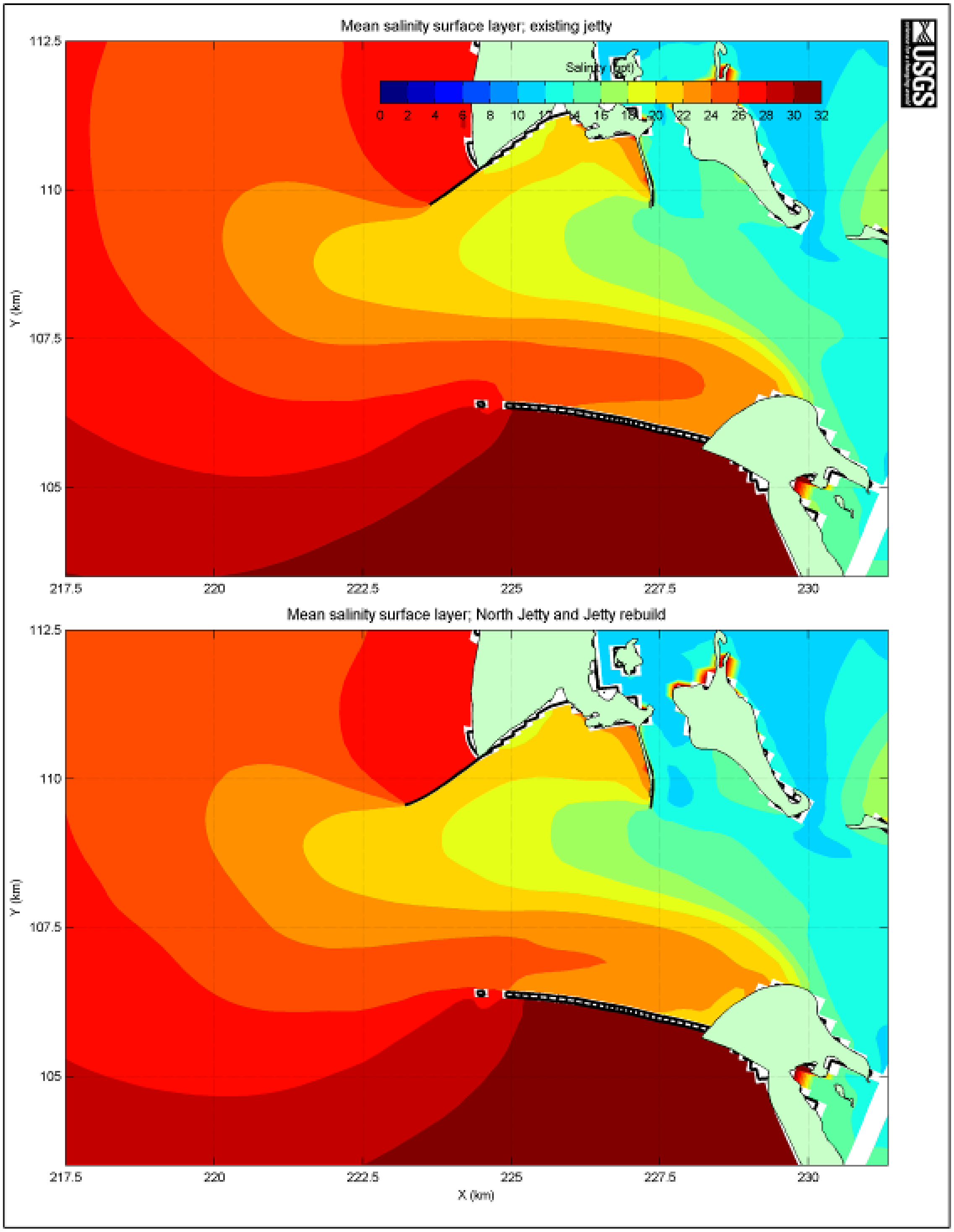


Figure 52. Mean Salinity for Surface Layer for October/November Time Window



Plume Dynamics

The parameters of study in the USGS modeling were predicted to be less affected in the plume than in the entrance itself from construction of the larger rebuild project. It was evident from the above figures that there would be only small predicted changes to residual velocity and current directions for both bed layer and near surface layer for the August-September and October-November timeframes in the plume. A decrease in bed layer salinity of 0-4 ppt (from 28-30 ppt to 26-28 ppt) was predicted in the plume over an oval area west of the terminus of the North Jetty. Only small changes were predicted to residual bed load transport and residual total load transport within the plume for the August-September and October-November timeframes (Moritz 2010, USGS 2007). Under the current proposed action, no length rebuild is included. Because of this smaller scale of action, any minimal changes that were previously predicted under the model comparison would be less likely. The existing conditions of the previous model are somewhat representative of the current proposed action with the addition of spur groins.

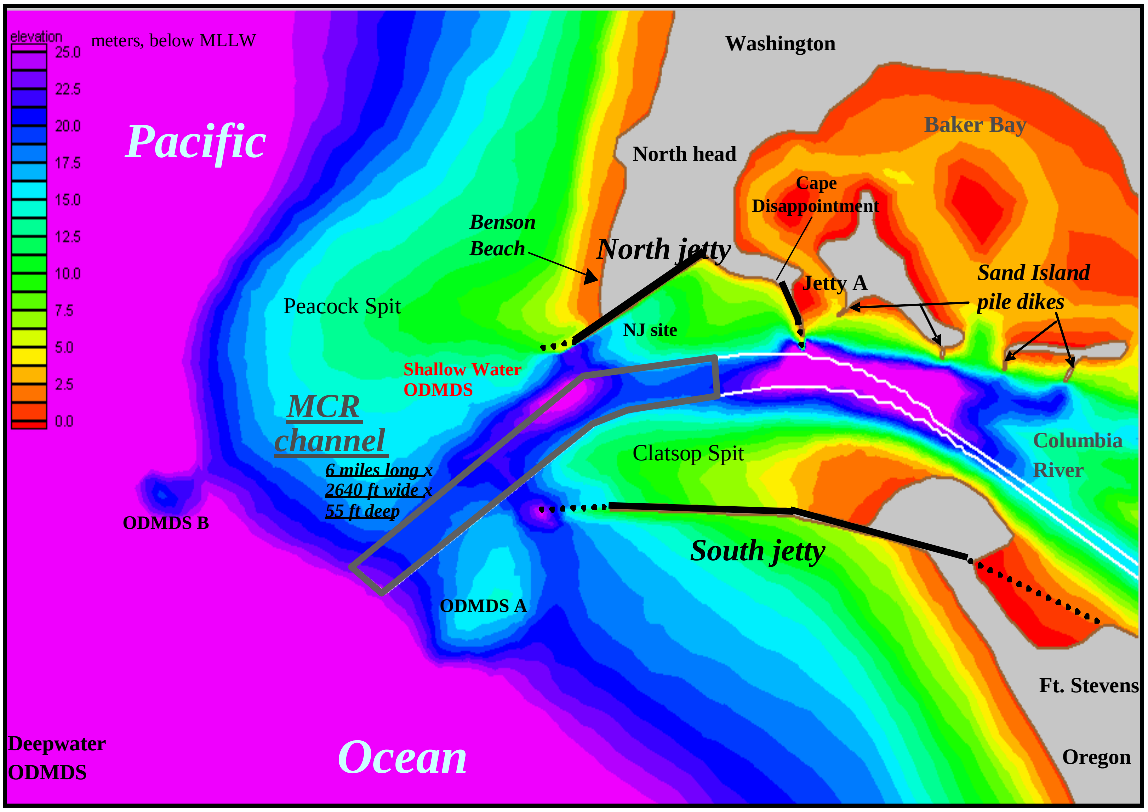
Bed Morphology

Modeling predicted some bed level changes along the seaward channel- side of the North Jetty due to the rebuilt lengths and implementation of spur groins. With longer jetties, change were predicted for both modeled timeframes, but was more pronounced in the winter, with an approximately 8.3% differences in bed elevation of 1.25 to 1.50 meters change from the existing 12 to 24 meters depth. This change is relatively small, however, considering the dynamic environment at the MCR (bathymetry at the MCR is shown in Figure 53). From the ERDC modeling results of the groin structures, it was predicted that a temporary increase in bed level due to sedimentation would occur upstream of the spurs, but that a temporary decrease in bed level due to erosion would occur immediately downstream of the spurs.

There were predicted changes that would occur to bed levels with implementation of the proposed length rebuild project. The most obvious change to bed level would have resulted in deeper water habitat than currently exists along the channel side of the seaward half of the North Jetty. This change was predicted to exist for both the August-September (Figure 54) and October-November (Figure 55) timeframes, but was more pronounced for the latter, with differences in bed elevation of 1.25 to 1.50 meters. This change is relatively small, however, considering that water here is 12 to 24 meters deep (Moritz 2010, Connell and Rosati 2007).

Bed morphology changes were predicted to occur in similar areas during the August-September and October-November timeframes but more scouring and deposition is predicted to occur during the latter. In addition to the result described above for the channel side of the seaward portion of the North Jetty, decreases to bed level with implementation of the proposed action were predicted for a broad area in deep waters of the navigation channel off of Jetty A and deep waters around the seaward portion of Jetty A and for locations north of the North Jetty, which includes shallow nearshore waters. Areas predicted to have an increase in bed level occurred upstream and downstream of Jetty A, downstream of the above-mentioned broad area in the navigation channel, on the ocean side of the North Jetty, and downstream of Clatsop Spit (Moritz 2010, Connell and Rosati 2007). As mentioned before, the scale of the current proposed action is much smaller and precludes a length rebuild. Therefore, any changes previously predicted would be even smaller or unlikely.

Figure 53. Bathymetry at the MCR



From the ERDC modeling results of the groin structures, it is predicted that a temporary increase in bed level due to sedimentation would occur upstream of the spurs, but that a temporary decrease in bed level due to erosion would occur immediately downstream of the spurs (Moritz 2010, Connell and Rosati 2007).

Temporally, effects from hydraulics and hydrologic process would occur as a single event with construction as described under Rock Placement. Any minor subsequent effects would be long-term, but are discountable within the range of natural dynamic conditions and are of limited geographical extent.

In summary, previous modeling results indicated the changes to velocities, currents, salinity, plume dynamics, and bed morphology were minimal under the much larger jetty length rebuild scenario. Also, the existing or "original" conditions of the previous model represented lengths that are retained under the current proposed action. Because of previous results, no significant overall changes to the hydraulics or hydrology of the MCR system are anticipated under the new, smaller proposed action.

Figure 54. Difference in Bed Level (meters) for August/September Time Window

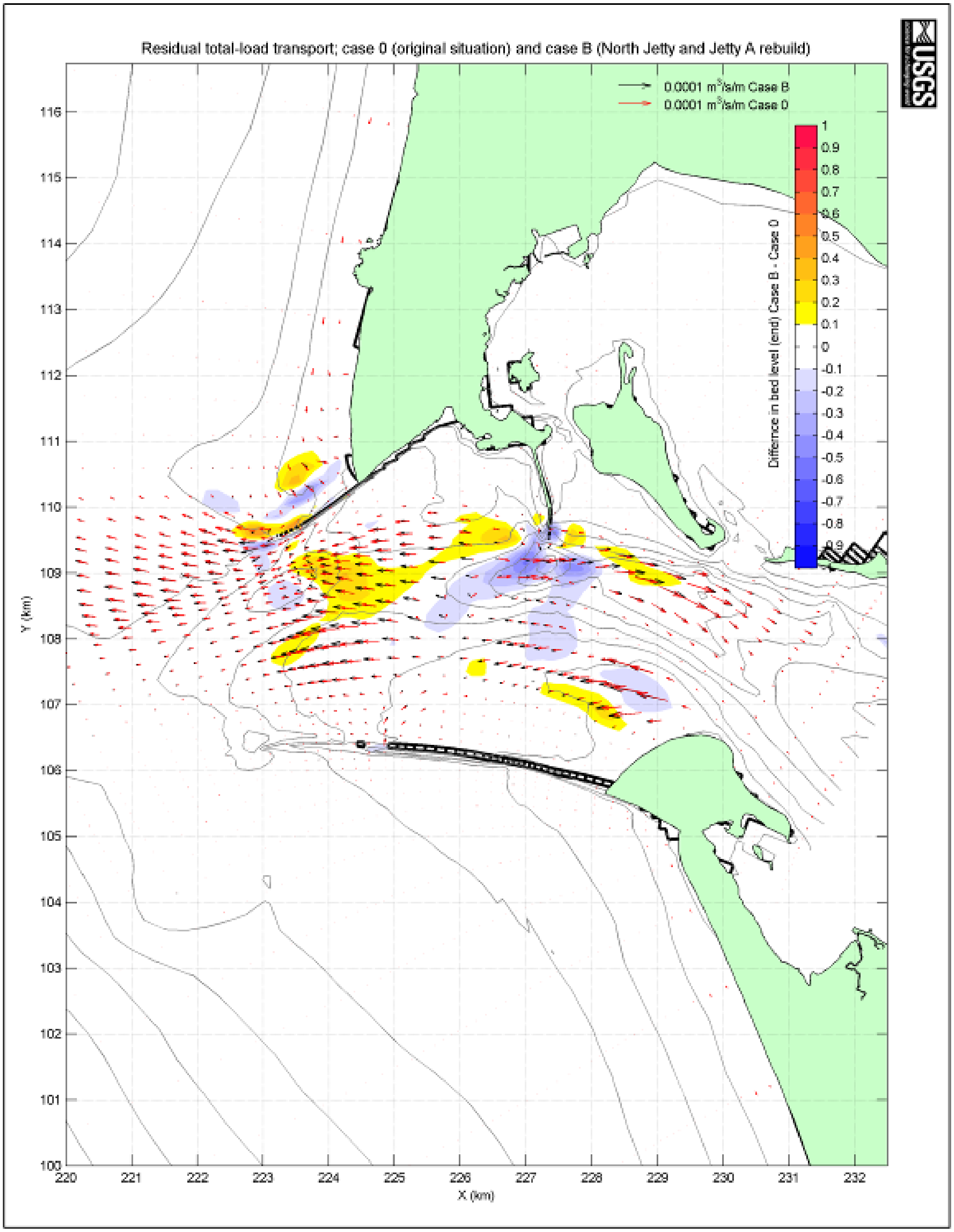
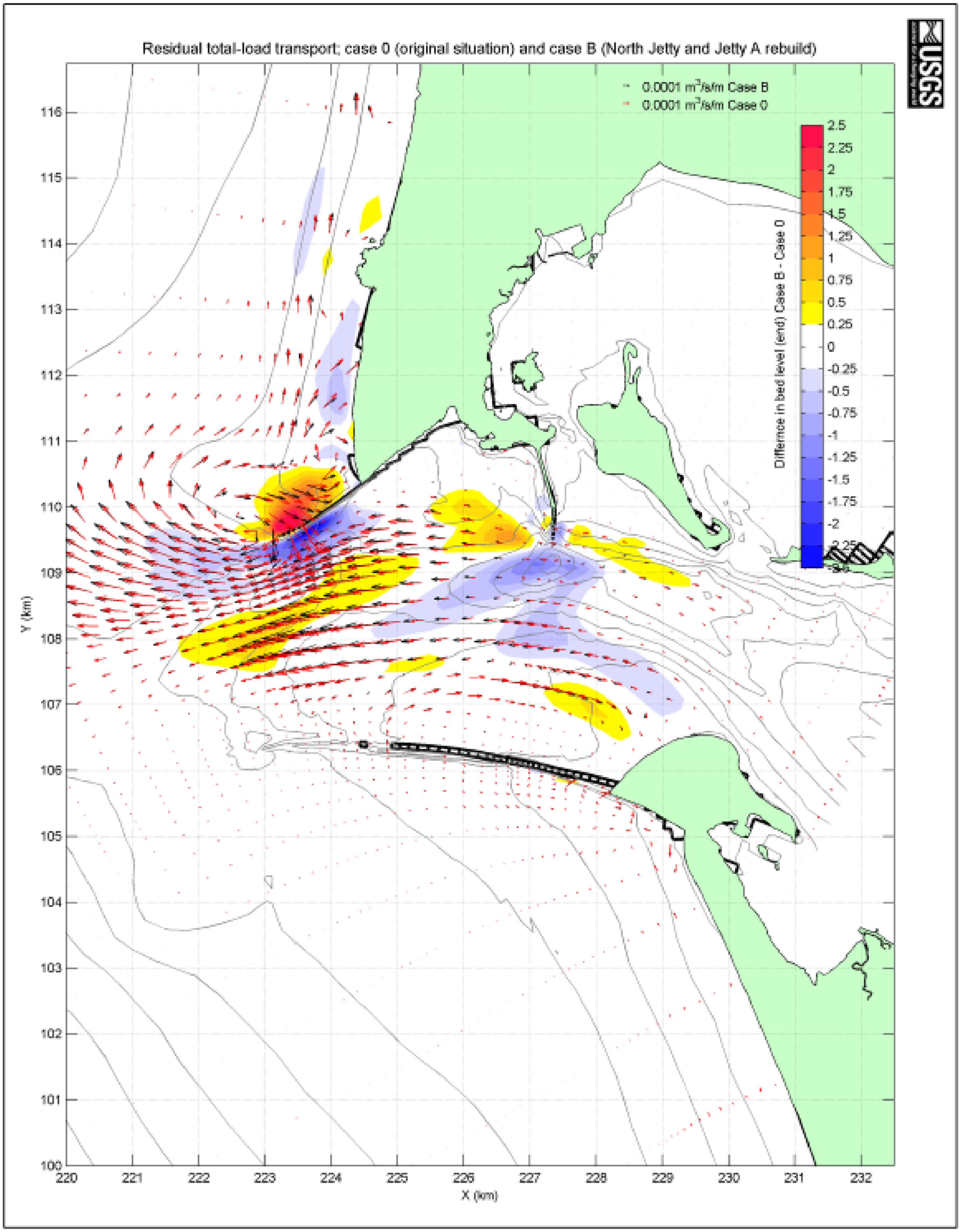


Figure 55. Difference in Bed Level (meters) for October/November Time Window



MITIGATION AND HABITAT IMPROVEMENTS

In this BA, the Corps has proposed ecosystem restoration at its discretion under Section 7(a) (1) of the ESA. These actions will restore and improve the habitat for the benefit of listed and candidate salmonid species as well as other native species found in the lower Columbia River ecosystem. Under the Clean Water Act, the Corps is also required to provide mitigation for wetland impacts. The Corps will develop detailed proposals, which will be coordinated with the Services and State partners, and then work to implement them using the AMT.

As described in the proposed action, the Corps has developed a wetland mitigation and habitat improvement package with a suite of potential actions to offset wetland impacts and to improve shallow-water habitats. In the long term, implementation of wetland mitigation and habitat improvement actions along with upland plantings will increase the overall square footage of wetlands and improve uplands, potentially also improving wetland-stream hydrologic functions in the Columbia River estuary. Restoration of low saltwater marsh habitat will improve resting and rearing habitat access for juvenile fish, as well as improved and increased instream and riparian and estuarine functions; for example, creation of brackish intertidal and mudflat habitat, restoration of hydrologic regimes, and improvement of riparian and canopy cover. These actions will be focused on higher value habitats and functions than those which are being affected in the immediate vicinity of the jetties.

Actions could also increase estuarine productivity lower in the Columbia River system for a wide range of species. Re-establishment of native plant communities and improvement of riparian functions would improve water quality function, habitat complexity, and trophic inputs. Reintroduction of a greater range of flows and more natural tidal regimes to uplands and diked pasturelands would also improve the likelihood of re-establishing native intertidal species. Re-establishing hydrologic and tidal regimes increases the opportunity to develop edge networks, dendritic channels, and mud flat habitats for use by listed species. Increased benthic habitat could also improve food web productivity. Dike breaches and tide and culvert retrofits would also increase adult fish passage and restore access to expanded spawning and rearing areas.

In relationship to the recovery plan in the estuary module (NMFS 2007c), the 7 (a) (1) actions being proposed by the Corps address threats identified in the recovery plan, and specifically relate to Columbia River Estuary (CRE) management actions. Depending on final plan selection, habitat improvements may specifically address the following CRE actions: 1 (riparian protection and restoration); 4 (restoring flow regimes via improved/restored tributary hydrologic connectivity); 5 (replenishment of littoral cell via beneficial use of dredged materials); 8 (removal of pile dikes); 9 (protection of remaining high-quality off-channel habitat from degradation), and; 10 (improvement of off-channel habitat via levee and dike breaches). Several of these CREs were also in the higher rankings for benefits with implementation, and higher percentages for Survival Improvement Targets (NMFS 2007c).

Therefore, the Corps expects these actions to have either direct or indirect long-term beneficial rather than adverse effects to most of the listed species and their designated critical habitat in the action area. In the short-term, temporary disturbance and increased suspended sediment may result in higher turbidity during in-water construction at restoration sites. This is not likely to occur during upland planting. However, these actions will be limited in duration and intensity, as BMPs to reduce and avoid pollutant runoff described in the proposed action would also be applicable to actions at restoration sites. Suspended sediments from in-water work will be monitored per State Certification conditions, and appropriate BMPs to minimize turbidity will also be implemented to ensure levels do not reach a duration or intensity that will harm species.

For invasive species removal, the Corps proposes to use no herbicides within 100 feet of the Columbia River or associated water bodies, and therefore, does not expect increased pollutant loads or effects on instream or riparian function. Short-term noise disturbances are likely to attenuate near the source and project locations are likely to be much further away from habitat used by marine mammals. These acoustic effects will likely be minimal and discountable.

Temporally, implementation of different components of wetland mitigation and habitat improvement projects could occur throughout the year. It would likely be possible to complete associate in-water work during the appropriate in-water work windows that protect listed species. Concurrent with initial impacts to wetlands, construction would likely occur in one or two seasons with subsequent monitoring. Temporally, this limits the repetition of disturbance activities associated with the construction of these projects. Short-term effects to water quality may occur on a daily basis, but would be limited and similar to those describe in the Water Quality effects discussion.

EFFECTS OF THE ACTION ON LISTED SPECIES

Harassment applies to actions that create the potential for injury by significantly disrupting normal behavioral patterns including breeding, spawning, rearing, migrating, feeding or sheltering. To be significant, harassment must be capable of resulting in the death or injury of fish or wildlife. Harm applies to actions that result in actual injury or death, including actions that cause environmental damage leading to injury or death.

Based on migratory and residence time, listed marine and anadromous fish including salmon, steelhead, eulachon, and green sturgeon will be present in the action area during the proposed period of jetty repair, rehabilitation, and maintenance operations. Listed sea turtles, listed marine mammals, including Steller sea lions and whales, may also be present. The following actions and effects have been evaluated for these species.

- Rock Transport
- Construction Access, Staging, Storage, And Rock Stockpiling
- Rock placement
- Dredging
- Disposal
- Barge Offloading Facilities
- Pile Driving
- Lagoon And Wetland Fill And Culvert Replacement
- Dune augmentation
- Water Quality
    - Suspended Sediment
        - Dredging
        - Disposal
        - Pile driving
    - Spills and Leaks
    - Contamination
- Hydraulic & Hydrological Processes
    - Salinity and Plume dynamics
    - Bed Morphology
    - Water Velocity
- Wetland Mitigation and Habitat Improvements

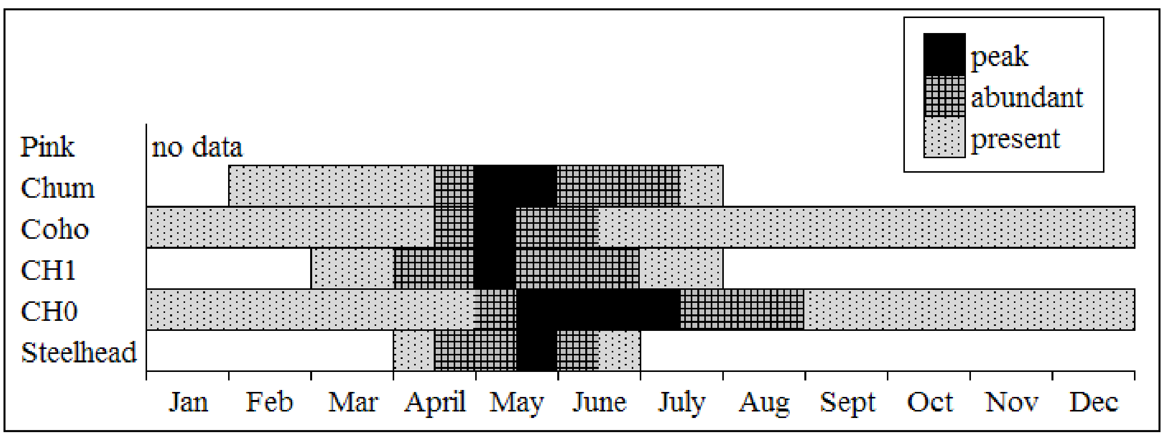
Listed Marine and Anadromous Fish

Salmonids

A variety of anadromous fish occur in the Columbia River near and offshore areas. Occurrence of adult migratory salmon in the offshore area is correlated primarily with their period of upstream migration. Migratory juvenile salmon are present following their migration out of the Columbia River estuary primarily in the spring and fall. Anadromous species occur throughout the year with many using the estuary as a rearing and nursery area (Corps 1999). Adult salmonids may be present and holding in the estuary during upstream migrations on their way to spawning grounds (Figures 56 and 57). Juvenile salmonids occur in the action area during their out-migration to the ocean. Juveniles that have already become smolts are present in the lower river for a short time period. Juveniles that have not become smolts, such as Chinook subyearlings, spend extended periods of time rearing in the lower river. They normally remain in the lower river or estuary until summer or fall or even to the following spring when they smoltify and then migrate to the ocean. Rearing occurs primarily in shallow backwater areas.

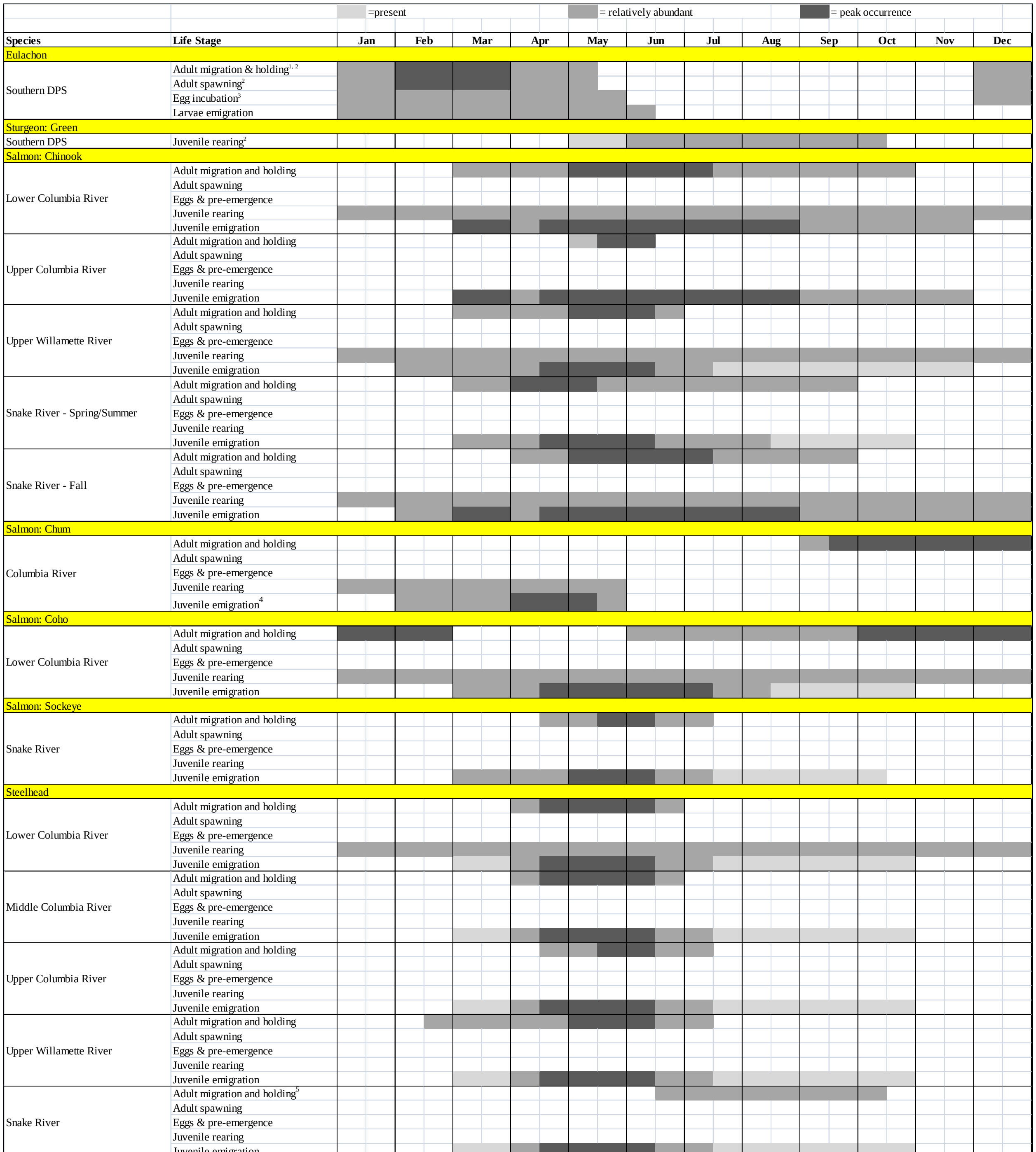
In the estuary, most rearing of juvenile salmonids occurs in the upper part of the water column near the shore and in shallow-water areas (Bottom et al. 2005). Use of deeper areas does occur; it is known that juvenile chum salmon prefer feeding in shallow waters but food limitations may induce movement to deeper waters (NMFS 1991). Also, it is known that subyearling Chinook and chum salmon occupy shallow, nearshore habitats but shift to deeper habitats farther away from the shoreline as they grow to fingerling and smolt stages (Bottom et al. 2005).

Figure 56. Timing of Salmonid Life History Events in the Lower Columbia River



General trends in presence and abundance of juvenile salmonids in the lower Columbia River estuary at and downstream of Jones Beach (RKM 75; Dawley et al. 1986; McCabe et al. 1986; Roegner et al. 2004; Bottom et al. 2008).

Figure 57. Fish Presence in Lower Mainstem Columbia River below Sauvie Island (RM 87)



[1] Eulachon Status Review Update, 20 January 2010. Available at: http://www.nwr.noaa.gov/Other-Marine-Species/upload/eulachon-review-update.pdf

[2] Personal communication. Conversation between WDFW (Brad James, Olaf Langness, and Steve West), ODFW (Tom Rien), and NMFS (Rob Markle, Bridgette Lohrman) regarding green sturgeon and eulachon presence in the Columbia River. June 23, 2009.

[3] Eulachon egg incubation estimated relative to spawning timing and 20 to 40 day incubation period.

[4] Carter et al. 2009 (Seasonal juvenile salmonid presence and migratory behavior in the lower Columbia River).

[5] Good et al. 2005 (Updated status of federally listed ESUs of West Coast salmon and steelhead

Citations:

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In a study in an artificial estuary, juvenile Chinook salmon showed a preference for deep saline habitats to shallow freshwater habitats and were shown to make brief forays into the upper freshwater habitat if food availability was sufficiently high (Webster et al., 2007). Although specific size-depth relationships may vary by species, studies have found juvenile salmon distributed along a depth continuum based on size of the fish: juvenile Chinook and chum salmon less than 50-60 mm fork length (FL) occur primarily in shallow water (less than 1 meter in depth); fish 60-100 mm FL are found in slightly deeper habitats (shoals, tributary channels); and fish greater than 100 mm FL may be found in both deep and shallow-water habitats. This relationship between size and depth tends to be less reliable in hours of darkness when schooling fry or fingerlings often disperse from shore (Bottom et al. 2005).

Juvenile salmon movement toward the ocean is facilitated by ebb tides when current movement in the channel is generally in an east to west direction. Of the Salmonid species, sub-yearling Chinook salmon stay in the estuary for the longest period of time and use the greatest variety of estuarine habitats (Bottom et al. 2005), mainly slower, shallower, backwater areas. Healey (1982) proposed that Chinook salmon is the most estuarine dependent of Salmonid species. These slow water areas are not typically available in close proximity to the jetties, but even in this high energy environment, sub-yearling Chinook still show a tendency to linger and to use nearshore areas. This is further demonstrated by acoustic tagging studies in the lower Columbia.

A 2005 Pacific Northwest National Lab (PNNL) study on acoustically tagged sub-yearling and yearling Chinook salmon and steelhead was conducted in the vicinity of the mouth of the Columbia River North and South jetties (McMichael et. al. 2006). Detection nodes were placed across the channel at RM 5.6 (primary node) and at RM 1.8 (secondary node). The secondary node did not extend all the way to the south side of the channel, however. As a result, fish could pass close to the South Jetty without being detected. A third set of detection nodes were placed near the North Jetty disposal area. Chinook salmon, both sub-yearling and yearling, were run-of-the-river fish tagged and released at the Bonneville Second Powerhouse bypass at the juvenile fish facility. Steelhead were Snake River-origin hatchery fish that were collected from fish transport barges between John Day and Bonneville dams and released mainly at Skamania Landing downstream of Bonneville (some were transported/released at Astoria-Megler Bridge).

In the 2005 study, sub-yearling Chinook salmon were shown to move back and forth past the nodes, remaining longer in the vicinity of the nodes than yearling Chinook salmon and steelhead, and tended to use nearshore areas (closer to the North Jetty) more than yearling Chinook salmon and steelhead. Yearling Chinook salmon and steelhead were concentrated more in deeper waters near the navigation channel than sub-yearling Chinook salmon. Larger fish tended to spend less time (9-24 minutes) within the MCR detection area that smaller subyearling Chinook (mean=160 minutes). Yearling Chinook and steelhead indicated a more directed emigration pattern relative to sub-yearling Chinook. Sub-yearling Chinook salmon residence times within the detection areas were up to 15-20 times longer than yearling Chinook salmon and steelhead, usually passing on two to three ebb tides instead of one. Also, they took longer to reach the MCR from Bonneville Dam (average 4.5 days) than yearling Chinook salmon and steelhead (mean = 3.5 days; McMichael et al. 2006). Though these metrics do not indicate actual time fish spent in the area around the jetties themselves, they can be used to roughly extrapolate the overall range of residence time in the area. Considering the sampled area was approximately 70 acres out of about 2,600 acres across the river between the tips of the jetties and Cape Disappointment, extrapolating from the data indicated that subyearling Chinook could spend anywhere from a few hours to a maximum of about 4.6 days within the larger MCR area. Steelhead and yearling Chinook spend even less time (usually a few hours to less than 1 day), as they are more directed in their emigration (McMichael et al. 2006). Furthermore, detections at each array were within a spherical range of approximately 200 meters, which means fish detected on arrays closest to the jetties could still be up to 200 meters away from the structure itself (McMichael et al. 2010). Therefore, juvenile residence time within the MCR area and their potential exposure to jetty repair activities is of short and relatively limited duration. Residence time with immediate proximity to the jetties themselves would logically be even smaller.

The PNNL conducted subsequent similar studies that monitored and mapped migration pathway and habitat associations and behaviors relative to these pathways for acoustic-tagged juvenile yearling Chinook salmon, steelhead, and subyearling Chinook salmon downstream of Bonneville Dam as they migrated seaward through the Columbia River and its estuary. In the action area in 2009, receiver arrays were deployed across the entire river channel at two locations near the mouth of the river at East Sand Island (RKM 8.3) and the Columbia River bar (RKM 2.8; Figure 58). Partial arrays were also deployed across the primary channel at the Astoria Bridge (RKM 22.0; McMichael et al. 2010).

The 2009 PNNL study indicated that acoustic-tagged yearling Chinook detected in the Bonneville Dam forebay and at the mouth of the Columbia River had a mean travel time of 3.4 days. Travel times decreased throughout the migration period. Travel rates of both yearling Chinook salmon and steelhead decreased as they moved between Oak Point and the Astoria Bridge and increased and was more variable downstream of RKM 22. Steelhead had a mean travel time of 3.1 days, and travel times decreased throughout the migration period. Subyearling Chinook salmon had a mean travel time of 4.1 days between RKM 236 and RKM 8.3. Travel times increased slightly throughout the migration period. Travel rate of subyearling Chinook salmon decreased as they moved between the array at Cottonwood Island (RKM 113) and RKM 22, and then increased and was more variable downstream of RKM 22. Furthermore, timing of arrival of tagged fish at most arrays in the lower 50 km of the estuary was influenced more by tide than by time of day for all three groups. Most tagged fish passed the lower three arrays on ebb tides, and this relationship was most evident when the difference between high and low tide was greatest (McMichael et al. 2010).

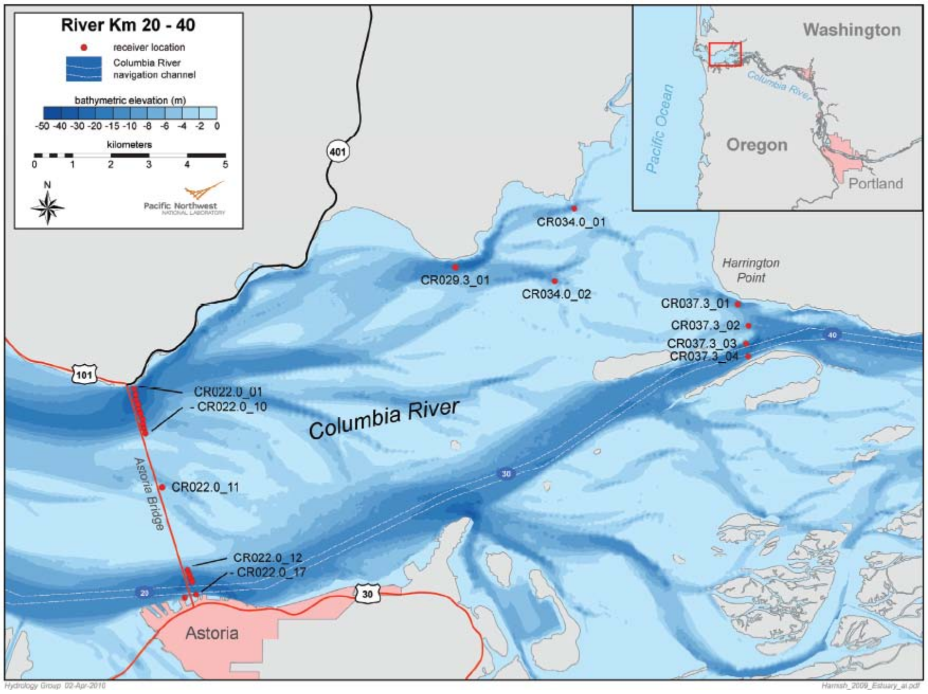
These PNNL studies also evaluated cross-channel distribution at the arrays within the action area, and 2009 results are shown in Figures 59-61. These studies give some indication of distribution near the jetties and offloading facilities, though arrays were not specifically at these locations. Similar to the 2007 and 2008 studies, results obtained from 2009 also indicated that a greater proportion of subyearling Chinook salmon migrated through off-channel areas (outside the primary channel) than yearling Chinook salmon or steelhead which concentrated more towards the navigation channel (McMichael et al. 2010). For 2007 and 2008 (when more arrays were located nearer the South Jetty than in 2005) migration patterns for subyearling Chinook indicated cross-channel distribution that was more skewed towards the Washington shore in the vicinity of the MCR. However, fish distribution did not peak at the nodes in closest proximity to the jetties (Carter et. al. 2009). Furthermore, in 2007, approximately 93% of juvenile yearling Chinook detected passed farther than 200 meters away from the North Jetty (200 m is the approximate spherical detection radii of the arrays), and over 99% detected passed at an even greater distance away from the South Jetty (Carter et. al. 2009). In 2008, approximately 96% of detected juvenile subyearling Chinook passed at a distance greater than 200 meters from the North Jetty, and over 99% passed at an even farther distance away from the South Jetty (Carter et. al. 2009). Results for 2009 showed similar trends for all juveniles, and in particular subyearling Chinook. These are shown in Figures 59-61 (McMichael et al. 2010).

In 2010, nodes were briefly moved for a short time so that one node was placed on the upriver side of Jetty A, one at the tip of Jetty A, and one on the western, oceanside of Jetty A (McMichael et al. 2010). Preliminary results indicated that 378 subyearling Chinook were detected at the upstream node, 385 at the tip, an only 8 at the ocean side node. This seems to indicate that fish move downstream towards Jetty A without moving very close to Jetty A on the ocean side (McMichael et al. 2010). Furthermore, at the array near the mouth, in 2010, 7 out of the 1,144 fish (or 0.6%) detected on the array passed on the node nearest the North Jetty (McMichael et al. 2010). Again, this is within a 200 meter range of detection, so actual immediate proximity to the stone structure may be even less.

Distribution of juveniles and use of and near the jetties may further be considered in light of a 1998 study Pacific County, Washington that was conducted to determine effects on juvenile salmon from the construction of a 1,600 foot long above-water spur groin, known locally as Jacobson's Jetty, and a 930 foot long underwater dike (Miller et al. 2002). The structures were constructed on the north side of Willapa Bay at Washaway Beach to halt erosion adjacent to State Route 105. Large tidal exchange in and out of Willapa Bay results in strong currents around the structures, similar to the jetties at the MCR. Observations on juvenile salmonids and potential predators were made at the Washaway Beach site during May 2002 at the structures and at reference points and beach habitat both east and west of the structures in an attempt to ascertain structure effects. Juvenile salmon, primarily Chinook, were observed during snorkel and dive surveys adjacent to the structures and over the dike in the upper 1 m of the water column and were observed feeding on plankton near the structure and barnacles on the structure. They were in groups of generally five or fewer in the size range of 85-110 mm. It has been shown that juvenile salmonids, especially sub-yearling Chinook salmon, outmigrate in close proximity to the MCR North Jetty. They may outmigrate in close proximity to the South Jetty as well. From knowledge gathered from the Washaway Beach study, it is likely that juvenile salmonids use jetty rock habitat at the MCR for feeding during their outmigration. However, compared to the overall cross-channel distribution of fish detected in the PNNL studies at both jetties, this is likely a relatively small percent of out-migrants (4%-7% of sub yearling Chinook, and an even smaller percentage of yearling Chinook and steelhead). Also as indicated by the PNNL studies, the short juvenile residence time the high energy environment at the jetties means fish use in these areas is likely further limited.

Figure 58. Locations of Acoustic Telemetry Receiver Arrays, 2009

At Harrington Point (CR037.3) and Astoria Bridge (CR022.0) and locations of single receivers in Grays Bay (CR034.0_01, CR034.0_02, and CR029.3_01) in relation to bathymetry (McMichael 2010).



At East Sand Island (CR008.3) and the Columbia River Bar (CR002.8) (McMichael 2010).

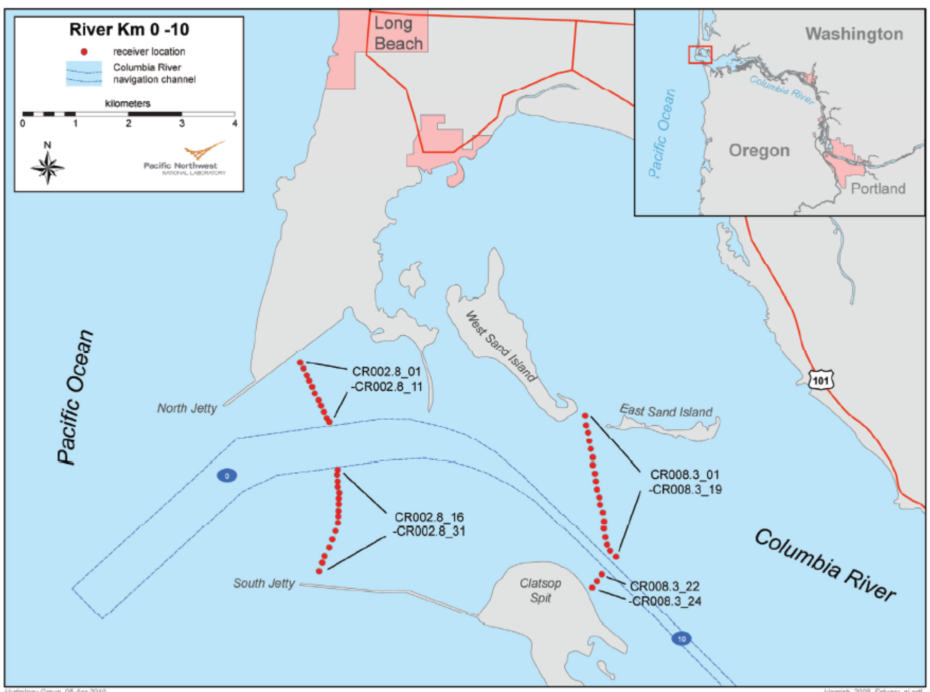


__Figure 59. Cross-channel Distribution of Acoustic-tagged Yearling Chinook Salmon__

First detections at arrays at Astoria Bridge (CR022.0), East Sand Island (CR008.3), and Columbia River Bar (CR002.8; McMichael et al. 2010).

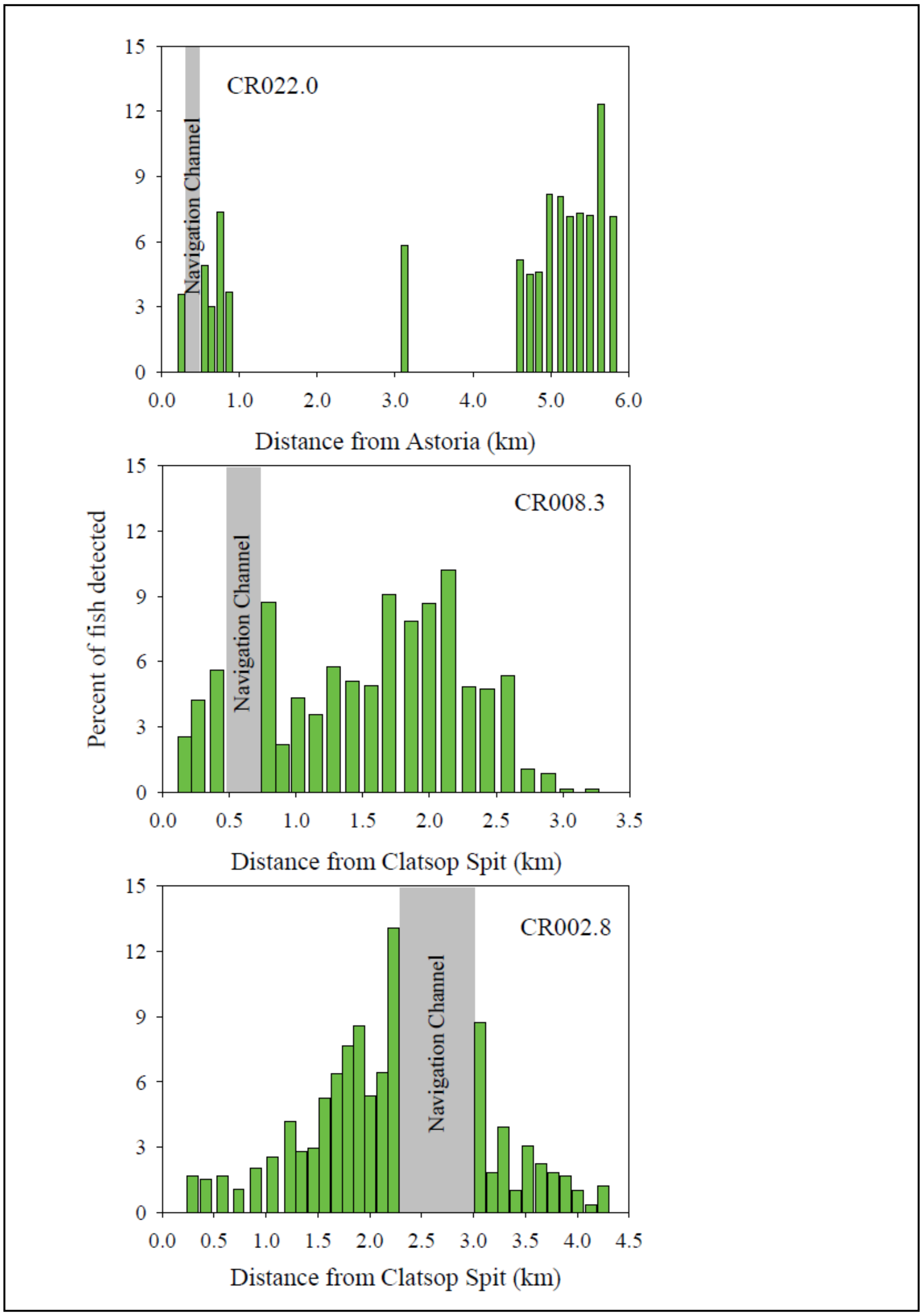


Figure 60. Cross-channel Distribution of Acoustic-tagged Steelhead

First detections at arrays at Astoria Bridge (CR022.0), East Sand Island (CR008.3), and Columbia River Bar (CR002.8; McMichael et al. 2010).

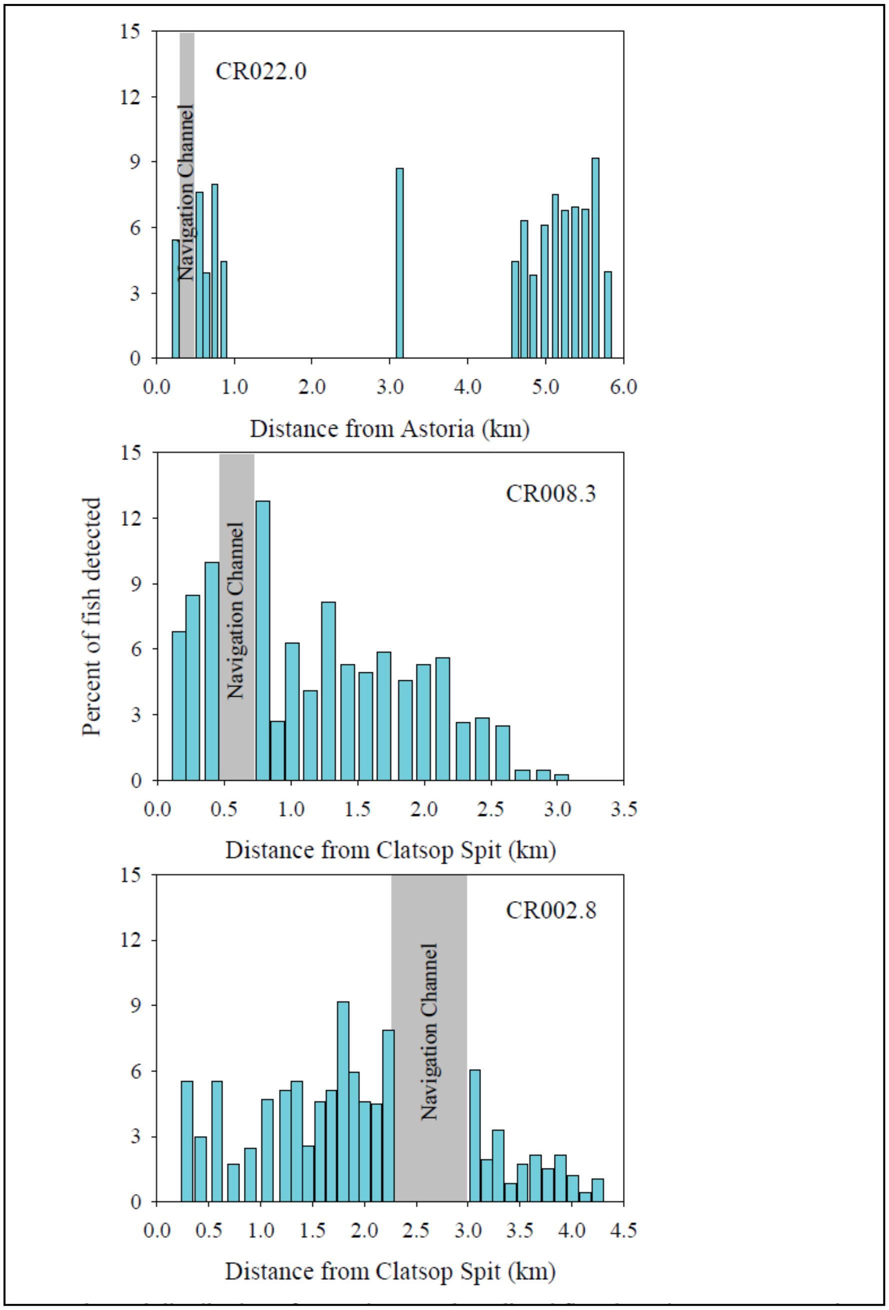
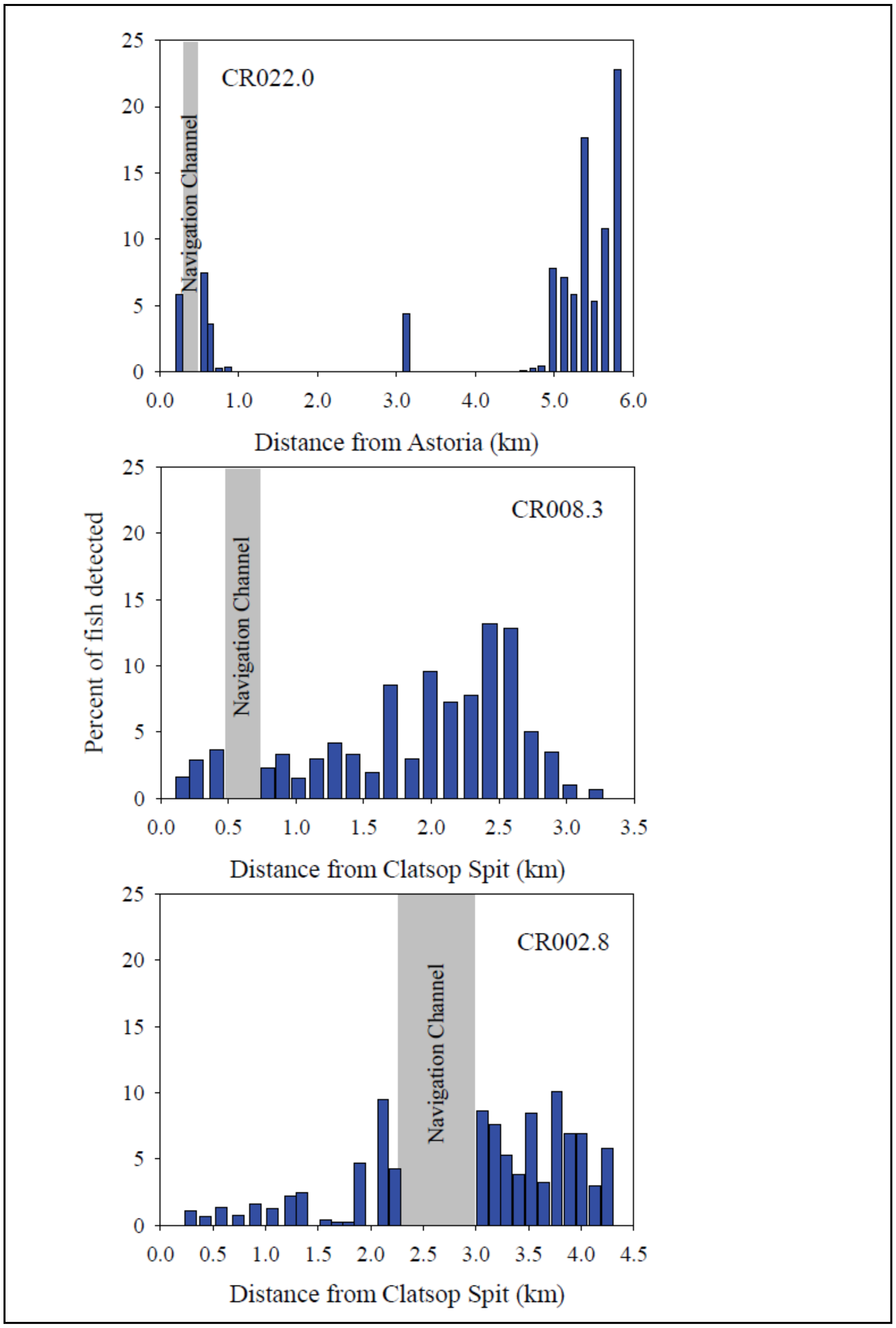


Figure 61. Cross-channel Distribution of Acoustic-tagged Subyearling Chinook Salmon

First detections at arrays at Astoria Bridge (CR022.0), East Sand Island (CR008.3), and Columbia River Bar (CR002.8; McMichael et al. 2010).



The Columbia River plume is the zone of freshwater/saltwater interface where the freshwater exiting the Columbia River meets and rises above the denser saltwater of the Pacific Ocean, just seaward of the MCR. The plume is formed as thin, buoyant lenses of fresher water flowing over denser, oceanic water and is more pronounced when flow from the river is large in comparison to tidal volume. The Columbia River plume is ephemeral and may persist for several hours and is controlled by fluctuating tide. A frontal boundary (front) is formed between the river plume and adjacent marine waters. The front is richer in zooplankton than adjacent marine waters and plume waters, being attributed to increased abundance of surface-oriented organisms (Morgan et al. 2005). The plume front is easily identified by well defined horizontal gradients in salinity and water clarity and by the accumulations of foam and flotsam (De Robertis et al., 2005).

Nutrients were not found to be more abundant in the fronts than adjacent plume and ocean waters and, therefore, it is unlikely that plume fronts are regions of greater production. Greater zooplankton biomass in the plume front was largely due to the concentration of surface-oriented species along the front, particularly Dungeness crab (*Cancer magister*) megalopae and the concentration of the eggs of northern anchovy (*Engraulis mordax*) and sanddab (*Citharichthys* spp.). This increased concentration of surface-oriented zooplankton is caused by convergent water flows at the frontal boundary. Although biomass was greater, density of all zooplankton combined (including non-surface-oriented zooplankton) was not found to be greater at the plume compared to adjacent plume and ocean waters. More bird feeding activity was noted at the front compared to the adjacent plume and ocean waters (Morgan et al. 2005). Increased bird foraging could contribute to limiting salmon use of fronts.

In the study by Morgan and others (2005), there was no significant difference in the mean temperature among the three habitats in 2001 but the plume was significantly warmer than the ocean and front habitats in 2002. The mean salinity of the front was more similar to that of the plume in 2001 and to the ocean habitat in 2002.

This multi-layered mixing zone plays an important role as habitat for juvenile salmonids. The first few weeks of their ocean life, some of which is spent in the plume, are critical for recruitment success of salmonids (Pearcy 1992). The Columbia River plume provides a high turbidity refuge from predation, provides fronts and eddies where prey become concentrated, and provides a stable habitat for northern anchovy spawning (Richardson 1981, Bakun 1996). A strong, quickly moving plume also helps juvenile salmonids move rapidly offshore.

Studies in the Columbia River plume show that juvenile salmonids typically use upper waters, above about 12 meters (Emmett et al. 2004). Many Columbia Basin salmonids enter the ocean when river flow is high and frontal formation is intensified, during spring and early summer. Therefore, there is potential for juveniles to take advantage of high prey biomass at the plume front (Morgan et al. 2005). The surface-oriented organisms found to be concentrated at the plume front are all prey that juvenile salmon have been found to consume (Morgan et al. 2005) but analysis of juvenile salmon stomach contents did not reveal greater amounts of frontal surface-oriented prey from fish occurring at fronts, nor did it identify prey groups indicative of salmon feeding in the frontal areas. Stomach fullness tended to be higher in the more marine shelf waters than either the front or plume areas, which does not support the hypothesis that salmonids consistently ingest more prey at frontal regions (De Robertis et al. 2005).

De Robertis and others (2005) found that juvenile salmonids tended to be abundant in the frontal and plume regions compared to the more marine shelf waters, but this pattern differed among species and was not consistent across two study years. Juvenile chum and yearling coho salmon were more abundant in the front than adjacent plume or ocean, while juvenile steelhead were more abundant in the front and plume than adjacent ocean. No significant differences were observed in Chinook habitat use during 2001. In 2002, both yearling coho and Chinook were more abundant in the plume than adjacent front and ocean, whereas juvenile steelhead were more abundant in the front than adjacent plume and ocean. Small numbers of chum captured in 2002 precluded statistical analysis. There was no significant difference in the fraction of marked (hatchery) fish among ocean, front, and plume habitats (this appears to indicate that hatchery fish did not use habitats differently than wild fish). This study did not support the hypothesis that juvenile salmonids congregate to feed at the plume fronts. De Robertis and others (2005) postulated that the short persistence time of these ephemeral fronts may prevent juvenile salmon from exploiting this food-rich zone. They caution that given that the plume is the first area salmon encounter during ocean entry, changes in plume structure may significantly influence the distribution and survival of salmon.

In 2009 samples and preliminary studies of juvenile Chinook salmon were conducted in the nearshore areas at the beaches immediately adjacent to the North and South Jetties; with additional sampling conducted at the North Jetty in 2010 (Marrin Jarrin and Miller, unpublished data). Sampling methodology (beach seine from approximately 1 meter depth where surf-zone borders with swash zone) was the same as that detailed in a 2009 study near the mouth of Coos Bay, which investigated yearling Chinook migratory patterns and use of nearshore, surf-zone and sandy beach habitat (Marin Jarrin 2009). Between June 23, 2009 and September 2, 2009, a total of 10 juvenile Chinook salmon were caught adjacent to the North Jetty; no Chinook were caught adjacent to the South Jetty during that same period. Additionally, between July 14, 2010 and August 12, 2010, no salmon were caught adjacent to the North Jetty (Marrin Jarrin and Miller, unpublished). Juvenile use of MCR nearshore environment may be similar to other findings from Marin Jarrin (2009) that suggest surf zone environments close to large estuaries provide important habitat for further juvenile development due to significant prey supply, shelter from predators, and proximity to low-salinity water masses, which may further aid in acclimation.

Green Sturgeon

Green sturgeon spend more time in the marine environment than other sturgeon species (Adams et al. 2002 and in press). The southern green sturgeon likely uses the action area as habitat for adult and subadult migration and feeding, as well as growth and development to adulthood by subadults. According to NMFS (NMFS 2010), when not spawning, this anadromous species is broadly distributed in nearshore marine areas from Mexico to the Bering Sea. Although it is commonly observed in bays, estuaries, and sometimes the deep riverine mainstem in lower elevation reaches of non-natal rivers along the west coast of North America, the distribution and timing of estuarine use are poorly understood (NMFS 2010). Green sturgeon in the ocean can be assumed to remain largely inside the 100-meter depth contour (Erickson and Hightower 2004). Southern DPS green sturgeon, radio-tagged in the Sacramento River, have recently been shown to occur seasonally in northern estuaries including the Columbia River estuary during the summer and early fall (Moser and Lindley 2007). Green sturgeons have been commercially harvested in the Columbia River. In the Columbia River, Israel and May (2006) found the percentage of southern DPS fish to exceed 80% (of total northern and southern DPS fish) during late summer and early fall of some years.

Observations of green sturgeon in the Columbia River are concentrated in the estuary but have been made as far upriver as Bonneville Dam. No evidence exists for spawning in this system (Rien et al. 2002). Information based primarily on fishery-dependent sampling suggests that green sturgeon occupy large estuaries only during the summer and early fall. Southern population DPS green sturgeon are known to occur in the Columbia River estuary from June until October. Tagging studies indicate that green sturgeon from all known spawning populations inhabit the Columbia estuary in summer, including a significant portion of green sturgeon from the southern DPS (Moser and Lindley 2006).

Habitat use and food habits of green sturgeon in northern estuaries have not been investigated in detail. Digestive tract contents from 46 commercially caught Columbia River green sturgeon were found to contain only algae (species unknown) and pebbles. One Rogue River green sturgeon digestive tract sample contained an exoskeleton of one crayfish (*Pacifasticus* spp.) and algae (ODFW 2005). It is possible that the algae and pebbles were incidentally ingested, however. The Rogue River fish was likely from the northern DPS.

The Corps and USGS have recently been working on a green sturgeon study in the Coos and Columbia River estuaries. Though results are preliminary and sample sizes are relatively small, acoustic receivers detected green sturgeon presence several times off the tip of Jetty A, near the North Jetty, and in the area of Social Security beach off the Clatsop Spit (USGS Preliminary 2009-2010 data). Information about specific use in the action area is still under development, but activities at Jetty A and North Jetty could cause some avoidance behavior by green sturgeon present during construction.

Eulachon

Most eulachon production originates in the Columbia River basin with spawning in the mainstem of the Columbia River upstream of the estuary and action area, (Emmett et al. 1991, Musick et al. 2000) in January or February (Beacham et al. 2005). Eulachon spawn in the mainstem Columbia River and usually spawn every year in the Cowlitz River, with inconsistent runs and spawning events occurring in the Gray's, Elochoman, Lewis, Kalama, and Sandy rivers (ODFW and WDFW 2009). Prior to the construction of Bonneville Dam, occasional reports were received of smelt occurring upstream as far as Hood River, Oregon, and possibly farther (Smith and Saalfeld 1955). In times of great abundance, (e.g., 1945, 1953) eulachon have been known to migrate as far upstream as Bonneville Dam (Smith and Saalfeld 1955, Howell et al 2001), and are suspected of passing through the ship locks, having reached the Klickitat River (Smith and Saalfeld 1955). Though eulachon have been observed migrating up the Columbia River, spawning has not been documented in the mainstem above RM 80 (Romano et al. 2002).

Larval forms outmigrate through the estuary and juvenile forms rear in marine waters extending out along the continental shelf (NMFS 2008d). Young eulachon larvae are about 4.0 to 8.0 mm in length and, are rapidly flushed to the ocean, often within days of hatching, and subsist on their yolk sac during this downstream dispersal (ODFW and WDFW 2001).

Information on the distribution and ecology of juvenile eulachon is scanty due to these fish being too small to be detected in fisheries surveys, and too large to occur in ichthyoplankton surveys (Hay and McCarter 2000). It is likely that juvenile eulachon rear in near-shore marine areas at moderate or shallow depth (Barraclough 1964) and feed on pelagic plankton, including euphausiids (krill). As they grow at sea, they tend to utilize waters of greater depths and have been found as deep as 625 meters (Allen and Smith 1988).

Adult eulachon range in size from 14 to 30 cm and are planktivorous in the ocean, but stop feeding when returning to fresh water to spawn (McHugh 1939, Hart and McHugh 1944). The homing instinct of eulachon (returning to birth streams) is not clear, but it is postulated that larvae may spend weeks to months in nearby estuarine environments where they grow significantly in size and may develop the capacity to imprint on large estuaries and eventually home to these areas as adults (McCarter and Hay 1999, Hay and McCarter 2000).

Eulachon return to fresh water to spawn at 2 to 5 years of age. Spawning in the lower Columbia River can occur soon after freshwater entry (ODFW and WDFW 2009). Eulachon typically enter the Columbia River in early to mid-January (though a small 'pilot' run may occur in December), followed by tributary entry in mid- to late January. Peak tributary abundance is usually in February, with variable abundance through March and an occasional showing in April (ODFW and WDFW 2009). Therefore, migrating adults and larvae may be in the vicinity of the jetties, and adults and rearing juveniles may be present in the near and offshore environments of the action area. However, during most of the proposed construction activities, it is unlikely that adult, eulachon will be present, though juvenile or larval life stages may be in the estuary.

Table 35 shows the life stages of marine and anadromous species that could be present in the action area during some part of the year, though not always during the bulk of associated construction actions. Many of the effects from the proposed action will be similar for all of the species. Therefore, effects discussed below are applicable to all species, unless differences or additional effects are otherwise specified.

Table 35. Life Stages of Marine and Anadromous Species

Salmon and steelhead	Sturgeon	Eulachon
1. Juveniles a. Rearing b. Migration c. Smoltification 2. Adults a. Sub-adult growth and development b. Upstream migration and holding c. Seaward migration (steelhead)	1. Adults a. Sub-adult growth and development b. Upstream migration and holding c. Seaward migration d. Seasonal holding e. Estuarine, nearshore and marine movements	1. Juveniles a. Rearing b. Migration c. Metamorphosis 2. Adults a. Sub-adult growth and development b. Upstream migration and holding

As described above, certain aspects of the proposed action are reasonably likely to result in effects to ESA-listed species in the action area. Some juvenile salmon and steelhead will be migrating and rearing in the action area, as well as eulachon, and green sturgeon over the approximately 20-year construction period. The Corps does not expect adult eulachon, sturgeon, salmon and steelhead to be injured or harmed by the proposed action. Furthermore, during the bulk of construction and vessel activities, it is very unlikely that adult eulachon will be present in the vicinity of the MCR. Most of the adults will already be upstream, and the peak emigration of juvenile and larval forms will have likely been flushed from the estuary after the spring freshets.

Rock Transport

Though within the navigation channels rock transport could increase the possible disturbance of salmon, steelhead, sturgeon or eulachon, this is unlikely to occur. Adult species are likely already attuned to this traffic, and their swimming speeds and mobility would allow perception and avoidance of these vessels. The proposed action will also not cause a significant increase in the intensity of traffic levels. Therefore, vessel traffic is unlikely to affect adult migration or holding patterns in any significant manner. Furthermore, juvenile salmonids tend to use predominantly shallower and nearshore habitat than that used by barges. The seasonality of potential larval, juvenile, or adult eulachon usage has little overlap with the likely timing of most of the barge traffic, and therefore this action is not likely to increase eulachon exposure to vessel traffic in the vicinity of MCR. Green sturgeon adults and juveniles may be present, but would likely be lower in the water column and tend to move at night. Therefore their exposure to traffic would be geographically and temporally limited. Any encounters with barge traffic will be transitory and discountable for all species. Disturbance from vessel traffic could cause movement in salmon, steelhead, eulachon, and sturgeon species that would not otherwise occur. However, proposed actions are not expected to have significant long-term impacts to migration, rearing, or holding behaviors for any of these species.

Construction Access, Staging, Storage, and Rock Stockpiling

Effects to water quality and natural habitat cover are expected to be minimal and therefore are not expected to have impacts to juvenile rearing, migration, or development, nor to adult migration or holding patterns for any of these species. Most actions will occur in the uplands above MHHW and are therefore not expected to cause in-water disturbances that could induce movements or significantly change fish behavior. Species exposure to any of these effects is highly unlikely. Construction BMPs and water quality monitoring will ensure that there are no discharges of pollutants. In the unlikely event of increased turbidity, monitoring will ensure that it does not reach the levels or duration that would have harmful impacts to fish species.

Rock Placement

Eulachon are unlikely to be present during these actions, though juveniles could be in the estuary during early summer operations. There may be some effects to this life stage, but they are not expected to be significant, as the timing does not overlap well with the peak emigration period. As indicated in the multi-year PNNL studies, in comparison to higher peaks in distribution nearer the navigation channel, cross-sectional distribution of migrating juvenile Chinook and steelhead salmon suggested only a small percentage of juveniles (~4-7% of subyearling Chinook, less for yearlings and steelhead) use the areas within a 200m proximity to the jetties. Furthermore, the residence time of juveniles within the larger MCR area ranges from a few hours up to at most a few days for the less-directed subyearling Chinook emigrants. Yearling Chinook and steelhead are more directed and within the larger MCR area have an even shorter residence times. The Corps expects that actual residence time for all juveniles in the immediate proximity of the jetty structures is likely even smaller than these extrapolations for the larger area indicated. Furthermore, a majority of the stone placement for work on the jetty root, trunk, and head will occur above MHHW, and an even higher percentage (70% or more in most cases) will occur above the MLLW elevation, which further limits the geographical distribution of the effects relative to marine and anadromous fish use in the area. Most fish present will be migrating in the water column at elevations significantly lower than this zone of work, and this is particularly true of green sturgeon. Therefore, juvenile exposure to any effects from rock placement are unlikely and would be of short duration if exposure occurred.

Migration. Some effects to migration from artificial obstruction by rock placement may occur, but they are not expected to be measurable. Besides the expected limitations to exposure, this is also because a majority of the spur groins most likely to be encountered by juveniles and adults are submerged so that fish can easily pass over the tops of them. In Table 36, MLLW represents the average height of the lower low waters over a 19-year period.

Table 36. Depths of Spur Groins with Respect to MLLW

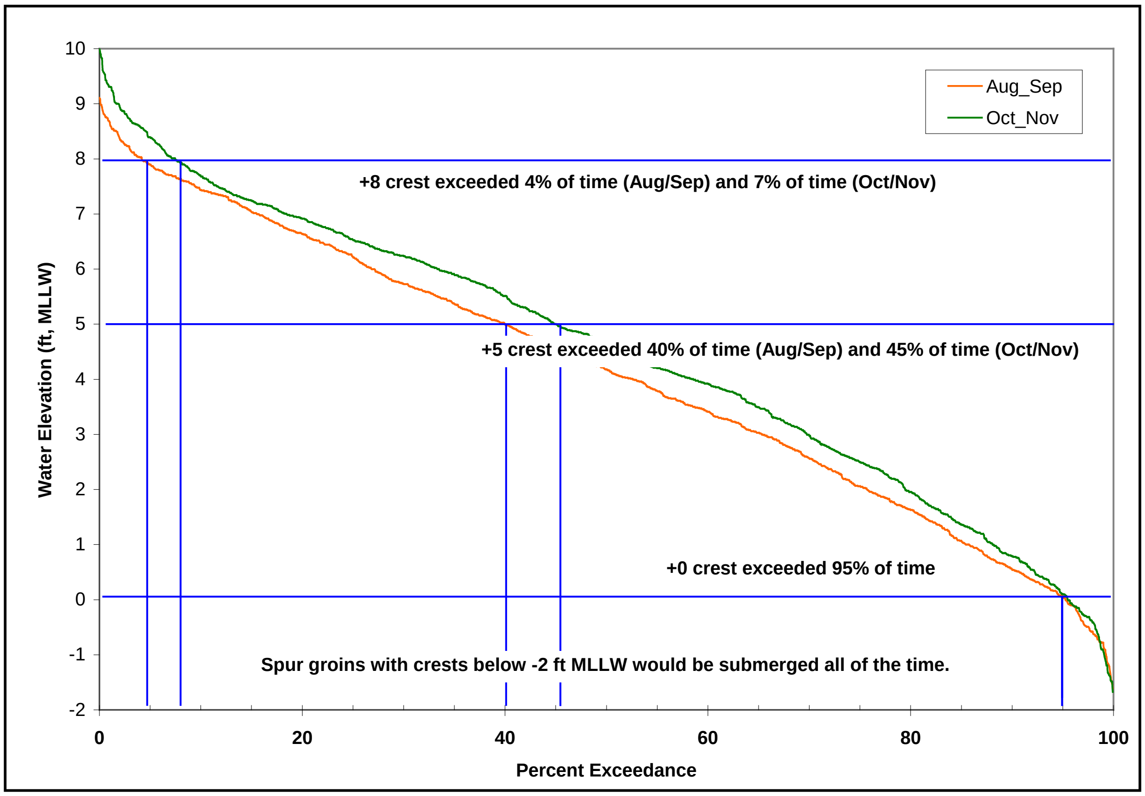
Jetty	Spur Groin	Side	Approximate Dimension (feet; LxWxH)	Acreage (+/-20%)	Depth (feet MLLW)
North	NJ1C	Channel	100x80x10	0.18	-5
North	NJ2C	Channel	170x115x19	0.45	-15
North	NJ3O	Ocean	60x80x10	0.11	+8
North	NJ4C	Channel	170x115x19	0.80	-35
A	J1C	Channel (East)	135x105x18	0.33	-5
A	J2O	Ocean (West)	125x100x15	0.29	-5
South	SJ1O	Ocean	60x80x9	0.11	+8
South	SJ2C	Channel	70x80x10	0.13	+5
South	SJ3C	Channel	70x80x10	0.13	+5
South	SJ4C	Channel	90x90x12	0.19	0
South	SJ5O	Ocean	190x125x22	0.55	-15

As discussed earlier, a limited number of juvenile salmonids could use the North Jetty area for migration. Little data is available regarding juveniles use of the South Jetty area, but it is possible that outmigration occurs in close proximity to the South Jetty as it does the North Jetty. Only spur groins on the channel side with elevations at or above MLLW could be capable of altering outmigration routes of juvenile salmonids by forcing them away from the shallower waters along the jetty proper and into deeper waters as they swim around spur groins. Otherwise, juveniles are assumed to pass over the submerged groins. Spur groins that could interfere with outmigration at times, depending on tidal level, would be located only on the South Jetty and include spur groins SJ2C and SJ3C at +5 MLLW (both 70 feet long) and spur groin SJ4C at 0 MLLW (90 feet long). Use of the jetties by eulachon and green sturgeon is also not well known.

Figure 62 shows percentage of time that the crests of spurs at 0 MLLW, +5 MLLW, and +8 MLLW would be exceeded (i.e., overtopped by water). Both spur groins with elevation +8 MLLW are not relevant to outmigration because they are on the ocean side of the jetties. Spurs

SJ2C and SJ3C on the South Jetty at an elevation of +5 MLLW would be above water 60% of the time for August-September and 55% for October-November. Spur SJ4C would be above water 5% of the time. It is expected that at some point on most ebb tides that spurs SJ2C and SJ3C would be above water, and that fish outmigrating within 70 feet of the South Jetty during that part of the ebb tide when the tops of these spur groins are exposed would have to swim around them. Though sub-yearling Chinook use nearshore areas by the North Jetty more than older juvenile salmonids and typically leave the MCR area over a period of more than one ebb tide, their exposure to these effects is expected to be minimal, and not anticipated to measurably change their migration behaviors.

Figure 62. Tidal Elevations at the MCR for August/September and October/November Time Windows with Respect to Spur Groins Subjected to Periodic Submergence



It is suspected that many, if not most, sub-yearling Chinook salmon swim to shallow, nearshore waters (i.e. just off the surf zone) after being swept out to the ocean by Columbia River flows (Emmett et al., 2004). Purse seine catches in these areas have indicated that shallow nearshore habitats are important for small (<130 mm FL) sub-yearling Chinook salmon (D. Miller, unpublished data cited in Emmett et al., 2004). Demonstration of nearshore habitat use by juvenile Chinook was also supported by studies and preliminary findings at the North and South Jetties (Marin Jarrin 2009, Marin Jarrin and Miller 2010). Fish migrating along the North Jetty could experience some minor artificial obstruction from the ocean-side spurs and be forced farther offshore in the plume before migrating to nearshore waters, although it is uncertain how far out they go with the plume before beginning migration shoreward. Therefore, because of slightly greater required swimming distance they could also conceivably be exposed to some artificial obstruction effects from rock placement, as well as possible increased risks of predation before reaching preferred shallow water nearshore habitat. However, these effects are not expected to cause measurable changes in migration or foraging behavior. These effects are even less likely at the South Jetty, where juvenile Chinook presence was not established in the initial study samples by Marin Jarrin and Miller (2010).

Rock placement is not expected to cause direct fish mortality. It is much more likely that fish would be temporarily displaced during rock placement from disturbance from rocks entering the water. Furthermore, a majority of the rock would be placed above MLLW water, which greatly reduces the likelihood of any exposure to placement actions. Additionally, as the PNNL study indicated for juvenile salmonids, the short residence time in the immediate vicinity of the jetties suggests minimal potential for significant temporal exposure to jetty constructions and maintenance activities (McMichael et. al. 2006).

Habitat Conversion: Some sandy, shallow-water inter-tidal and lagoon habitat will be converted to fill or rocky inter-tidal habitat. This includes actions from stone placement for lagoon fill at the North Jetty; the construction of spur groins, barge offloading and turn-out facilities at all jetties; and a possible slight expansion of the jetty prism at Jetty A. The conservatively estimated total of this footprint for all placement actions is 15.5 acres (North Jetty ~ 7 acres; South Jetty ~ 3.5 acres; and Jetty A ~ 5 acres). Consequently, these conversions and disturbances could result in disturbance of benthic invertebrates and a possible conversion of biological communities. Within an estimated 3-mile proximity of the MCR jetties, about 19, 575 acres of shallow water habitat (anything -20 ft or shallower) exists, of which 15.5 acres represents a difference of much less than 1 %. Therefore, these effects of habitat conversion are expected to be minimal, and unlikely to significantly impact food resources or foraging behavior of juvenile or adult salmonids or sturgeon. Bottom feeding sturgeon may experience slightly greater effects, but habitat conversion is not expected to be of an extent that would significantly limit food resources. Spawning does not occur in the areas of habitat conversion, so effects from the proposed action will not impact spawning substrate or behavior. Further, eulachon are planktonic feeders, so minimal losses of benthic invertebrates would not affect their foraging behaviors. It is also expected that juvenile salmonids and sturgeon could utilize new ephemeral sand habitat that accretes behind spur groins for migration and rearing. Deposition behind the spur groins (landward side) would provide calmer waters. Deposition of sand upstream of existing spurs has been shown on the channel side of the South Jetty.

Predator Attraction. For the proposed action it is possible that piscivorous fish capable of preying on juveniles could recruit to the spur groins, rebuilt portions of the jetties, causeways, and barge offloading facilities. When juvenile salmonids or eulachon are near these locations they could be susceptible to predation. However, the short residence time of both juvenile salmon and eulachon reduces the likelihood and duration of increased exposure. Along the jetties is also not the preferred route for juveniles as demonstrated by the PNNL studies. Furthermore, the increase in the jetty prism and expansion of the footprint is very small relative to the existing structure, and a majority of stone placement is above MLLW; therefore an increase in piscivorous fish habitat and species interaction is not expected to occur. Green sturgeon are also not likely to be significantly affected by increased predation, since they would likely remain closer to the bottom with even less exposure to predators further up in the water column and within the jetty rock structure.

At the Washaway Beach site, beach seines were deployed during May 2002 to characterize the occurrence of shallow-water fish. A total of 34,754 fish comprising 24 species were captured, 85.7% of which were surf smelt (*Hypomesus pretiosus*). Species richness (i.e., number of species per sample) was greater at the structures (19.5 species) compared to 11 and 15 at the west reference and east beach reference points, respectively. Potential predators of juvenile salmonids collected by beach seining included sub-adult coho salmon, Pacific staghorn sculpin (*Leptocottus armatus*), and lingcod (*Ophiodon elongates*). Staghorn sculpin and lingcod are both demersal ambush predators that feed on crustaceans and small fish (Emmett et al. 1991). The relatively high abundance of juvenile lingcod at Washaway Beach suggests that lingcod are recruiting to groin-associated habitats. It is clear that the structures provided habitat for predatory fish. From results of the Washaway Beach study, it is expected that piscivorous fish capable of preying on juvenile salmonids would recruit to rock structures (rebuilt jetty, spur groins, and causeways). However, a significant increase in salmonid exposure to predators is also unlikely, since juvenile residence times at the MCR and their proximal use at the jetty interface is minimal. Predators would be more likely to be within the stone structure and juvenile use in the near proximity of the jetties is limited.

Potential avian predator sightings at Washaway Beach during May 2002 in the vicinity of the structures included gulls (*Larus* spp.), Bonaparte's gull (*Larus philadephia*), surf scoter (*Melanitta perspicillata*), common loon (*Gavia immer*), Pacific loon (*Gavia pacifica*), cormorants (*Phalacrocorax* spp.), Northwestern crow (*Corvus caurinus*), tern (*Sterna* spp.), Western grebe (*Aechmophorus occidentalis*), and bald eagle (*Haliaeetus leucocephalus*). The mean number of avian predators observed per survey was less at the structures than at the reference points. At the MCR, the relatively small amount of additional rock from rehabilitation of jetties and construction of spur groins and causeways could increase perching opportunities for piscivorous birds, especially cormorants and brown pelicans. However, these perching opportunities are currently abundant in the lower Columbia River and are not expected to increase cormorant and pelican use of this area such that predatory pressure would be measurably increased. Similarly, the addition of stone is not expected to increase use by pinnipeds preying on adult salmonids, eulachon, or green sturgeon, since availability of jetty rock is not currently a limiting factor for pinniped populations. Effects of increased predation at the jetties are expected to be immeasurable and discountable.

Dredging

The elevation at barge offloading sites will require access to navigable waters and a dredge prism with a finish depth of -25 feet below MLLW, with maximum advance maintenance and disturbance depths not to exceed -32 feet MLLW. Facilities will have an approximate footprint of 400 feet x 400 feet. The depth along the barge unloading sites would be maintained during the active period for which the rock barges will be unloaded. Each facility will require about 4 acres of dredged area, and there are 2 facilities identified for the South Jetty and one each at North Jetty and Jetty A.

If all four offloading facilities were utilized simultaneously, this would result in a dredged area of approximately 16 acres. Within an estimated 3-mile proximately of the MCR jetties, about 19, 575 acres of shallow water habitat (anything -20 ft or shallower) exists. Therefore, as with stone placement, this results in a habitat conversion of less than one percent. Furthermore, it is more likely that only one or two facilities would be needed per year, which makes the relative percent of habitat conversion even smaller. Though there will be loss of benthic invertebrates in areas dredged, only negligible losses to food resources of juvenile salmonids or sturgeon are expected to result. Because eulachon feed on plankton, their foraging habitat will not be affected. Some sandy, shallow-water inter-tidal habitat will be converted to deeper inter- and sub-tidal habitat. Consequently, these conversions and disturbances could result in a possible conversion of biological communities with changes in depth and light penetration. The extent is expected to be minimal and recolonization is expected to be rapid. These effects are unlikely to significantly impact food resources or foraging behavior of juveniles or adults.

Most rearing of juvenile salmonids in the Columbia River estuary occurs in the upper part of the water column near the shore and in shallow-water areas (Bottom et al. 2005 cited in Corps 2004). Also, it is known that subyearling Chinook and chum salmon occupy shallow, nearshore habitats (Healey 1982 and others cited in Bottom et al. 2005). Therefore, it is likely that juvenile salmonids could use areas near the bottom where dredging for barge offloading facilities would be required. However, juvenile salmonid entrainment by clamshell dredges is very unlikely. This is supported by the assessment in the recent Coastal Biological Opinion (NMFS 2010), which evaluated dredging and disposal actions on a much larger scale relative to those proposed in this action. Green sturgeons are more likely to utilize bottom habitats that could be dredged, but they are equally likely to avoid entrainment. Temporary displacement of fish from disturbance could occur for short periods of time. More likely, fish would be forced into moving to other nearby suitable habitat during dredging. Eulachon may be affected during dredging activities, but it is not expected to be significant, and the timing is not likely to overlap with the emigration peak.

Effects on fish from changes in water quality due to dredging are discussed in that section.

Disposal

The effects of these actions are not expected to be different than those previously considered when the ODMDS were under evaluation. Activities from the proposed action are expected to be of significantly smaller scale and frequency than a majority of the disposal actions already occurring at the sites. As with dredging, there will be a temporary loss of benthic invertebrates in disposal areas. Some mounding could occur, resulting in some temporary changes to biological assemblages. However, actions are expected to be confined to the existing ODMDS disposal sites, and rapid invertebrate recruitment is expected. Therefore, only negligible losses to food resources of juvenile salmonids and sturgeon are expected to result.

As mentioned, subyearling Chinook and chum salmon shift to deeper habitats farther away from the shoreline as they grow to fingerling and smolt stages (Healey 1982 and others cited in Bottom et al. 2005). Therefore, they may be present in the disposal area along with adult and juvenile green sturgeon and eulachon. Though some exposure to the disposal plume may occur on an annual basis, fish would likely practice avoidance behaviors and be forced into moving to other nearby suitable habitat during disposal activities. Direct fish mortality from the disposal plume is not expected. These actions are not expected to significantly affect rearing, holding, or migration patterns of juveniles or adults.

Effects on fish from changes in water quality due to disposal are discussed in that section.

Barge Offloading Facilities

As described, construction of barge offloading facilities, including stone placement, dredging, and pile installation and removal could cause temporary minor disturbance to fish. The coming and going of barges could also induce movement in salmonids and sturgeon that may be present in the vicinity. Though vessel movement may occur several times daily during construction season, it will be temporally limited in duration and geographically isolated to the navigation channel and facility. As with stone placement, fish distribution identified by PNNL studies could also indicate that use in the vicinity of the facilities is expected to be relatively low, and changes in migration or behavior patterns are expected to be immeasurable. Eulachon are not likely to be present during construction or use of barge offloading facilities and will not experience increased exposure to these effects.

Effects to fish from increased piscivory are not expected, as piling caps will avoid any significant increase in new perch sites. The effects to fish from dredging, pile installation and removal, and water quality at these facilities are discussed under their respective sections.

Pile Installation and Removal

As mentioned previously, for initial construction of all four facilities combined, up to approximately up to 96 Z- or H-piles could be installed as dolphins, and up to approximately 373 sections of Z or H piles installed to retain rock fill. However, it is unlikely that all facilities would be installed at the same time. Installation is likely to happen early in the construction season sometime between April and June, and is weather dependent. Piles will be located within 200-ft of the jetty and offloading structures. Vibratory drivers will be used and will dampen any acoustic effects to fish and other species. Further, impacts would be of short duration and intermittent in frequency. It is likely that sound will attenuate to near background levels a short distance from the source. Because of the vibratory methods being used, sound levels are not expected to reach levels that are harmful to fish. Additionally, fish distribution in the immediate vicinity of the jetties is less likely than further towards the navigation channel, so fewer juveniles will be in near proximity of the piles. Minor avoidance behavior may occur as a result of pile installation and removal, but this is not expected to significantly alter juvenile or adult migration or holding patterns. Eulachon are not likely to be present in the vicinity of the action area when installation happens, and will not be exposed to acoustic effects. Therefore, this action is not expected to have any significant or direct negative effects to marine or anadromous fish.

Wetland and Lagoon Fill and Culvert Replacement

As mentioned, the lagoon and wetlands at both the North and South Jetties are thought to be separated from direct regular ocean connectivity. There is little likelihood that listed species are present in these areas or that they would be exposed to any of these actions. The fill is also not expected to have any significant negative effects on the habitat values or functions in the vicinity of the MCR such that impacts to water quality, natural cover, or forage would occur. Proposed fish salvage and fish exclusion measures that the South Jetty will further preclude the likelihood of impacts or exposure to effects of fill activities.

Dune Augmentation

A majority of the work and the entire amount of proposed fill for this action occurs above MHHW. Therefore, fish exposure to effects is highly unlikely. There is little likelihood of having any direct or indirect negative impacts to water quality or intertidal species, and the amount of dry sand conversion is relatively small compared to the amount of similar adjacent habitat that is available. Effects to marine and anadromous species are expected to be immeasurable.

Water Quality

Water quality effects of the proposed action which could indirectly affect fish include possible exposure to increased suspended sediments. It has been noted (NMFS 2004) that for coho salmon, concentrations of 250 ppm of suspended sediment for 1 hour caused a 95% reduction in feeding rates in juveniles, concentrations of 1,200 ppm for 96 hours killed juveniles, and concentrations of 53.5 ppm for 12 hours caused physiological stress (Noggle 1978) and changes in behavior (Berg 1983). In the high energy environment of the proposed project, however, it is expected that turbidity would dissipate before these sorts of adverse impacts would result. Also, fish are expected to be capable of escaping turbid situations. Background levels in the Columbia River have shown that turbidity readings can fluctuate by over 10% for samples taken at the same time in close proximity to each other (Corps 2005).

Salmon, sturgeon, and eulachon are mobile enough even as juveniles to avoid areas of high turbidity. Further, salmonids may intentionally use the very turbid plume extensively during their outmigration. It has been hypothesized that juvenile salmonids seek out turbid waters in estuaries in order to better conceal themselves from potential predators (Simenstad et al. 1982, Thorpe 1994). Because of rapid dissipation of turbidity in a high energy environment and motility of juvenile and adult salmonids, increases in turbidity will likely not result in reduction in feeding rates and growth, physiological stress, or increased mortality. Movement from turbid areas and behavioral avoidance of turbid areas by salmonids would likely result.

Operation of heavy equipment requires use of fuel, lubricants, etc which if spilled into the water can have direct negative effects and can kill or injure aquatic organisms. Because of preventative and response measures required in a Spill Prevention and Response Plan as well as the low chance of occurrence, it is unlikely that spills would adversely affect fish. Additional BMPs described in the proposed action further reduces the likelihood of spills or leaks occurring.

Furthermore, migration of creosote and its components [e.g., copper and polynuclear aromatic hydrocarbons (PAHs)] from treated wood in lotic environments can adversely affect juvenile salmon (NMFS December 1998). However, this exposure is unlikely because use of treated wood has been prohibited. Increased contamination from the dredge and disposal actions is equally unlikely to cause direct or indirect harm to water quality or fish, as all test results have indicated safe levels for in-water disposal.

Hydraulic and Hydrological Processes

As mentioned, modeling results were indicative of small changes that were predicted from a larger-scale length rebuild scenario. Results remain informative because the relatively small changes that were expected from a larger action were still not expected to have significant negative effects on juvenile salmonids. The smaller currently proposed action, which only includes spur groins and not additional lengths from the original model, would be expected to have even few effects. The majority of juvenile salmonids outmigrates in late spring and early summer, although fall Chinook salmon typically have a more extended outmigration period than other Columbia Basin salmonids and commonly outmigrate in late summer as well. Therefore, modeling results for the August-September timeframe were more relevant than results for the October-November timeframe since riverine flow and oceanographic/circulation conditions from the August-September timeframe were more similar to the heavy outmigration period of late spring and early summer. Similarly, since juvenile salmonids typically use near surface waters, modeling results for these waters, as opposed to bed zone waters, are of primary interest. Changes to bed zones would be more applicable to green sturgeon.

As discussed previously, most rearing of juvenile salmonids in the Columbia River estuary occurs in the upper part of the water column near the shore and in shallow-water areas (Bottom et al. 2005). Also, it is known that subyearling Chinook and chum salmon occupy shallow, nearshore habitats but shift to deeper habitats farther away from the shoreline as they grow to fingerling and smolt stages (Healey 1982). Changes to bed morphology were not expected to result in extensive or significant deepening of shallow water habitats important to juvenile salmonids and sturgeon for rearing. Negative impacts to juvenile green sturgeon and salmonid rearing habitat will not likely result from the changing environmental conditions at the MCR jetties themselves. The most significant scouring effects that were predicted at the seaward half of the North Jetty and near the tip of Jetty A are no longer as likely under the current scenario, as no changes in lengths are proposed. Maximum change to bed level was predicted to be 1.25 to 1.50 meters in these areas, which was a small percentage (8%) of the existing 12-24m depth. This scouring was also predicted to occur in deep areas, much too deep for juvenile salmonids to be using near bottom habitat. As discussed earlier, juvenile salmonids typically seek out shallower waters while rearing in the estuary. For green sturgeon, bed load effects may be more relevant, but were not expected to be significant enough to alter habitat use or foraging opportunities.

Juvenile salmonids gradually acclimate to increased salinity as they move downstream through the Columbia River estuary. Juvenile salmonids can regulate the salinity around them by moving up or down in the water column, since heavier, more saline waters are found at greater depths. Ocean-type salmonids (e.g., sub-yearling Chinook) tend to occupy less saline waters in estuaries than stream-type salmonids (e.g., coho). Previously predicted local mean salinity changes of 0-4 ppt compared to the natural 20 ppt variation was and is not thought to represent a change at the MCR that would adversely affect juvenile salmonids, since it is a small change relative to natural variation that occurs in the area. Without a length rebuild, changes to salinity are highly unlikely and discountable.

Changes to water velocities are not thought to adversely alter how juvenile salmonids use the MCR. Surface current direction for the August-September timeframe is predicted to change slightly toward the north as water flows around Jetty A, forming a more pronounced clockwise eddying effect west of Jetty A and tending to force water more directly toward the North Jetty. It is possible that creation of a more pronounced eddying effect west of Jetty A may induce some juvenile salmonids, especially those that tend to spend more time in the estuary (e.g., sub-yearling Chinook salmon), to use habitat just downstream of Jetty A to a greater degree with the proposed action.

Wetland Mitigation and Habitat Improvements

In the long term, implementation of wetland mitigation and habitat improvement actions along with upland plantings will increase the overall square footage of higher-value wetlands, thus potentially improving wetland-stream hydrologic functions in the Columbia River estuary. This could also help improve water quality, natural cover, and forage opportunities that could benefit adults and juveniles. Improvement and restoration of low saltwater marsh habitat and shallow-water, intertidal sand and mudflat habitat in the estuary and within the vicinity of MCR will increase and improve habitat access for juveniles and adults near the area where the majority of the proposed actions will occur. This will also help improve and increase instream, riparian, and estuarine functions (e.g., creation of brackish intertidal and mudflat habitat, streambank stability, and improved canopy cover). Project goals and actions would result in benefits to listed species including increased juvenile habitat for resting, rearing, and refuge. Restoring tributary connectivity to the estuary would also reduce artificial obstructions and improve adult fish passage and access to headwaters and expanded potential spawning habitat. Wetland mitigation will restore any short functional losses associated with fill activities, which are expected to be minimal and short-term in nature.

Proposed actions that convert uplands and pasturelands to interdunal and saltwater marsh wetlands and high-quality, shallow-water, lower-velocity habitats available to juvenile fish would provide improvements that are beneficial to several species including sturgeon and salmon. Adult salmonids would also benefit by improved access and connectivity to additional tributary habitat. As previously discussed, several of the potential 7 (a) (1) projects contain management actions that have been included in Estuary Module of the Recovery Plan (NMFS 2007c). These management actions also received higher rankings for potential benefits, and higher percentages for increased survival of salmonids. The Corps expects long-term benefits and improvements to have a positive effect on the species.

Temporary short-term effects of the action to water quality and noise levels will be of limited duration and geographical scope due to BMPs. For invasive species removal, the Corps proposes to use no herbicides within 100 feet of the Columbia River or associated water bodies, and therefore does not expect negative effects on instream or riparian function. Short-term disturbances are expected to be minimal and discountable.

Marine Mammals

Marine mammals known to occur in the Columbia River offshore area include whales, dolphins, porpoises, sea lions, and seals. Most cetacean species observed by Green and others (1992) occurred in slope (600- to 6,000-foot depths) or offshore waters. Harbor porpoises and Gray whales were prevalent in shelf waters less than 600 feet deep. Pinniped species likely to occur in the vicinity of the jetties are harbor seal, California sea lion, and Steller sea lion (also known as northern sea lion). An important haul out area for Steller sea lions occurs on the South Jetty.

Steller Sea Lions

The Steller sea lion breeds along the west coast of North America from California's Channel Islands, to the Kurile Islands and the Okshotsk Sea in the western north Pacific Ocean and are year-long residents along the Oregon Coast. Steller sea lions are found in Washington waters and use haul out sites primarily along the outer coast from the Columbia River to Cape Flattery, as well as along the Vancouver Island side of the Strait of Juan de Fuca. Although breeding rookeries are located along the Oregon and British Columbia coasts, no breeding rookeries are found in Washington. In Washington, Steller sea lion numbers vary seasonally with peak counts of 1,000 animals present during the fall and winter months. Haulout sites are found on jetties, offshore rocks, and coastal islands. This species may also be found occasionally on navigation buoys in Puget Sound (Jeffries et al., 2000). Important haul out sites in Oregon include the Columbia River South Jetty, Ecola State Park, Sea Lion Caves, Three Arch Rock, Cape Arago, and Seal Rock. Steller sea lions are not known to use the MCR North Jetty or Jetty A. While breeding areas in Oregon including Rogue Reef (Pyramid Rock) and Orchard Reef (Long Brown Rock and Seal Rock) are federally-designated as critical habitat, the MCR South Jetty is not.

Steller sea lion population counts for Oregon have increased since 1976. Counts were relatively stable in the 1980s in Oregon and ranged from 2,000 to 3,000 Steller sea lions. The 1996 Steller sea lion count for the Oregon Coast was 3,990 (Hill and DeMaster 1998). In 1984 and 1985, year-round counts ranged from 769 to 2,352. During this survey, peak counts (2,352) were made on May 21 and 23, 1984 with haul out attendance greatest at Ecola State Park, Sea Lion Caves, Orford Reef, and Rogue Reef (Brown 1988). Peak attendance at the two Oregon rookeries occurs during May, June, and July. Sea lions begin to leave the rookeries in August. Males are the first to leave, followed by females within a few months (Gentry and Winthrow 1986). Seasonal shifts in the use of haul out sites are common among Steller sea lions. Steller sea lion numbers appear to be lower off Oregon in the winter than summer. Steller sea lions forage at river mouths and nearshore areas along the coast. Roffe and Mate (1984) determined that proximity to the mouth of a river was the most important factor in determination of forage areas.

The Columbia River South Jetty is used only as a haul out site and no known reproductive activity occurs there, although limited reproductive activity may occur. Use occurs chiefly at the far west end (approximately the last 1,000 yards) west of the highly eroded area. With erosion of the jetty landward, this area has become and island and is different than the rest of the jetty as it is composed of concrete blocks instead of irregularly shaped rocks. California sea lions (*Zalophus californianus californianus*) also use this area and can intermingle with Steller sea lions but use the rubble mound structure more; it appears Steller sea lions outcompete California sea lions for the preferred haul out area on the concrete block structure. A flyover count of the

South Jetty on May 23, 2007, observed 1,146 Steller sea lions on the concrete block structure and none on the rubble mound, while 352 California sea lions were observed on the rubble mound and none on the concrete block structure. Both species use the rubble mound structure extensively during winter when the concrete block structure is underwater with high seas.

California sea lions are known to occur in close proximity to human activity at various locations in Oregon bays and rivers and over the past several years have caused concerns because of their presence at Bonneville Dam, including in the fish ladder. Steller sea lions generally don't occur in close proximity to human activities in Oregon, but during spring of 2007 several were recorded at Bonneville Dam along with California sea lions and were trapped and relocated.

The Steller sea lion has no distinct migration but disperse to areas like the jetty from rookery areas after the breeding season (spring). Steller sea lions are present, in varying abundances, all year (Table 37). Abundance is typically lower from May-July as adults are at the breeding rookeries, although this is not always true as evidenced by the flyover count of the South Jetty on May 23, 2007 (WDFW 2007). Only non-breeding individuals are typically found on the jetty during May-July, and a greater percentage of juveniles are present. Abundance increases following the breeding season. All population age classes, and both males and females, use the South Jetty for haul out as opposed to the California sea lions, where only dispersing males from the south (California and Mexico) are found as far north as Oregon and use the jetty.

Table 37. Average Number of Pinnipeds by Month at South Jetty, 1995-2004

Month	Number of Years Surveyed	Average Number of Steller Sea Lions	Average Number of California Sea Lions	Average Number of Harbor Seals
January	1	246	18	0
February	4	246	50	0
March	1	635	39	0
April	3	613	48	1
May	4	252	42	0.75
June	8	245	82	1.75
July	4	385	56	0
August	2	486	27	0
September	0	---	---	---
October	1	168	63	0
November	1	923	297	0
December	1	1,106	725	0

Data from Oregon Department of Fish and Wildlife

Rock Transport. Though within the navigation channels rock transport could increase the possible exposure for vessel collisions with Steller sea lions, negative effects are unlikely to occur. Marine mammals using this area are likely already attuned to this traffic, and their swimming speeds and mobility would allow perception and avoidance of these vessels. Further, vessels are slow-moving, follow a predictable route, and do not target sea lions.

Steller sea lions may be more skittish than California sea lions on the South Jetty. During a boat trip around the South Jetty on June 20, 2006, a group of approximately 50 sea lions, all or the majority being Steller sea lions, were flushed off the seaward end of the rubble mound upon approach of a Corps' hydro-survey boat. Flushing occurred at a distance greater than 100 yards, and was reported to NMFS under Section 109 of the MMPA (Corps 2006). This group of sea lions was observed back on the jetty 0.5 hour later. On that day, three California sea lions that were hauled out at approximately station 287 at the area of the South Jetty formerly known as the "notch" (landward of the group of Steller sea lions) permitted closer approach without flushing than did the Steller sea lions on that same day. With major rehabilitation of the Columbia River jetties, an IHA permit would again be obtained from the NMFS. With issuance of the IHA, disturbances of pinnipeds are recorded and reported to NMFS throughout the construction period. Sound disturbance is discussed in further details under Pile Installation and Removal.

Construction Access, Staging, Storage, and Rock Stockpiling. As mentioned previously, South Jetty is an important year-round, non-breeding haul out site for Steller sea lions. They primarily use the concrete block structure which has separated and become an island with erosion of the rubble mound structure landward of the concrete monolith. This concrete block structure is the farthest ocean-ward, above-water portion of the South Jetty. Steller sea lions are not known to use the North Jetty or Jetty A. Because Steller sea lions and other pinnipeds are known to haul out on the rubble mound structure in the vicinity of where the jetty head will be rebuilt, disturbance from construction will likely force animals off the rubble mound structure. However, construction will occur within limited temporal scale from May to October of any given year. During this time, sea levels typically allow sea lions to access the concrete block structure, rather than forcing them to use the more landward jetty root and trunk. Sea lions use the rubble mound structure more in the winter when the concrete block structure is under water. Available space on the concrete block structure is greater during summer because fewer animals are typically there. None of the proposed actions at the South Jetty directly involve these locations, so it is unlikely that activities will have a long-term effect on use of the nearshore waters, haulouts, or traditional rafting sites.

Noise will be generated above and below the water by operation of construction equipment and related activities. The trucks and crane used to move the jetty rocks will generate a moderate degree of noise. Acoustic disturbance may have some effect on the zones around terrestrial and aquatic habitats used by sea lions and therefore could cause some disturbance and movement. However, this is not expected to be significant, given responses under previously conducted actions. Interim repairs on the South Jetty during spring and summer of 2007 occurred to station 290 and had minimal effects on pinnipeds. Monitoring of sea lions (and harbor seals, *Phoca vitulina*) during construction was required by an Incidental Harassment Authorization (IHA) permit issued by NMFS under the Marine Mammal Protection Act (MMPA; NMFS 2007b). During construction, sea lions were often seen in the water close to the jetty and to a lesser extent on the jetty but appeared to be unaffected by construction activities and often swam close to construction activities and at times appeared to feed (several animals diving underwater at the same time) in close proximity to construction activities. Two incidental harassments of pinnipeds were reported during the 2007 interim repairs, and both occurred when a pinniped monitor unknowingly approached close to animals on the jetty; one was a California sea lion and the other was a harbor seal (Corps 2007). Both occurrences were minor and resulted in the animals moving. The majority of Steller sea lions occurring on the concrete block structure were far away from construction activities and undisturbed.

The Corps will again request an IHA permit from NMFS for incidental harassment of Steller sea lions, as well as non-federally listed California sea lions and harbor seals during construction.

Rock Placement. Acoustic and equipment traffic disturbances and effects similar to those described in the Construction Effects section may also occur during rock placement and are applicable here. Construction is not expected to change current patterns around the South Jetty head since the gap between the rubble mound head and the concrete block structure will not be filled in. Prey resources for sea lions are not expected to be affected. When construction is complete, more available jetty rock will exist but is not expected to substantially improve haul out opportunities; this not a limiting factor controlling Steller sea lion population numbers at the South Jetty. The preferred concrete block structure used extensively for haul out of Steller sea lions will be unaffected by repair actions. Steller sea lions are not expected to experience direct or long-term negative effects due to changing environmental conditions at the MCR.

According to the Biological Opinion for interim jetty repairs (NMFS September 2006), behaviorally, Steller sea lions respond to anthropogenic disturbances by vacating the area. Sea lions will likely redistribute themselves along portions of the jetty away from construction activities and to other haul out sites in the lower river and along the coast to the south and north. With this expected response the number of sea lions present on the jetty will likely temporarily decrease, followed by a gradual re-population of the jetty as substrate for hauling out is left undisturbed after construction. The proposed action likely will not cause a permanent reduction in the number of Steller sea lions that haul out on the South Jetty. Because the nearest breeding in Oregon occurs farther to the south, the proposed action will not affect Steller sea lion breeding activity because breeding adults will not be present during the proposed construction periods and. The project likely will cause short-term displacement of individuals but no mortality or injuries (NMFS September 2006). See Pile Installation and Removal for additional discussion regarding acoustic effects.

Dredging. Besides avoidance responses similar to that described under Rock Transport and Construction Staging, dredging activities are not likely to have any other significant impacts to the prey resources or habitat use by Steller sea lions. Slightly increased acoustic effects are not expected to reach harmful levels, though through disturbance could cause additional movement. Facilities requiring dredging are likely to be at least 1000 ft from the concrete monolith, and could be as far as 6000 feet from the monolith. This will allow some sound attenuation and reduces exposure sea lions will experience from construction and maintenance of the nearest offloading facility. These actions are also not expected to significantly alter aquatic habitats or nearshore waters around this haul out, or affect traditional rafting sites.

Disposal. As with disposal actions and vessel traffic, these activities are not expected to increase disturbance levels that will have additional significant negative impacts to Steller sea lions. Acoustic impacts from disposal will be even less than those from dredging, as disposal sites are further away from the South Jetty. They would be unlikely to cause any increase above background noise or vessel traffic near the South Jetty head. Water quality effects are discussed below.

Barge Offloading Facilities. These facilities will not be located along the jetties where sea lions prefer to haul out. Though they could experience effects previously described under Rock Placement as well as under Pile Installation and Removal, these indirect disturbances are expected to be minor and of short duration. No nearshore or haul-out habitat would be permanently reduced or altered in a way that would significantly reduce access by Steller sea lions. Facilities requiring piles are likely to be at least 1000 ft from the concrete monolith, and could be as far as 6000 feet from the monolith, which is one of the areas of heaviest use. This reduces some of the effects exposure sea lions will experience from construction of the nearest offloading facility. Sound levels will likely attenuate closer to background at this distance.

Pile Installation and Removal. Pilings for the barge offloading facility on the South Jetty would be in closest proximity to the haul-out area most heavily used by stellar sea lions. This means about 24 Z- or H-piles of 12-16 inches in diameter could be installed as dolphins, and up to about 94 sections of Z or H pile to retain rock fill installed by vibratory hammer within 200-ft of the jetty structure. These facilities are likely to be at least 1000 ft from the concrete monolith, and could be as far as 6000 feet from the monolith. This reduces some of the exposure sea lions will experience from construction of the nearest offloading facility. Furthermore, vibratory hammers will attenuate most of the acoustic effects from these installation and removal operations. Acoustic effects are not expected to reach harmful levels and will be further dampened farther from the source, becoming somewhat closer to background in the vicinity of the monolith. The additional sound levels may cause some avoidance behavior, but it is not expected to cause a long-term alteration in use of the haul-out or to foraging behavior. According to NMFS guidance (NMFS 2010c), current in-water acoustic thresholds (excluding tactical sonar and explosives) for Level B Behavioral Disruption from non-pulse noise like vibratory hammers is 120 dB_{RMS}. The threshold for Level A Injury is 190 dB_{RMS} for pinnipeds and 180 dB_{RMS} for cetaceans. Current in-air acoustic thresholds for Level A injury are not established. For Level B, behavioral disruption in harbor seals, the threshold level is 90 dB_{RMS}, and for non-harbor seal pinnipeds is 100 dB_{RMS}. Frequency bands relevant to pinnipeds (Steller and California sea lions, harbor seals, northern elephant seals) are 0.75-75 kHz (NMFS 2010c).

According to the NMFS Biological Opinion and analysis done for interim jetty repairs (NMFS September 2006), for marine mammals, sound pressure levels (SPLs) greater than 100 decibels (dB) in air re:20μPa when using an impact hammer to drive a pile have been shown to affect behavior. In addition to airborne sound, underwater sound produced by in-water pile driving can have detrimental effects on marine mammals, causing stress, changes in behavior, and interference with communication and detection of predators and prey. The most significant detrimental effect that loud underwater noises can have on marine mammals is a temporary or permanent loss of hearing. Based on studies, previous pile-driving projects, and consultation with experts, and review of the literature, the previous analyses concluded that marine mammals may exhibit behavioral changes when exposed to underwater impulse SPLs of 160 dB root mean square (RMS) re:1μPa (70 FR 333-338; 68 FR 64595) (NMFS September 2006). In addition, underwater SPLs at 190 dB_{RMS} re:1μPa (impulse) and above can cause temporary or permanent hearing impairment in sea lions (NMFS September 2006). NMFS used the practical spreading model for sound levels, $dB = 15*\log(R1/R2)$, with peak and RMS values of 177 and 165 dBRMS re: 1μPa respectively (Popper and Hastings 2005), the distance within which Steller sea lions will likely show behavioral changes is 75 feet (NMFS September 2006). The sound level values used in the equation were for driving 12-inch timber piles with a drop hammer which is a close estimate to the 16-inch timber piles driven with a vibratory hammer in the previously proposed project (NMFS September 2006).

The response of Steller sea lions to disturbances can consist of head alerts, approaches to the water, and flushes into the water. Disturbance of Steller sea lions will occur intermittently throughout the proposed work windows. The number of Steller sea lions disturbed daily will vary based on weather conditions, season, and daily fluctuations of abundance at the South Jetty. Steller sea lions will likely be hauling out in the action area for the duration of the proposed project. Disturbance from airborne and underwater construction noise and pile driving is likely to have no more than a short-term, negligible adverse effect from impact on their behavioral patterns at the South Jetty (NMFS September 2006).

Lagoon and Wetland Fill and Culvert Replacement. These proposed actions will likely be mostly out of the preferred vicinity near the South Jetty haul-out. It is not likely to have any significant affects on foraging behavior or prey availability, and actions are not likely to cause any changes to habitat usage. Acoustic effects are expected to be discountable at this distance from the South Jetty.

Dune Augmentation. This activity may have some effect on nearshore areas that could be used by Steller sea lions due to its proximity to the haul-out at the South Jetty head. Acoustic effects are described further under the Pile Installation and Removal Section. However, this action is expected to occur for a short duration in a single season at a distance of 2.6 miles from the South Jetty monolith, and therefore is unlikely to have any measurable negative impacts on sea lion use of that area.

Water Quality. Water quality effects to Steller sea lions could be similar to those for anadromous fish. However, exposure to suspended sediment could be easily avoided, though possible exposure to spills and contamination could be equally harmful. However, as described under Water Quality in the anadromous fish section, the likelihood of a significant spill occurring is relatively low with the Spill Plan and BMPs that are proposed. Contaminated sediments are also not an issue at the site.

Hydraulic and Hydrological Processes. Any potential effects to water velocity, salinity, plume dynamics or bed morphology are not expected to have significant or negative effects on the aquatic prey resources or physical habitat features utilized by sea lions in the area. Any changes to currents or velocities in the area are expected to be minimal and localized. Sea lions have swimming speeds and mobility that should not be affected by any insignificant modifications to these conditions.

Mitigation and Habitat Improvements. The Corps is not proposing wetland mitigation or habitat improvements that will directly affect Steller sea lions. Indirectly, an improvement in habitat conducive to anadromous fish survival and development could also improve the amount of prey species that may be available to sea lions.

Whales

The blue whale, fin whale, sei whale, sperm whale, humpback whale, and the killer whale all occur as migrants in waters off the Washington and Oregon coasts. They could occur in the vicinity of the barge transport routes, but would be unlikely in the shallower, nearshore and estuary vicinity of the MCR area. Though these species may occur near the proposed project area, information on numbers, distribution, and feeding habits in the immediate action area is lacking. The Southern Resident killer whale population consists of three pods designated J, K and L, each containing 24, 22 and 44 members respectively (Ford et al. 2000; Center for Whale Research 2006, unpublished data). These pods generally spend late spring, summer and fall in inland waterways of Washington State and British Columbia. They are also known to travel as far south as central California and as far north as the Queen Charlotte Islands. Winter and early spring movements are largely unknown for this DPS. There have been four sightings of Southern Resident DPS within the Columbia River plume (NMFS 2007d). There have been four documented sightings of Southern Resident killer whales off the coast of Oregon and Washington near the Columbia River, in 2005 and 2006. Two sightings were in March and two in October (NMFS 2008a).

Several whales were observed from the South Jetty during the 2007 interim repairs. According to Maser and others (1981), occurrence of blue whales off the Oregon Coast is primarily in May and June and August through October. Blue whales typically occur offshore as individuals or in small groups and winter well south of Oregon. Fin whales also winter far south of Oregon and range off the Oregon and Washington coasts during summer. Whaling records indicate that fin whales were primarily harvested off Oregon from May to September. Sei whales also winter south of Oregon. Based on information from central California, sei whales probably occur in southward migration off the Oregon Coast in late summer and early fall. Sperm whales occur as migrants and some may summer off the Oregon and Washington coasts. Sperm whales forage in deep waters and strandings have occurred along the Oregon Coast. Humpback whales primarily occur off the Oregon Coast between April and October with peak numbers occurring during June, July, and August. The following analysis of effects applies to all listed whale species in the action area, including: blue, fin, humpback, killer, sei, and sperm whales.

Rock Transport. As with Steller sea lions, rock transport could increase the exposure for vessel collisions for whales within the navigation channels. However, negative effects are unlikely to occur because the level of traffic increase is insignificant (a maximum increase of 8-22 vessels per year), whales using this area are likely already attuned to this traffic, and their swimming speeds and mobility would allow perception and avoidance of vessels. Further, tugs and barges are slow moving, follow a predictable course, do not target whales, and are easily detectable. Vessel strikes are extremely unlikely and therefore discountable. Any potential encounters with whales are expected to be sporadic and transitory in nature. Sound produced by tugs towing a loaded barge (approximately peak of 500 Hz) are expected to be below the peak hearing sensitivity levels of whales (1-100kHz for killer whales) (based on Szymanski et al. 1999), and sound pressure levels from vessels are expected to return to background levels a short distance from the source. Thus, sounds from vessels are unlikely to mask acoustic signals of biological significance and will most likely be below the behavioral threshold for avoidance.

Remaining Effects. Because a majority of the proposed actions will occur within the vicinity of the MCR, very few of the other effects from the proposed actions will be applicable to whales. These species are extremely unlikely to be present in the vicinity of the action area where most of the work will occur. Whales are expected to be in the deeper, offshore waters and well out of the geographic extents of most of the effects. Faint hydroacoustic effects from pile installation and removal, dredging, disposal, and rock placement could cause minor avoidance behavior, but these effects are not expected to cause significant or permanent changes to migration or feeding patterns. Frequency bands relevant to Killer whales (resident and transient) is 1-100 kHz (based on Szymanski et al. 1999). For all baleen whales (humpback, gray and minke whales) it is 0.07-22 kHz (based on Southall et al. 2007). Acoustic effects from these actions are not expected to reach harmful levels and will likely return to background a short distance from the source. For acoustic effects from pile installation, see that section of analysis for Stellar sea lions. Whales are unlikely to occur in the shallow areas where pile installation and dredging will occur. In the unlikely event that they were in the vicinity, sound would likely be below the disturbance threshold (greater than 160 decibels (dB) in water re:1μPa) and likely will return to closer to background a short distance from the source. Whales are not expected to experience any exposure to effects from upland activities like staging, and storage, wetland fill, or dune augmentation that have been described in previous sections. Water quality effects are expected to be minimal and temporary with respect to suspended sediment, and unlikely with respect to significant spills and leaks. Harmful levels of contaminants have not been identified at the site. Potential minor changes to local hydraulics will not affect whales, since they are not expected to be in the vicinity of the jetties. Piling installation will not create or alter migration routes, as whales will not be present in the vicinity. The close proximity to the jetty and low density of piles and dolphins for the barge offloading facilities will not impede whale movement, and the potential to alter the pathway of whales through the project area is discountable. The Corps is not proposing wetland mitigation or habitat improvement actions that will directly affect whales. However, indirectly, an improvement in habitat conducive to marine and anadromous fish survival and development could also improve the amount of prey species that may be available to whales.

Marine Turtles

The loggerhead turtle, green turtle, leatherback turtle, and the Olive ridley turtle have all been recorded from strandings along the Oregon and Washington coasts since 1982 (J. Scordino, NMFS cited in Green et al., 1992). Green and others (1992) recorded 16 leatherback turtles during their survey of Oregon and Washington coastal waters and found that they were associated with warmer waters over the Pacific slope during summer. Leatherback, loggerhead, green, and olive ridley turtle occurrences off the Oregon and Washington coasts are associated with the appearance of albacore. Albacore occurrence is strongly associated with the warm waters of the Japanese current that tends to approach the Oregon Coast in late summer. During El Nino events, warm water may occur closer to the Oregon and Washington coasts than usual, but typically warm water associated with the Japanese current does not closely approach the Oregon and Washington coasts, generally occurring 30 to 60+ miles offshore.

Leatherbacks forage primarily on cnidarians (jellyfish and siphonophores) and to a lesser extent on tunicates (pyrosomas and salps) (NMFS and USFWS 1998). They exploit convergence zones and areas of upwelling (Morreale et al. 1994). Highly productive areas off the coast of the

Pacific Northwest include wind-driven upwelling areas and areas associated with the Columbia River plume. The productivity of these areas is variable when comparing seasons and years, and upwelling varies considerably with location along the California Current, a south-flowing current, which predominates off the coast of the Pacific Northwest. Most of the present knowledge of Leatherback use of the California Current comes from recent telemetry studies, aerial surveys, and ship-based research conducted primarily in the nearshore areas off the central California coast. The telemetry work has documented trans-Pacific migrations between nesting beaches in the western tropical Pacific and the California Current, but specific migratory corridors, if they exist, remain undefined (NMFS 2009).

The nutrient-rich waters of the Columbia River plume tend to aggregate and retain jellyfish in the northern California Current (Shenker 1984). Graham and others (2001) found that jellyfish tend to collect along boundaries including mesoscale oceanic fronts, local circulation patterns, thermoclines, and haloclines and found that scyphomedusae are closely linked to the physical structure of the water column and the dynamics of upwelling-related circulations. There is some evidence that Leatherbacks feed farther offshore in association with the Columbia River plume and off of Washington in general than they do along the central California coast (PFMC 2006) where they feed in the vicinity of Monterey Bay (NMFS November 2006).

The brown sea nettle (*Chrysaora fuscesens*) appears to be the dominant jellyfish species off the coasts of Oregon and Washington (Shenker 1984; Suchman et al. unpublished data). In a study from the Columbia River to Coos Bay, Oregon conducted from May through August (Shenker 1984), brown sea nettles were found to be largest and most abundant during August, although they were present throughout the duration of the study. Suchman and Brodeur (2005) found brown sea nettles to be more common in August compared to June (but well represented in June) in a study from Newport, Oregon to Crescent City, California. Suchman et al. (unpublished data) found brown sea nettle common during July, August, and September in a study off the coasts of Oregon and Washington. Other species of jellyfish that appear to be much less common than brown sea nettles are also present during late spring, summer, and early fall (Shenker 1984; Suchman and Brodeur 2005; Suchman et al. unpublished data). Leatherbacks are most frequently sighted in ocean waters off Oregon and Washington from late spring to early fall (Bowlby 1994). From the limited amount of research on jellyfish and Leatherbacks in Pacific Northwestern nearshore waters, it appears that there is overlap in time of occurrence of jellyfish and Leatherbacks. Knowledge about Leatherback abundance in the Columbia River plume, as well as foraging activity, is sparse.

Most species of marine turtles are expected to occur further offshore and would not regularly be in the vicinity of the MCR or a majority of the proposed actions. There may be some occurrence of marine turtles along the potential barge routes, which may overlap with designated critical habitat. Leatherbacks are not known to enter the Columbia River, though they are known to feed offshore and nearer shore on jellyfish associated with the Columbia River plume, which acts to aggregate Leatherback food resources in the California Current.

Rock Transport. Similar to marine mammals, rock transport could increase the possible exposure for vessel collisions with marine turtles. However, negative effects are unlikely to occur because marine turtles using this area are likely already attuned to this traffic, and their swimming speeds and mobility would allow perception and avoidance of these vessels. Further, barges are slow-moving, follow a predictable course, and are easily detectable. Vessel strikes are extremely unlikely and therefore discountable.

Remaining Effects. Because the majority of the proposed actions will occur within the vicinity of the MCR and shallower estuarine and nearshore waters, very few of the other effects described in previous sections will be applicable to marine turtles. For the most part, turtles are expected to be in the deeper, offshore waters and well out of the geographic extent of most of the effects. Faint hydroacoustic effects from pile installation and removal, dredging, and rock placement could cause minor avoidance behavior if turtles were nearer shore, but these effects are not expected to cause significant or permanent changes to migration or feeding behavior. Sound waves from pile installation, dredging, or vessel traffic are expected to attenuate near the source and are unlikely to reach areas where turtles would be more likely to occur. The same could be said for the periodic disposal actions, which could occur in the Shallow or Deep Water disposal sites in somewhat closer proximity to potential passage routes. As with whales, marine turtles are not expected to experience any exposure to effects from upland activities such as staging and storage, wetland fill, or dune augmentation.

Water quality effects are expected to be minimal with respect to suspended sediment and turbidity, and unlikely with respect to significant spills and leaks. Contamination is not an expected issue regarding dredge or disposal of sediments, and therefore will not impact prey or contribute to bioaccumulation in the species. Furthermore, previous modeling for a larger rebuild of jetty lengths had indicated only minimal potential changes to local hydraulics. Impacts from earlier modeling were not predicted to significantly impact plume dynamics. Under the current proposed scenario, changes to plume dynamics are even less likely. Therefore, no negative effects on abundance or distribution of prey species reliant on the plume are expected. Turtle exposure to most of the effects is extremely unlikely, and would only be expected to be sporadic and transitory in the event that it did occur. Effects that could have minor impacts to turtles are easily avoided by turtles and are not expected to significantly alter their behavior, prey availability, or migration patterns.

CRITICAL HABITAT

Salmonids

In the action area, critical habitat was designated by the NMFS for all Columbia River steelhead trout and Columbia River salmon ESUs with the exception of the lower Columbia River coho salmon ESU (70 FR 52630; September 2, 2005). The PCEs of critical habitats (Table 38) designated for ESA-listed salmon and steelhead species relevant directly or indirectly in the action area include: (1) estuarine areas, (2) nearshore marine areas, and (3) offshore marine areas.

Table 38. PCEs of Critical Habitats Designated for ESA-listed Salmon and Steelhead and Corresponding Life History Events

Does not include SR spring/summer-run Chinook salmon, SR fall-run Chinook salmon, SR sockeye salmon, and SONCC coho salmon - see Table 39 for these species.

Primary Constituent Elements		**Species Life History Event**
Site Type	**Site Attribute**	
Freshwater spawning	Substrate Water quality Water quantity	Adult spawning Embryo incubation Alevin growth and development
Freshwater rearing	Floodplain connectivity Forage Natural cover Water quality Water quantity	Fry emergence from gravel Fry/parr/smolt growth and development
Freshwater migration	Free of artificial obstruction Natural cover Water quality Water quantity	Adult sexual maturation Adult upstream migration and holding Kelt (steelhead) seaward migration Fry/parr/smolt growth, development, and seaward migration
Estuarine areas	Forage Free of artificial obstruction Natural cover Salinity Water quality Water quantity	Adult sexual maturation and "reverse smoltification" Adult upstream migration and holding Kelt (steelhead) seaward migration Fry/parr/smolt growth, development, and seaward migration
Nearshore marine areas	Forage Free of artificial obstruction Natural cover Water quantity Water quality	Adult growth and sexual maturation Adult spawning migration Nearshore juvenile rearing
Offshore marine areas	Forage Water quality	Adult growth and sexual maturation Adult spawning migration Subadult rearing

The PCEs of critical habitats (Table 39) designated for SR spring/summer run Chinook salmon, SR fall-run Chinook salmon, SR sockeye salmon, SONCC coho salmon relevant directly or indirectly in the action area include adult and juvenile migration corridors, and areas for growth and development to adulthood.

Table 39. PCEs of Critical Habitats Designated for SR Spring/Summer-run Chinook Salmon, SR Fall-run Chinook Salmon, SR Sockeye Salmon, and SONCC Coho Salmon and Life History Events

Primary Constituent Elements		Species Life History Event
Site	**Site Attribute**	
Spawning and juvenile rearing areas	Access (sockeye) Cover/shelter Food (juvenile rearing) Riparian vegetation Space (Chinook and coho) Spawning gravel Water quality Water temperature (sockeye) Water quantity	Adult spawning Embryo incubation Alevin development Fry emergence Fry/parr growth and development Fry/parr smoltification Smolt growth and development
Juvenile migration corridors	Cover/shelter Food Riparian vegetation Safe passage Space Substrate Water quality Water quantity Water temperature Water velocity	Fry/parr seaward migration Smolt growth and development Smolt seaward migration
Areas for growth and development to adulthood	Ocean areas – not identified	Adult growth and development Adult sexual maturation Fry/parr smoltification Smolt/adult transition
Adult migration corridors	Cover/shelter Riparian vegetation Safe passage Space Substrate Water quality Water quantity Water temperature Water velocity	Adult sexual maturation Adult "reverse smoltification" Adult upstream migration Kelt (steelhead) seaward migration

For anadromous fish, potential direct or indirect effects of the proposed action on PCEs are summarized below as a subset of the habitat-related effects of the action that were discussed more fully above. In the action area, critical habitat was designated by NMFS for all Columbia River steelhead trout and Columbia River salmon ESUs with the exception of LCR coho salmon ESU (70 FR 52630; September 2, 2005). The PCEs of critical habitats designated for ESA-listed salmon and steelhead species (except for SR spring/summer run Chinook salmon, SR fall-run

Chinook salmon, SR sockeye salmon, SONCC coho salmon) with site attributes that may be affected directly or indirectly in the action area are included below. Overall, within the total project area that does or could fall under designated critical habitat, there could be permanent wetland impacts to an estimated total of ~ 38 acres. This estimate is likely to be significantly reduced after delineations are complete, and proposed wetland mitigation actions will restore long-term ecosystem functions. There will be some temporary effects, but they are not expected to be significant, as previously discussed in this analysis. In-water habitat conversions will total approximately ~ 40 acres. However, this is not expected to have significant negative effects, since it remains less than 1% of the available shallow-water habitat in the vicinity of MCR. Therefore, wetland fill and in-water conversions are not expected to measurably affect the PCEs described.

Temporally, many of the described effects are intermittent in the short term, but over the 20-year construction schedule may result in repetitive sporadic disturbances. However, in many cases these disturbances may occur in consecutive years, but in different geographical locations. Alternatively, effects may occur repetitively in the same location annually, and then a break in actions occurring in the particular geographical area could last for several years. The Corps does not expect that in the short or long-term these effects will cause a meaningful or measureable reduction in the conservation value of salmonid PCEs.

1. Estuarine Areas
    a. Forage – Minor and temporary impacts to benthic invertebrates are expected at localized dredging, disposal, and rock placement sites. Placement could occur during a limited time window on a seasonal daily basis, and the other actions are temporally limited to a few days only annually. However, this is not anticipated to limit productivity or to have any long-term effects on food availability or foraging behavior.
    b. Free of obstruction – Spur groins are small components of the jetty that will protrude slightly into the channel but are expected to accrete sand on their leeward sides, which may provide some resting area for out-migrating juveniles. Their depths and limited geographical effects are not expected to alter migration patterns of juveniles or adults. Pile structures will also be localized and of low density and are not expected to measurably interfere with migration patterns or behaviors.
    c. Natural cover – Most of the construction and staging areas will occur above MHHW. No effects are likely to occur.
    d. Salinity – Changes to the plume are not expected. Therefore, no effects to salinity are likely to occur.
    e. Water quality – Minor, localized, and temporary effects from increased suspended sediment due to dredging, disposal, rock placement, and piling installation and removal are likely. Placement could occur during a limited time window on a seasonal daily basis, and the other actions are temporally limited to a few days only annually or a single event basis. There is also an increased potential for spills or leaks, but BMPs reduce the likelihood of this occurrence. Monitoring will limit the levels and durations of turbidity; therefore long-term or significant effects to water quality are not likely.

f. Water quantity – No effects are likely to occur.

2. Nearshore Marine Areas
   a. Free of obstruction – Spur groins are a small component of the jetty structure that will protrude slightly into the nearshore areas, but they are expected to accrete sand on their leeward sides, which may provide some resting area for juveniles that are feeding and rearing in this environment. Their limited geographical effects are not expected to significantly alter migration patterns of juveniles or adults. Therefore, they are not expected to result in adverse effects to the nearshore areas.
   b. Natural cover – No effects are likely to occur. Most of the construction and staging areas will occur above MHHW.
   c. Salinity – Changes to the plume are not expected. Therefore, no effects to salinity are likely to occur.
   d. Water quality – Minor, localized, and temporal effects from increased suspended sediment due to dredging, disposal, rock placement, and piling installation and removal are likely. Placement could occur during a limited time window on a seasonal daily basis, and the other actions are temporally limited to a few days only annually or a single event basis. There is also an increased potential for spills or leaks, but BMPs reduce the likelihood of this occurrence. Monitoring will limit the levels and durations of turbidity to ensure protection of salmonids and aquatic organisms; therefore long-term or significant effects to water quality are not likely
   e. Water quantity – No effects are likely to occur.

The PCEs of critical habitats designated for SR spring/summer run Chinook salmon, SR fall-run Chinook salmon, SR sockeye salmon, and SONCC coho salmon with site attributes that may be affected directly or indirectly in the action area include:

1. Adult and Juvenile Migration Corridors
   a. Substrate – Shallow, sandy intertidal habitat may be converted to rocky or deeper subtidal habitat. This will be a single discrete temporal and geographical event that could occur annually at various locations described in the proposed action. Spawning does not occur in the action area, therefore actions will not impact spawning substrate, and are not expected to significantly limit rearing habitat.
   b. Water quality – Minor, localized, and temporal effects from increased suspended sediment due to dredging, disposal, rock placement, and piling installation and removal are likely. Placement could occur during a limited time window on a seasonal daily basis, and the other actions are temporally limited to a few days only annually or a single event basis. There is also an increased potential for spills or leaks, but BMPs reduce the likelihood of this occurrence. Monitoring will limit the levels and durations of turbidity to ensure protection of salmonids and aquatic organisms; therefore long-term or significant effects to water quality are not likely.
   c. Water quantity – No effects are likely to occur.
   d. Water temperature – No effects are likely to occur.

e. Water velocity – Small localized changes will occur in the vicinity of the spur groins. However, these are not expected to have larger scale or system-wide effects that would limit the habitat use or alter the migration routes of adults or juveniles.
f. Cover/shelter – No effects are likely to occur.
g. Food – Minor and temporary impacts to benthic invertebrates at localized dredging, disposal, and rock placement sites. This is not expected to have any significant or long-term effects on food availability.
h. Riparian vegetation – Most of the construction and staging areas will occur above MHHW and will not impact natural cover or areas of significant wood recruitment. No effects are likely to occur.
i. Space – No effects are likely to occur.
j. Safe passage– No effects are likely to occur.

2. Areas for Growth and Development to Adulthood
   a. Ocean areas – (not identified) – Spur groins will protrude slightly into the nearshore areas, but they are expected to ephemerally accrete sand on their leeward sides dependent on tide, which may provide some temporary resting area for juveniles that are feeding and rearing in this environment. Therefore, they are not expected to result in adverse effects to the nearshore areas.

The effects on the PCEs noted above will not be significant at the watershed or the designation scale of critical habitat for listed salmonid species. Additionally, in the above analysis, the long-term beneficial effects from the proposed wetland mitigation and habitat improvement projects were not incorporated. However, there may be beneficial effects to the PCEs in the areas of natural cover, water quality, forage, and food. As previously discussed, these habitat improvement actions are also in-line with CRE management actions that have been identified for protection and recovery of salmonids (NMFS 2007c). Therefore, they are expected to result in beneficial effects to critical habitat.

Green Sturgeon

Critical habitat was designated by the NMFS for green sturgeon. The PCEs of critical habitats (Table 40) relevant directly or indirectly in the action area include:

1. Estuarine areas
2. Coastal marine areas

Table 40. PCEs of Critical Habitats Proposed for Southern Green Sturgeon and Corresponding Life History Events

Primary Constituent Elements		Life History Event
Site Type	**Site Attribute**	
Freshwater riverine system	Food resources Migratory corridor Sediment quality Substrate type or size Water Depth Water flow Water quality	Adult spawning. Embryo incubation, growth and development. Larval emergence, growth and development. Juvenile metamorphosis, growth and development.
Estuarine areas	Food resources Migratory corridor Sediment quality Water flow Water depth Water quality	Juvenile growth, development, seaward migration. Subadult growth, development, seasonal holding, and movement between estuarine and marine areas. Adult growth, development, seasonal holding, movements between estuarine and marine areas, upstream spawning movement, and seaward post-spawning movement.
Coastal marine areas	Food resources Migratory corridor Water quality	Subadult growth and development, movement between estuarine and marine areas, and migration between marine areas. Adult sexual maturation, growth and development, movements between estuarine and marine areas, migration between marine areas, and spawning migration.

As discussed under effects to salmonid designated critical habitat, temporally there may also be repetitive effects to green sturgeon PCEs on a daily or annual basis, but they are not expected to cause significant long-term negative effects to that reduce the conservation value of PCEs for green sturgeon in the action area.

1. Estuarine Areas
    a. Food Resources – Minor and temporary impacts to benthic invertebrates are expected at localized dredging, disposal, and rock placement sites. Placement could occur during a limited time window on a seasonal daily basis, and the other actions are temporally limited to a few days only annually. This is not anticipated to have any significant or long-term effects on food abundance or distribution.
    b. Migratory Corridor – Spur groins are a small part of the jetties that will protrude slightly into the channel, but they are expected to accrete sand on their leeward sides, which may provide some resting area for out-migrating juveniles. Their limited geographical effects are not expected to significantly alter migration patterns of juveniles or adults.
    c. Sediment Quality – Harmful levels of contaminants have not been identified at the sites, and most of the substrate is over 90% sands. No effects are likely to occur.
    d. Water Flow – No effects are likely to occur.
    e. Water Quality – Minor, localized, and temporal effects from increased suspended sediment due to dredging, disposal, rock placement, and piling installation and removal are likely. Placement could occur during a limited time window on a seasonal daily basis, and the other actions are temporally limited to a few days only annually or to a single event. There is also an increased potential for spills

or leaks, but BMPs reduce the likelihood of this occurrence. Monitoring will limit the levels and durations of turbidity to ensure protection of salmonids and aquatic organisms; therefore long-term or significant effects to water quality are not likely.

f. Water Depth – Shallow, sandy intertidal habitat may be converted to rocky or deeper subtidal habitat. However, this is a very small percentage; it will not impact spawning substrate; and it is not expected to significantly limit holding, rearing, or foraging habitat.

2. Coastal Marine Areas
    a. Food Resources – Minor and temporary impacts to benthic invertebrates are expected at localized dredging, disposal, and rock placement sites. Placement could occur during a limited time window on a seasonal daily basis, and the other actions are temporally limited to a few days only annually. This is not anticipated to have any significant or long-term effects on food abundance or distribution.
    b. Migratory Corridor – Spur groins are a small component of the jetties that will protrude slightly into the channel, but they are expected to accrete sand on their leeward sides, which may provide some resting area for juveniles that are out-migrating. Their limited geographical effects are not expected to significantly alter migration patterns of juveniles or adults.
    c. Water Quality – Minor, localized, and temporal effects from increased suspended sediment due to dredging, disposal, rock placement, and piling installation and removal are likely. Placement could occur during a limited time window on a seasonal daily basis, and the other actions are temporally limited to a few days only annually or to a single event. There is also an increased potential for spills or leaks, but BMPs reduce the likelihood of this occurrence. Monitoring will limit the levels and durations of turbidity to ensure protection of aquatic organisms; thus, long-term or significant effects to water quality are not likely.

The effects on the PCEs noted above will not be significant at the watershed or the designation scale of critical habitat for green sturgeon.

Eulachon

Critical habitat has not been designated for this species.

Marine Mammals

Steller Sea Lions. Critical habitat was designated by the NMFS for the Eastern Population of Steller sea lions. PCEs of critical habitats include: air zones around terrestrial and aquatic habitats, nearshore waters around rookeries and haulouts; forage resources and habitats; and traditional rafting sites. However, neither the potential barge vessel routes nor the action area at MCR are within designated critical habitat.

Blue, Fin, Humpback, Sei, and Sperm Whales. There is no designated critical habitat in the proposed action areas.

Southern Resident Killer Whale. The PCEs of critical habitats for southern resident killer whales could be included in the action area passed through during vessel transport of rocks. Otherwise, the vicinity of the MCR is not included in the critical habitat designation. The PCEs essential for conservation of this species are:

1. Water Quality – Minor, localized, and temporal effects from increased suspended sediment due to dredge material disposal are likely, but are not expected to have significant effects on migratory or feeding behavior. Actions are temporally limited to a few days only annually. There is also a slight increased potential for localized spills or leaks, but BMPs reduce the likelihood of this occurrence and limit the geographical extent of the effects. Monitoring will limit the levels and durations of turbidity; therefore long-term effects to water quality are minimal and discountable.

2. Prey Species – Effects to prey resources like marine and anadromous fish are expected to be minor and discountable. Therefore effects to this PCE are not likely to limit or reduce prey species that occur in the designated critical habitat areas. Acoustic effects will be intermittent and likely to attenuate near the source. Therefore, they are not expected to interfere with important biological signals that would affect foraging behaviors or cause changes in prey availability.

3. Passage Conditions – Vessel traffic will be a short-term annual occurrence, and will likely be concentrated seasonally during fairer weather months. However, traffic is not expected to increase appreciably due to the action, and therefore not expected to have effects on migration, resting, and foraging behaviors or patterns. Effects to passage from vessel traffic are transitory and discountable. Piles and mooring dolphins will be installed within 200 feet of the jetties in relatively shallow waters. Therefore, they will not create obstacles or cause measurable effects to passage conditions. Acoustic effects will be intermittent and likely to attenuate near the source. Therefore, they are not expected to interfere with important biological signals that would affect passage conditions or cause long-term changes in migration patterns.

As discussed under effects to salmonid designated critical habitat, temporally there may also be repetitive effects to killer whale PCEs on a daily or annual basis, but they are not expected to cause significant long-term negative effects to that reduce the conservation value of PCEs for Southern resident killer whales in the action area. Further, the effects on the PCEs noted above will not be significant at the watershed or the designation scale of critical habitat for southern resident killer whales.

Marine Turtles

Loggerhead and Olive Ridley Sea Turtles. Critical habitat has not been designated for loggerhead turtle and the Olive ridley turtles.

Green Sea Turtle. Critical habitat for green sea turtles is designated but does not occur in the action area.

Leatherback Sea Turtle. In January 2010 there was a proposed rule to revise critical habitat designations for the leatherback turtles from Cape Flattery, Washington to the Umpqua River (Winchester Bay), Oregon east of a line approximating the 2,000 meter depth contour (75 FR 319), which would include the potential barge transport routes of the proposed action area. The PCEs of the proposed revised critical habitat for leatherback turtles relevant directly or indirectly in the action area include: water quality, prey species, and passage conditions. In the vicinity of the Columbia River plume, there is an occurrence of prey of species primarily scyphomedusae of the Semaeostomeae, including the genera *Chrysaora*, *Aurelia*, *Phacellophora*, and *Cyanea* of sufficient condition, distribution, diversity, and abundance to support individual as well as population growth, reproduction, and development. The following effects to PCEs of critical habitat could occur.

1. Water Quality – Minor, localized, and temporal effects from increased suspended sediment due to dredging, disposal, rock placement, and piling installation and removal are possible. Placement could occur during a limited time window on a seasonal daily basis, and the other actions are temporally limited to a few days only annually or to a single event. These water quality effects will be limited due to BMPs that are proposed, as well as the sandy, uncontaminated character of the substrate. Monitoring will limit the levels and durations of turbidity to protect aquatic life. Transitory exposure is unlikely, as turtles are not expected to be in the vicinity.

2. Prey Species – No significant changes to plume structure are expected; therefore, no effects to jellyfish or other prey items are anticipated. The proposed action is not expected to have short or long-term effects to prey abundance or distribution.

3. Passage Conditions – Vessel passage will be a short-term annual occurrence, and will likely be concentrated seasonally during fairer weather months. However, traffic will be transitory and will not cause a significant increase in traffic levels relative to background. Acoustic effects are expected to attenuate near the source. Sound levels are not expected to have long-term effects on important biological signals that would alter migration patterns. Piles and mooring dolphins will be installed within 200 feet of the jetties in relatively shallow waters. They will not create obstacles or cause measurable effects to passage conditions. Therefore actions are not expected to have significant effects on passage conditions or migration, resting, or foraging behaviors.

As discussed under effects to salmonid designated critical habitat, temporally there may also be repetitive effects to leatherback turtle PCEs on a daily or annual basis. However, they are discountable and are not expected to cause significant long-term negative effects to that reduce the conservation value of PCEs for leatherback sea turtles in the action area. Further, the effects on the PCEs noted above will not be significant at the watershed or the designation scale of critical habitat for the leatherback sea turtle.

CUMULATIVE EFFECTS

Cumulative effects are those effects of future State or private activities, not involving Federal activities, that are reasonably certain to occur within the action area of the Federal action subject to consultation (50 CFR 402.02). For the proposed action, the action area previously defined, there are no foreseeable non-federal actions subject to their own ESA consultation that have the potential to increase the impacts of actions described in this BA on federally listed species.

SYNTHESIS AND INTEGRATION OF EFFECTS

Species at the Population Scale

Effects to Fish Populations

The following life stages of marine and anadromous fish may be present in the action area and effects to fish at the population level are discussed below.

Salmon and steelhead	Sturgeon	Eulachon
1. Juveniles a. Rearing b. Migration c. Smoltification 2. Adults a. Sub-adult growth and development b. Upstream migration and holding c. Seaward migration (steelhead)	1. Adults a. Sub-adult growth and development b. Upstream migration and holding c. Seaward migration d. Seasonal holding e. Estuarine, nearshore and marine movements	1. Embryos and larvae a. Incubation b. Emergence 2. Juveniles a. Rearing b. Migration c. Metamorphosis 3. Adults a. Sub-adult growth and development b. Upstream migration and holding

Summary of Effects on Anadromous Fish

The action area provides habitat for rearing, smoltification, and migrating juvenile salmon and steelhead. The primary species using the area are ocean-type Chinook, chum, and coho salmon. Stream-type Chinook and juvenile steelhead may also be using the area during ocean outmigration. Adult migrating salmon and steelhead may also be present in the action area. This bulk of the effects analyses pertain to juvenile salmonids only, as adults that could be in the vicinity of the action area are highly mobile and in the process of migration. Adults are not expected to spend extended amounts of time in the vicinity of the jetties and could avoid areas of disturbance. No significant adverse permanent disturbances to habitat that adults use in the MCR would result from the proposed action. The effects on abundance and productivity at the population scale will be insignificant because such a small proportion of each population will be affected and effects on VSP characteristics will not be measurable or meaningfully expressed at the population scale. Therefore, project effects are not likely to impede the survival or recovery of the affected populations.

As described, certain aspects of the proposed action are reasonably likely to result in effects to ESA-listed species in the action area. The Corps does not expect adult salmon and steelhead to be injured or harmed by the proposed action. A summary of possible impacts considered in this analysis for juvenile salmonids from the proposed action includes the following:

Rock Transport. Vessel traffic may induce some movement in juveniles but is not expected to significantly or negatively alter migration, foraging, or holding patterns. Furthermore, juvenile salmonids will likely experience little exposure, as they tend to prefer shallower habitat outside navigation channels used by barges.

Construction Access, Staging, Storage, and Rock Stockpiling. A majority of these actions are above MHHW with BMPs that will avoid water quality effects and reduce juvenile exposure to any significant adverse effects.

Rock Placement. Rock placement may provide ephemeral shallower habitat on their leeward sides that could be used by juveniles. Direct mortality to juveniles is not expected, though, there may be a minimal increase in exposure to predators. There will also be insignificant and localized alteration to pathways immediately adjacent to and along the trunk of the jetties. However, juveniles will be able to pass over submerged groins under a majority of conditions. Rock placement is not expected to increase perching opportunities for avian piscivory, and therefore will not negatively affect juveniles or adults. Effects from habitat conversion are expected to be minimal, due to the relatively small scale and anticipated recovery of benthic and invertebrate food sources.

Dredging. There will be a temporary loss of benthic invertebrates in areas dredged but only negligible losses to food resources of juvenile salmonids, and effects are expected to be localized and minor in scale. Some sandy, shallow-water inter-tidal habitat will be converted to deeper inter- and sub-tidal habitat. While juvenile salmonids may use bottom areas where dredging for barge offloading facilities will occur, entrainment by clamshell dredges is very unlikely and should not result in significant negative effects.

Disposal. As with dredging, there will be a temporary loss of benthic invertebrates in disposal areas. However, this is not expected to result in significant effects to food sources. Juveniles may be present in the disposal area, but direct fish mortality from the disposal plume is not expected. Juveniles may be temporarily displaced while moving to other nearby suitable habitat during disposal activities. These actions are not expected to significantly affect rearing, holding, or migration patterns of juveniles.

Barge Offloading Facilities. Stone placement, dredging, and pile installation and removal could cause limited and temporary effects described in their respective sections. Localized vessel traffic at the offloading sites could induce localized and temporary movement in salmonids. No effects from increased avian piscivory are anticipated.

Pile Installation and Removal. Vibratory drivers will be used, which will dampen any acoustic effects to fish and other species. Acoustic effects from vibratory drivers would be of limited duration and intermittent in frequency, and therefore are not expected to have significant or long-term negative effects on juveniles. Minor avoidance behavior is not expected to significantly alter juvenile migration or holding patterns.

Wetland and Lagoon Fill and Culvert Replacement. Because these actions occur mostly in the uplands, fish use is unlikely, and there are no anticipated significant negative effects on habitat values and functions, no effects on fish are expected from these actions.

Dune Augmentation. These actions occur in the dry sand above MHHW and therefore are not expected to have significant effects on fish.

Water Quality. Water quality changes could occur in the form of temporary and localized increased suspended sediments and turbidity. Monitoring will ensure levels remain within ranges protective of aquatic life. There may also be a slight increased risk of exposure to leaks and spills; however, contamination is not expected to occur because sediments have tested clean and treated wood will be prohibited. Therefore, effects from water quality are expected to be of minimum extent and duration, and will not significantly affect fish.

Hydraulic and Hydrological Processes. Modeling results for a previously proposed, much larger scale lengthening and rehabilitation project indicated minimal and insignificant effects from changes to velocities, channel bed morphology, and salinity. Changes to plume structure were also insignificant. Under the current smaller proposed action, spur groins may have a limited and localized effect on bed morphology and velocities. However, the small range of potential change is not expected to have significant or negative long-term effects on juveniles.

Wetland Mitigation and Habitat Improvements. Actions are expected to have long-term, beneficial effects to juvenile and adult habitat, and would positively affect their PCEs. Therefore, no long-term or significant negative effects are expected.

As demonstrated in the summary above, based on this analysis the proposed action ***may affect and is likely to adversely affect*** all runs of salmonids and steelhead discussed in this BA.

Green Sturgeon

The bulk of this effect analysis pertains to juvenile green sturgeon only, as adults that could be in the vicinity of the action area are highly mobile. Adults are not expected to spend extended amounts of time in the vicinity of the jetties and could avoid areas of disturbance. No adverse permanent disturbances to habitat that adults use in the MCR would result from the proposed action. The effects on abundance and productivity at the population scale will be insignificant because such a small proportion of each population will be affected and effects will not be measurable or meaningfully expressed at the population scale. Therefore, project effects are not likely to impede the survival or recovery of the affected populations.

A summary of possible impacts on juvenile green sturgeon from the proposed action includes the following:

Rock Transport. Vessel traffic may induce some movement in juveniles. However, this is not expected to significantly or negatively alter juvenile migration or holding patterns. Green sturgeon juveniles may be present, but would likely be lower in the water column and tend to move at night. Therefore their exposure to traffic would be geographically and temporally limited.

Construction Access, Staging, Storage, and Rock Stockpiling. These actions are mostly above MHHW, which limit exposure to sturgeon. Actions are not expected to have any significant or adverse effects on juveniles.

Rock Placement. Rock placement may provide ephemeral shallower habitat on their leeward sides that could be used by juveniles. Direct mortality to juveniles is not expected due to swimming abilities. There will also be insignificant and localized alteration to migration pathways immediately adjacent to and along the trunk of the jetties. Sturgeons tend to utilize bottom habitats, and rock placement is not expected to increase exposure to piscivorous fish or avian piscivory. Effects from habitat conversion are expected to be minimal, due to the relatively small scale and anticipated recovery of benthic and invertebrate food sources.

Dredging. There will be loss of benthic invertebrates in areas dredged but only negligible losses to food resources of sturgeon, and effects are expected to be localized and temporary in scale. Some sandy, shallow-water inter-tidal habitat will be converted to deeper inter- and sub-tidal habitat. While sturgeon may use bottom areas where dredging for barge offloading facilities will occur, entrainment by clamshell dredges is very unlikely and should not result in significant negative effects.

Disposal. As with dredging, there will be a temporary loss of benthic invertebrates in disposal areas. However, this is not expected to result in significant effects to sturgeon food sources. Juveniles and adults may be present in the disposal area, but direct fish mortality from the disposal plume is not expected. Adults and juveniles may be temporarily displaced while moving to other nearby suitable habitat during disposal activities. These actions are not expected to significantly affect rearing, holding, or migration patterns of juveniles or adults.

Barge Offloading Facilities. Stone placement, dredging, and pile installation and removal could cause limited and temporary effects described in their respective sections. Localized vessel traffic at the offloading sites could induce localized and temporary movement in sturgeon.

Pile Installation and Removal. Vibratory drivers will be used, which will dampen any acoustic effects. Acoustic effects from vibratory drivers would be of limited duration and intermittent in frequency, and therefore are not expected to have significant or long-term negative effects on juveniles. Minor avoidance behavior is not expected to significantly alter juvenile migration or holding patterns.

Wetland and Lagoon Fill and Culvert Replacement. Because these actions occur mostly in the uplands, fish use is unlikely, and there are no anticipated significant negative effects on the habitat values, no effects on fish are expected from these actions.

Dune Augmentation. These actions occur in the dry sand above MHHW; therefore exposure is unlikely and actions are not expected to have significant effects on fish.

Water Quality. Water quality changes could occur in the form of temporary and localized increased suspended sediments and turbidity. There may also be a slight increased risk of exposure to leaks and spills; however, contamination is not expected to occur because sediments have tested clean and treated wood will be prohibited. Therefore, effects from water quality are expected to be of minimum extent and duration, and will not significantly affect fish.

Hydraulic and Hydrological Processes. Modeling results for a previously proposed, much larger scale lengthening and rehabilitation project indicated minimal and insignificant effects from changes to velocities, channel bed morphology, and salinity. Changes to plume structure were also insignificant. Under the current, smaller proposed action, spur groins may have a limited and localized effect on bed morphology and velocities. However, the small range of potential change is not expected to have significant or negative long-term effects on juveniles.

Wetland Mitigation and Habitat Improvements. Actions are expected to have long-term, beneficial effects to that could improve food resources, water flow, and water quality in the estuary. Therefore, actions are expected to positively affect sturgeon PCEs. Therefore, no long-term or significant negative effects to juvenile sturgeon are expected.

As demonstrated in the summary above, based on this analysis the proposed action ***may affect and is likely to adversely affect*** green sturgeon. Green sturgeons are not expected to experience long-term effects due to changing environmental conditions at the MCR.

Eulachon

The bulk of this effects analysis pertains to juvenile eulachon only, as adults that are not likely to be in the vicinity of the action area. There is little seasonal overlap with peak immigration and the majority of construction actions. Adults present are in the process of migration and highly mobile. Adults are not expected to spend extended amounts of time in the vicinity of the jetties and could avoid areas of disturbance. No adverse permanent disturbances to habitat that adult eulachon use in the MCR would result from the proposed action. The effects on abundance and productivity at the population scale will be insignificant because such a small proportion of each population will be affected and effects will not be measurable or meaningfully expressed at the population scale. Therefore, project effects are not likely to impede the survival or recovery of the affected populations.

A summary of possible impacts on juvenile eulachon from the proposed action includes the following:

Rock Transport. The seasonality of potential peak juvenile eulachon usage has little overlap with the likely timing of most barge traffic and therefore, this action is not likely to increase eulachon exposure to vessel traffic. Disturbance from vessel traffic could cause effects to juveniles that would not otherwise occur. However, proposed actions are not expected to have significant impacts to passive emigration behaviors.

Construction Access, Staging, Storage, and Rock Stockpiling. These actions are mostly above MHHW and limit exposure to eulachon. These actions are not expected to have any significant or adverse effects on eulachon.

Rock Placement. Significant direct mortality to juveniles is not expected. However, there may be a minimal increase in exposure to predators with the addition of channel-side spur groins due to predator attraction. There will also be insignificant and localized alteration to migration pathways immediately adjacent to and along the trunk of the jetties. However, juveniles will be able to pass over submerged groins under a majority of conditions. Effects from habitat conversion are not expected to impact food sources. The seasonality of peak potential juvenile eulachon usage in the vicinity of MCR during this activity has little overlap with the likely timing of rock placement. Therefore exposure to these effects is temporally and geographically limited.

Dredging. There will be loss of benthic invertebrates in areas dredged but as planktonic feeders, this will not affect juvenile eulachon. While juvenile eulachon may use bottom areas where dredging for barge offloading facilities will occur, they are more pelagic in nature and would be more likely found in the water column. Entrainment by clamshell dredges is possible, but unlikely and should not result in significant negative effects to the population.

Disposal. As with dredging, this is not expected to result effects to juvenile eulachon food sources. Juveniles may be present in the disposal area, but direct fish mortality from the disposal plume is not expected. Adults and juveniles may be temporarily displaced while moving to other nearby suitable habitat during disposal activities. These actions are not expected to significantly affect rearing or migration patterns of juveniles or adults.

Barge Offloading Facilities. Stone placement, dredging, and pile installation and removal could cause limited and temporary effects described in their respective sections. Occasional vessel traffic at the offloading sites could cause localized and temporary effects to eulachon. The seasonality of peak potential juvenile eulachon usage in the vicinity of MCR during this activity has little overlap with the likely timing of these effects; therefore, exposure is geographically and temporally limited.

Pile Installation and Removal. Vibratory drivers will be used, which will dampen any acoustic effects to eulachon. Acoustic effects from vibratory drivers would be of limited duration and intermittent in frequency, and therefore are not expected to have significant or long-term negative effects on juveniles. The seasonality of potential juvenile eulachon usage in the vicinity of MCR during this activity has little overlap with the likely timing of these effects; therefore, exposure is not likely.

Wetland and Lagoon Fill and Culvert Replacement. Because these actions occur mostly in the uplands, fish use is unlikely, and there are no anticipated significant negative effects on the habitat values, no effects on eulachon are expected from these actions.

Dune Augmentation. These actions occur in the dry sand above MHHW; therefore exposure is unlikely and actions are not expected to have significant effects on eulachon.

Water Quality. Water quality changes could occur in the form of temporary and localized increased suspended sediments and turbidity; but monitoring will ensure levels remain within ranges safe for aquatic life. There may also be a slight increased risk of exposure to leaks and spills; however, contamination is not expected to occur because sediments have tested clean and treated wood will be prohibited. Therefore, effects from water quality are expected to be of minimum extent and duration, and will not significantly affect eulachon.

Hydraulic and Hydrological Processes. Modeling results for a previously proposed, much larger scale lengthening and rehabilitation project indicated minimal and insignificant effects from changes to velocities, channel bed morphology, and salinity. Changes to plume structure were also insignificant. Under the current, smaller proposed action, spur groins may have a limited and localized effect on bed morphology and velocities. However, the small range of potential changes is expected to be minimal and discountable and is not expected to have significant or negative long-term effects on juvenile eulachon.

Wetland Mitigation and Habitat Improvements. No long-term or significant negative effects to juveniles are expected.

As demonstrated in the summary above, based on this analysis the proposed action ***may affect and is likely to adversely affect*** eulachon as discussed in this BA.

Steller Sea Lion

This effect determination pertains to Steller sea lions that could be in the vicinity of the action area. No adverse permanent disturbances to habitats that sea lions use at the MCR would result from the proposed action. The effects on abundance and productivity at the population scale will be insignificant because such a small proportion of each population will be affected and effects will not be measurable or meaningfully expressed at the population scale. Therefore, project effects are not likely to impede the survival or recovery of the affected populations.

A summary of possible impacts on Steller sea lions from the proposed action includes the following:

Rock Transport. Exposure to vessel traffic may cause some disturbance and avoidance behavior. However, sea lions using this area are likely already attuned to this traffic, and have the ability to and could exercise avoidance behavior. Therefore, these actions are not expected to have any significant or long-term negative effects. Additionally, an IHA permit would be obtained from the NMFS.

Construction Access, Staging, Storage, and Rock Stockpiling: Disturbance from construction could force animals off the rubble mound structure. However, seasonal use levels, construction location, and temporal spatial availability in and around the preferred haul-out site somewhat limits the overlap between high pinniped use and the peak construction season. Therefore, it is unlikely that activities will have a long-term effect on use of the nearshore waters, haulouts, or traditional rafting sites. Acoustic disturbance may have some effect on the zones around terrestrial and aquatic habitats used by sea lions and therefore cause some disturbance and movement. However, this is not expected to be significant, given pinniped responses during previously conducted actions.

Rock Placement. Acoustic and equipment traffic disturbances and effects similar to those described under the Construction effects section may also occur during rock placement; and are therefore applicable here. However, rock placement is not expected to significantly change physical conditions or prey resources in the vicinity of the MCR. Steller sea lions are not expected to experience direct or long-term negative effects due to changing environmental conditions at the MCR.

Dredging. Besides an avoidance response similar to that described under Rock Transport, dredging activities are not likely to have any other significant impacts to habitat use by Steller sea lions. Therefore, no negative effects to aquatic habitats, or nearshore waters, or traditional rafting sites are expected.

Disposal. As with disposal actions, these activities are not expected to have additional negative impacts to Steller sea lions.

Barge Offloading Facilities. These facilities will not be located along the jetties where sea lions prefer to haul out. Although they could experience effects described under the Rock Placement and Pile Installation and Removal sections, these indirect disturbances are expected to be minor and of short duration. No nearshore or haul-out habitat would be altered in a way that would have negative effects to Steller sea lions.

Pile Installation and Removal. Acoustic effects may cause some temporary avoidance behavior, but are not expected to cause long-term negative effects. Acoustic effects are not expected to reach levels that cause significant or long-term disturbance or harm.

Lagoon and Wetland Fill and Culvert Replacement. Because these proposed actions are out of the immediate vicinity of the South Jetty, potential exposure to disturbance is not likely to have any significant affect on behavior or habitat usage.

Dune Augmentation. This activity is in proximity to the haul-out and may have some minimal discountable effect on nearshore areas that could be used as a rafting site.

Water Quality. Water quality effects from suspended sediment are not likely, though exposure to spills is possible but the likelihood is reduced due to BMPs.

Hydraulic and Hydrological Processes. No significant or negative effects to prey resources or physical habitat features are expected. Therefore, no direct effects are expected.

Wetland Mitigation and Habitat Improvements. Indirect benefits from improved prey resources may affect sea lions but no negative long-term or significant adverse effects are expected.

As demonstrated in the summary above, based on this analysis the proposed action ***may affect and is likely to adversely affect*** Steller sea lions. No long-term effects due to changing environmental conditions at the MCR are expected.

Whales

This effect determination pertains to whales that could be in the vicinity of the barge transport routes or disposal sites at the MCR. No adverse permanent disturbances to habitats that whales use in the vicinity of the MCR would result from the proposed action. The effects on abundance and productivity at the population scale for all whale species will be insignificant because such a small proportion of each population will be affected and effects will not be measurable or meaningfully expressed at the population scale. Therefore, project effects are not likely to impede the survival or recovery of the affected populations. A summary of possible impacts on whales from the proposed action includes the following:

Rock Transport. Whales within navigation channels could have increased exposure to vessels; however, there is no appreciable increase in traffic expected, and their perception and avoidance abilities make collisions unlikely.

Remaining Effects. Because whales are expected to be in the deeper, offshore waters and not within the geographic extent of the proposed actions, effects from activities are anticipated to be immeasurable and discountable. Periodic disposal actions in closer proximity to potential whale passage routes are not expected to cause significant or permanent changes to whale migration or feeding behavior. Water quality effects are expected to be minimal and discountable. Minor changes to local hydraulics and proposed restoration actions will have no negative effects on whales. Acoustic effects are not expected to reach levels that cause significant or long-term disturbance or harm. Proposed wetland mitigation and habitat improvement actions will have no long-term or significant negative effects on whales, nor will upland actions.

As demonstrated in the summary above, based on this analysis the proposed action ***may affect, but is not likely to adversely affect*** each of the six whale species discussed in this BA (blue whale, fin whale, sei whale, sperm whale, humpback whale, and killer whale). No long term effects due to changing environmental conditions at the MCR are expected.

Marine Turtles

This effect determination pertains to marine turtles that could be in the vicinity of the barge transport routes or disposal sites at MCR. No adverse permanent disturbances to habitats that marine turtles use in the vicinity of the MCR would result from the proposed action. The effects on abundance and productivity at the population scale for all whale species will be insignificant because such a small proportion of each population will be affected and effects will not be measurable or meaningfully expressed at the population scale. Therefore, project effects are not likely to impede the survival or recovery of the affected populations. A summary of possible impacts on turtles from the proposed action includes the following:

Rock Transport. Marine turtles within navigation channels could have increased exposure to vessels. However, there is no appreciable increase in traffic expected, and their perception and avoidance abilities make collisions unlikely.

Remaining Effects. Because turtles are expected to be in the deeper, offshore waters and not within the geographic extent of the proposed actions, no impacts are anticipated from activities. Marine turtles do not typically occur close to shore and would only occur in the vicinity of the proposed project site under unusual circumstances. Periodic disposal actions in closer proximity to potential turtle passage routes are not expected to cause significant or permanent changes to migration or feeding behavior. Water quality effects are expected to be minimal with respect to suspended sediment, and unlikely with respect to significant spills and leaks. Minor changes to local hydraulics are not expected to affect the plume, and proposed wetland mitigation and habitat improvement actions will have no negative long-term or significant effects on marine turtles. Upland actions will have no affect on turtles.

As demonstrated in the summary above, based on this analysis the proposed action will have ***no effect*** on each of the four marine turtle species discussed in this BA (loggerhead sea turtle, green sea turtle, leatherback sea turtle, and Olive Ridley sea turtle).

Critical Habitat at the Watershed Scale

Salmonids

The effects on PCEs of estuarine areas and nearshore marine areas in the action area will not be significant at the watershed or the designation scale of critical habitat for all Columbia River steelhead trout and Columbia River salmon ESUs, with the exception of the lower Columbia River coho salmon ESU that is not designated (70 FR 52630; September 2, 2005).

Critical habitat designations for ESA-listed salmon and steelhead species (except for SR spring/summer run Chinook salmon, SR fall-run Chinook salmon, SR sockeye salmon, SONCC coho salmon) have PCEs of with site attributes that may be affected directly or indirectly in the action area which include: minor impacts to benthic invertebrates and foraging opportunities, as well as minor and temporary impacts to water quality. Insignificant permanent habitat conversion will occur, and spur groins may cause minor disturbance and insignificant obstructions to migration patterns in the local proximity of the jetties. Estuarine and nearshore marine areas may also experience temporary and insignificant effects to water quality.

The PCEs of critical habitats designated for SR spring/summer run Chinook salmon, SR fall-run Chinook salmon, SR sockeye salmon, SONCC coho salmon with site attributes that may be affected directly or indirectly in the action area include adult and juvenile migration corridors and areas for growth and development to adulthood. Substrate conversion will be localized and insignificant, and is not expected to limit spawning (which does not occur in the action area) or rearing habitat. There will also be temporary and localized impacts to water quality. Localized changes in velocity will occur near the spur groins, but changes are not likely to significantly affect juvenile or adult rearing, migration, or holding patterns. Minor and temporary impacts to benthic invertebrates are not expected to have any significant or long-term effects on food availability. In ocean areas, spur groins will protrude slightly into the nearshore areas, but are not expected to result in significant adverse effects to the rearing or migration.

The effects on the PCEs noted above will not be significant at the watershed or the designation scale of critical habitat for listed salmonid species. Additionally, in the above analysis, effects from the proposed wetland mitigation and habitat improvement actions were not incorporated. However, there may be beneficial effects to the PCEs in the areas of natural cover, water quality, forage, and food.

For these reasons, the proposed action ***may affect and is likely to adversely affect*** critical habitat designated for listed salmonids discussed in this BA (LCR coho salmon currently has no designated critical habitat).

Green Sturgeon

The effects on PCEs of estuarine areas and coastal marine areas in the action area will not be significant at the watershed or the designation scale of critical habitat for green sturgeon. The PCE site attributes that may be directly or indirectly affected include insignificant impacts to food resources from minor, localized impacts to benthic invertebrates. Limited and minor effects on migratory corridors could occur from the localized protrusions of the spur groins. Temporary, minor, and localized effects to water quality could occur from the proposed action, but are not expected to have significant impacts on rearing, migration, or development. Insignificant impacts to water depths will occur as habitat is converted, but this is not expected to impact spawning substrate (no spawning occurs in the vicinity of MCR) or holding, rearing or foraging habitat. These effects are not expected to result in significant negative impacts to estuarine or coastal marine PCEs.

The effects on the PCEs noted above will not be significant at the watershed or the designation scale of critical habitat for green sturgeon. Additionally, in the above analysis, effects from the proposed wetland mitigation and habitat improvement actions were not incorporated. However, there may be beneficial effects to the PCEs in the areas of food resources and water quality.

For these reasons, the proposed action ***may affect and is likely to adversely affect*** critical habitat designated for listed green sturgeon discussed in this BA. However, Green sturgeons are not expected to experience long-term effects due to changing environmental conditions at the MCR.

Eulachon

Critical habitat has not been designated for this species.

Marine Mammals

Steller Sea Lions. Critical habitat was designated by the NMFS for the Eastern Population of Steller sea lions, but is not located within the proposed action areas.

Blue, Fin, Humpback, Sei, and Sperm Whales. These species do not have designated critical habitat in the action area.

Southern Resident Killer Whale. Water quality effects that could occur are localized and temporary, as are minor effects to passage conditions. No significant long term-effects are anticipated to prey species. Therefore, effects to PCEs are not expected to have measurable effects on critical habitat of southern resident killer whale. The noted potential effects on PCEs will not be significant at the watershed or the designation scale of critical habitat for southern resident killer whales. For these reasons, the proposed action ***may affect but is not likely to adversely affect*** critical habitat designated for southern resident killer whales as discussed in this BA. This species is not expected to experience long-term effects due to changing environmental conditions at the MCR.

Marine Turtles

Loggerhead Sea Turtle and Olive Ridley Sea Turtle. Neither species has designated critical habitat in the action area.

Green Sea Turtle. Critical habitat for green sea turtles is designated but does not occur in the action area.

Leatherback Sea Turtle. Currently, there is no critical habitat designated in the vicinity of the proposed action, but there is a proposed revision that would include parts of the action area. Potential barge routes may occasionally come within the vicinity of proposed critical habitat PCE migratory pathway conditions that allow for safe and timely passage and access to/from/within high use foraging areas. Water quality effects in the potential routes would be minor, temporary and localized. Because changes are not expected to affect the plume, reduction or distribution of prey species are not anticipated, and effects to passage conditions are not expected to cause significant changes to migration or behavior patterns of leatherback sea turtles.

The effects on the PCEs noted above will not be significant at the watershed or the designation scale of critical habitat for the leatherback sea turtle.

For these reasons, the proposed action ***may affect but is not likely to adversely affect*** potential critical habitat designated for listed leatherback turtles as discussed in this BA. Leatherback sea turtles are not expected to experience long-term effects due to changing environmental conditions at the MCR.

CONCLUSION

Due to the minimal likelihood that species would encounter any elements of the proposed action or that actions would affect their critical habitat, the Corps has determined that the proposed action will have no affect on the following species of marine turtles: loggerhead sea turtles (*Caretta caretta*), green sea turtles (*Chelonia mydas*), and olive ridley sea turtles (*Lepidochelys olivacea*). Due to the minimal likelihood that species would encounter any elements of the proposed actions, or that actions would significantly affect PCEs their critical habitat, the Corps has determined that the proposed action is not likely to adversely affect (NLAA) leatherback sea turtles (*Dermochelys coriacea*). Due to the minimal likelihood that species would encounter any elements of the proposed actions, or that vessel traffic would significantly affect their critical habitat, the Corps has determined that the proposed action is not likely to adversely affect (NLAA) the following marine mammal species: blue whales (*Balaenoptera musculus*), fin whales (*B. physalus*), humpback whales (*Megaptera novaeangliae*), sperm whales (*Physeter macrocephalus*), killer whales (*Orcinus orca*) and sei whales (*B. borealis*). This Biological Analysis further demonstrates the Corps' determination that the proposed action is likely to adversely affect eulachon (*Thaleichthys pacificus*). The Corps has also determined that the proposed action is likely to adversely affect green sturgeon (*Acipenser medirosris*) and Stellar sea lions (*Eumotopias jubatus*). Finally, through this analysis the Corps has also reached the determination that the proposed action may affect and is likely to adversely affect all runs of listed salmonids and steelhead.

MAGNUSON-STEVENS FISHERY CONSERVATION AND MANAGEMENT ACT

The consultation requirement of section 305(b) of the MSA directs Federal agencies to consult with NMFS on all actions or proposed actions that may adversely affect EFH. Adverse effects include the direct or indirect physical, chemical, or biological alterations of the waters or substrate and loss of, or injury to, benthic organisms, prey species and their habitats, and other ecosystem components, if such modifications reduce the quality or quantity of EFH. Adverse effects on EFH may result from actions occurring within EFH or outside EFH, and may include site-specific or EFH-wide impacts, including individual, cumulative, or synergistic consequences of actions (50 CFR 600.810). Section 305(b) also requires NMFS to recommend measures that may be taken by the action agency to conserve EFH.

The Pacific Fishery Management Council (PFMC) described and identified EFH for groundfish (PFMC 2005), coastal pelagic species (PFMC 1998), and Chinook salmon, coho salmon, and Puget Sound pink salmon (PFMC 1999). The proposed action and action area for this consultation are described in the Introduction to this document. The action area includes areas designated as EFH for various life-history stages of species noted in Table 17.

The NMFS conducted groundfish stock assessment studies in the areas offshore of California, Oregon, Washington, and southern British Columbia triennially from 1977 to 2001 (Weinberg et al., 2002). The 2001 assessment collected data from depths ranging from 55 to 500 meters and provides useful information on the distribution of groundfish species. A detailed discussion of EFH for groundfish is provided in Appendix B of Pacific Coast Groundfish Fishery Management Plan [Pacific Fisheries Management Council (PFMC) 2005]. The report includes groundfish life history descriptions (Part 2), EFH text descriptions (Part 3), and habitat suitability maps for groundfish species with life history stages. A detailed discussion of EFH for coastal pelagic species is provided in Amendment 8 to the Coastal Pelagic Species Fishery Management Plan (PFMC 1998). The salmon EFH is discussed in Appendix A of Amendment 14 to the Pacific Coast Salmon Plan (PFMC 1999). The Corps reviewed all of this information to assess the possible impacts to these species' EFH from the proposed action.

Based on information provided in this BA and the analysis of effects presented in the ESA portion of this document, the Corps concludes that the proposed action will have effects on EFH designated for the species identified in Table 17. Permanent negative impacts could be imparted on EFH for Chinook salmon, coho salmon, English sole, sand sole, and starry flounder. Short-term disturbances to EFH would result for lincod, English sole, sand sole, starry flounder, and black, brown, China, copper and quillback rockfish species. Permanent positive effects from addition of rock would increase the area of EFH for lincod and black, brown, China, copper and quillback rockfish species.

POTENTIAL EFFECTS OF THE PROPOSED ACTION ON EFH

Salmon EFH

Marine EFH for Chinook and coho salmon includes (1) estuarine rearing; (2) ocean rearing; and (3) juvenile and adult migration. Important features of this estuarine and marine habitat include (1) adequate water quality; (2) adequate temperature; (3) adequate prey species and forage base; and (4) adequate depth, cover, marine vegetation, and algae in estuarine and near-shore habitats.

The proposed action has the potential to impact EFH of adult and juvenile salmon migration habitat and juvenile rearing habitat. Noise from pile installation and removal is expected to be minimal and not cause an impact since all piles will be installed by vibratory driver. Sound levels will likely be somewhat attenuated towards background in the vicinity of the source. Offloading and under water placement of rock may temporarily displace both adult and juvenile salmon during their migration.

Short-term increases in suspended sediment and resultant turbidity from installing piles or the placement of jetty stones and larger rocks may also impact salmon EFH. Increases in suspended sediment and turbidity will generally be limited to the construction areas along the jetty bases and will be intermittent and of short duration. No contaminated material would be suspended, as sediment in the region is nearly pure sand. Course-grained sand, characteristic of the region, will tend to settle relatively quickly; therefore effects to water quality are expected to be minimal. Alteration of bottom habitat by pile installation and removal or additional rock placement to repair the jetties or add spur groins along the jetties should not adversely affect salmon EFH since these areas do not provide valuable resting or feeding habitat. The MCR is an active migration corridor and it is unlikely that salmon are feeding to any extent in this area. Consequently, there will be no effect on salmon feeding habitat.

Juvenile rearing habitat could be negatively affected by the proposed action. Approximately 15.5 acres of shallow water, and nearshore sandy habitat would be covered at the North and South Jetties and at Jetty A by spur groins, barge offloading facilities, and rehabilitation construction: 7 acres at the North Jetty, 5 acres at Jetty A, and 3.5 acres at the South Jetty. Some causeway structures would be removed upon project completion.

Shallow water, nearshore sandy habitat that could be used as rearing habitat by juvenile salmonids will likely be temporarily (5-20 years of construction is projected) negatively affected by dredging barge offloading facilities at the North Jetty, Jetty A, the Clatsop Spit near the South Jetty adjacent the jetty and also at Parking Area D at the east end of Clatsop Spit in Fort Stevens State Park. Dredging would occur to a finish depth of -25 below MLLW, with a possible overdredge depth of -32 feet in shallow water (a range of water depths from 0 to 20 feet below MLLW) that could be used by rearing juvenile salmonids. Approximately 16 acres of shallow water, sandy bottom habitat would be dredged.

Some effects to migration from artificial obstruction by rock placement may occur, but they are not expected to be measurable. Besides the expected limitations to exposure, this is also because a majority of the spur groins most likely to be encountered by juveniles and adults are submerged so that fish can easily pass over the tops of them (see Table 36). A limited number of juvenile salmonids could use the North Jetty area for migration. Little data is available regarding juveniles use of the South Jetty area, but it is possible that outmigration occurs in close proximity to the South Jetty as it does the North Jetty. Only spur groins on the channel side with elevations at or above MLLW could be capable of altering outmigration routes of juvenile salmonids by forcing them away from the shallower waters along the jetty proper and into deeper waters as they swim around spur groins. Otherwise, juveniles are assumed to pass over the submerged groins. Spur groins that could interfere with outmigration at times, depending on tidal level, would be located only on the South Jetty and include spur groins SJ2C and SJ3C at +5 MLLW (both 70 feet long) and spur groin SJ4C at 0 MLLW (90 feet long).

Figure 62 shows percentage of time that the crests of spurs at 0 MLLW, +5 MLLW, and +8 MLLW would be exceeded (i.e., overtopped by water). Both spur groins with elevation +8 MLLW are not relevant to outmigration because they are on the ocean side of the jetties. Spurs SJ2C and SJ3C on the South Jetty at an elevation of +5 MLLW would be above water 60% of the time for August-September and 55% for October-November. Spur SJ4C would be above water 5% of the time. It is expected that at some point on most ebb tides that spurs SJ2C and SJ3C would be above water, and that fish outmigrating within 70 feet of the South Jetty during that part of the ebb tide when the tops of these spur groins are exposed would have to swim around them. Though sub-yearling Chinook use nearshore areas by the North Jetty more than older juvenile salmonids and typically leave the MCR area over a period of more than one ebb tide, their exposure to these effects is expected to be minimal, and not anticipated to measurably change their migration behaviors.

Coastal Pelagic EFH

Northern Anchovy. The water column near the MCR jetties provides EFH for the northern subpopulation of northern anchovy. The northern subpopulation ranges from Monterey Bay, California to British Columbia. There is a major spawning area of the northern subpopulation off Oregon and Washington that is associated with the Columbia River plume. Anchovy spawn year-round but peak spawning occurs from February to April. Females release eggs into the water column at 7- to 10-day intervals throughout the spawning season. Eggs and larvae are both found near the water surface. Anchovies are typically found in schools at the surface where they feed upon phytoplankton and zooplankton. It is unlikely that rehabilitation of the MCR jetties would affect northern anchovy EFH, because it occurs primarily at the surface away from the jetty construction zones. The previous USGS modeling results predicted that changes to environmental conditions in the plume would be negligible with implementation of the earlier, larger-scale proposed action. The current proposed action is of smaller scale and maintains the current jetty lengths. Therefore environmental changes to conditions in the plume would be even less likely than before.

Jack Mackerel. The MCR area provides EFH for jack mackerel. Jack mackerel are a pelagic schooling fish that ranges from the coastal areas to over 200 miles offshore in deep water. They move offshore and inshore as well as north and south depending upon the time of year. They are generally more abundant on the offshore banks in the late spring through early fall. In the southern portion of their range, they are found offshore but are near the coastline north of Point Conception, California. Jack mackerel collected off Oregon and Washington ranged from 30-62 cm in length. Recent data collected at the Shallow Water Ocean Disposal Site off the tip of the North Jetty showed a large abundance of jack mackerel during October 2002 sampling. Most collected were ripe and appeared ready to spawn (Jack Word, MEC Analytical, personal communication). Although peak spawning occurs from March to July in the southern portion of the range, it apparently occurs later in the northern part of the range. Jack mackerel are water column feeders feeding primarily on plankton and pelagic fish. It is unlikely that rehabilitation of the MCR jetties would affect jack mackerel EFH. These fish are predominately a pelagic species that do not occur near the bottom or near the MCR jetties.

Pacific Sardine. Pacific sardine are a small, pelagic schooling fish that occur in coastal waters from Baja California to Alaska. Historically, sardines may have been the most abundant fish in the California Current. The population off Oregon and Washington is part of a northern subpopulation that ranges from northern Baja California to Alaska. Abundance of sardines in the northern part of the range is seasonal. During years of high abundance sardines will move north as far as Alaska but during years of low abundance they are not found any further north than Point Conception. They migrate north in the summer and return to the southern part of the range in the fall. It is normally the older and larger fish that move the furthest north. Sardine spawn in loosely aggregated schools in the upper 50 meters of the water column. The principal spawning area is from Point Conception to San Diego out to 100 miles offshore and occasionally as far as 250 miles offshore. Spawning has been observed off Oregon and Washington and young fish have been observed as far north as British Columbia during periods of warm water temperatures. Sardines are pelagic feeders feeding on both phytoplankton and zooplankton. It is unlikely that rehabilitation of the MCR jetties would affect Pacific sardine EFH. Pacific sardines occur primarily in the upper water column, offshore of the MCR; thus the MCR area does not provide important EFH for Pacific sardine.

Pacific Mackerel. Pacific mackerel range from Mexico to southeastern Alaska, but are most common south of Monterey Bay, California. Pacific mackerel that occur off Oregon and Washington are part of the northern subpopulation that extends from Mexico north. Although Pacific mackerel are most abundant off Point Conception, they migrate north to off Tillamook Bay in the summer. During periods of warm ocean temperatures they may migrate much further north. Pacific mackerel are usually found within 20 miles of shore but occasionally occur out to 250 miles offshore. Adults are found near shallow banks while juveniles are found off sandy beaches, around kelp beds and in open bays. Pacific mackerel seldom spawn north of Point Conception, although young of the year fish have been found off Oregon and Washington in recent years when water temperatures have been higher than normal. Pacific mackerel feed primarily in the water column on zooplankton and pelagic fish. It is unlikely that jetty rehabilitation would affect Pacific mackerel EFH. They are a pelagic species and would not be near the bottom where the construction activity is occurring. In addition they occur primarily in California and only rarely occur as far north as the MCR. Thus, the MCR area does not provide important EFH for Pacific mackerel.

Market Squid. Market squid range from Mexico to Alaska, although they are most abundant from Monterey Bay to Mexico. Although they are considered pelagic they actually occur from the surface to depths of 800 meters. They prefer ocean salinities and are rarely found in bays, estuaries, or near river mouths. Squid spawn in dense schools on the bottom in spawning areas that range in depth from near shore shallow areas to depths of 800 meters. Known spawning areas are inshore protected areas with sand or mud bottoms at depths between 5 and 55 meters. Squid spawning off Oregon has been observed from May to July and in late summer off Washington and Canada. No squid spawning areas have been found off the MCR. Squid feed on copepods as juveniles and gradually change to euphausiids, other small crustaceans, small fish, and squid. The proposed action would have no effect on market squid EFH. Squid do not occur in the vicinity of the MCR where salinities are lower than ocean waters. As discussed previously, the USGS modeling results predicted that changes to environmental conditions in the plume, including salinity, would be negligible with implementation of the earlier action. However, the current proposed action is of smaller scale and maintains the current jetty lengths; thus, environmental changes to conditions in the plume would be less likely.

Groundfish EFH

The MCR jetties are designated as EFH for several species of groundfish. Some of these species use the MCR as a migratory corridor to rearing areas in bays and intertidal areas that have large concentrations of food organisms, such as the amphipod *Corophium salmonis*. Other groundfish species, principally rockfish, may use the jetties as habitat. Effects on groundfish migratory EFH, however, is likely to be minor since the jetty areas to be disturbed are small relative to the amount of available migratory habitat at the MCR. It is unlikely that disturbance to this small amount of migratory habitat would impact the population levels of groundfish in the MCR area.

Impacts to EFH habitat associated with the jetties is also likely to be minor because the jetties do not provide highly productive rocky habitat because of the low benthic productivity, unstable bottoms, and high current and wave action in the jetty areas. Some groundfish species that use this habitat may be affected in the short term by the disturbance during construction. However, the rehabilitation at the MCR jetties will create additional rocky habitat that will benefit these species, and they will likely quickly recolonize the areas after construction is completed.

California Skate. California skates range from Canada south to Mexico along the Pacific Coast. They are most common off the California Coast inshore and in shallow water bays. They occur at depths from 18 to 671 meters primarily on muddy bottoms. No information is available on spawning habitat. Fertilization is internal and the egg cases are laid on the bottom and drift with the current. When the eggs hatch the young are fully developed though they still have a yolk sac that is slowly absorbed. No California skates have been collected off the MCR though it is possible that they occur in the area. Since they prefer muddy bottoms, it is unlikely that California skates would be in any of the jetty work areas, as these areas are characterized by sand bottoms. Consequently, the proposed actions are not expected to affect California skate EFH.

Soupfin Shark. Soupfin shark are an abundant coastal pelagic species that ranges from Canada to Mexico. They inhabit bays and muddy shallow water areas where they are associated with the bottom. They occur in depths from 2 to 471 meters. Adult males occur in deeper water in northern California while females occur closer to shore in southern California. Juveniles are also more abundant in the southern portion of the range associated with the females. Juveniles also occur in bays such as San Francisco Bay to rear. Soupfin shark exhibit large coastal migrations; the population moves north in the summer and south in the winter. The purpose of these movements is not known. Mating occurs in the spring and fertilization is internal. The gestation period is about 1 year and the females move into bays to give birth to live young. Based on this information, it is unlikely that rehabilitation of the MCR jetties would affect soupfin shark EFH, as the project would not likely influence movement of this species into and out of the estuary.

Spiny Dogfish. Spiny dogfish are an inner shelf mesobenthal species that occur at depths from 0 to 900 meters, but most occur in depths less than 350 meters. Adult females move inshore to shallow waters in the spring to release their young. Young juveniles are neritic while juveniles and adults are sublittorial bathyal. Juveniles occur principally on mud bottoms when not in the water column while adults can occur from the intertidal to great depths. Based on these habitat requirements, the MCR jetty areas would provide only migratory habitat for adult and juvenile spiny dogfish moving in and out of the estuary. However, the jetty areas do not provide any unique habitat that is not available elsewhere, and contain only a small proportion relative to the amount of available migratory habitat for spiny dogfish at the MCR. The project would not likely influence movement of this species into and out of the estuary. Consequently, rehabilitation of the MCR jetties is not expected to adversely affect spiny dogfish EFH.

Ratfish. Ratfish are a middle shelf mesobenthal species that occur in depths from 0 to 913 meters. They are most abundant in depths from 100 to 150 meters. They also occur in the estuaries during the winter and early spring to feed and mate. Ratfish are generally a deep water species that prefer low relief, rocky bottoms or exposed gravel or cobble. They are not commonly found over sand or boulders. Based on these habitat requirements, the MCR jetty work areas do not provide EFH habitat for ratfish. Consequently, jetty rehabilitation is not expected to affect ratfish EFH.

Lingcod. Lingcod are an estuarine mesobenthal species that occurs in depths from 0 to 475 meters. Spawning occurs from 3 to 10 meters below mean lower low water over rocky reefs in areas of swift currents. Larvae occur in near shore areas from winter to late spring. Larger larvae are epipelagic, primarily found in the upper 3 meters of the water column. Juveniles settle in estuaries and shallow waters along the coast while older juveniles move offshore as they grow but are most common in waters greater than 150 meters. Adults prefer slopes of submerged banks 10 to 70 meters below the surface with sea weeds, kelp and eelgrass beds that form feeding grounds for small prey fish. They also prefer channels in rocky intertidal areas with swift currents that concentrate plankton and plankton feeding fish. Based on these habitat requirements, the MCR jetty areas may provide some habitat for lingcod. They were shown to utilize newly constructed jetty habitat at Washaway Beach, Washington. Jetty rehabilitation is expected to disturb habitat for lincod in the short term, while adding some additional habitat with construction of spur groins.

Cabezon and Kelp Greenling. Both of these species are abundant all year in estuarine and subtidal areas. Larvae and young juveniles are pelagic and have been found offshore in waters over 300 kilometers in depth. Juveniles settle to the bottom and are found primarily in shallow-water bays and estuaries. The MCR jetty areas only provide minimal habitat for cabezon and kelp greenling. Rehabilitation of the jetties is not expected to adversely affect cabezon and kelp greenling EFH.

Pacific Cod. Pacific cod are a member of the inner shelf-mesobenthal community. The majority of Pacific cod are found at depths from 50 to 300 meters with spawning occurring at depths from 40-265 meters. The eggs are demersal, adhesive, and are found sublittorally. Larvae and small juveniles are pelagic, with the highest abundance in the upper 15 to 30 meters of the water column. Larvae are found over the continental shelf from winter through summer. Small juveniles occur in depths from 60 to 150 meters gradually moving to deeper water with increased age. Larger juveniles and adults are parademersal occurring over mud, sand and clay, and occasionally coarse sand and gravel bottoms. Based on these habitat requirements, the MCR jetty areas would not provide habitat for Pacific cod. Consequently, rehabilitation of the jetties is not expected to affect Pacific cod EFH.

Pacific Hake. Pacific hake is a migratory species that inhabits the continental slope and shelf from Baja California to British Columbia. Juvenile hake usually reside in shallow coastal waters, bays, and estuaries with adults occurring further offshore, usually at depths from 50 to 500 meters. Along the Pacific Coast from British Columbia to California, adults use a narrow band of feeding habitat near the shelf break for 6-8 months per year. Based on these habitat requirements, the MCR jetty areas would not provide habitat for Pacific hake. Consequently, rehabilitation of the jetties is not expected to affect Pacific hake EFH.

Sablefish. Sablefish are an inner shelf-bathybenthal species that occurs in deep water. Sablefish are most abundant in depths from 200 to 1,000 meters but have been reported to depths of 1,900 meters. Spawning occurs at depths greater than 300 meters. Larvae and young juveniles are pelagic and may move inshore and remain there for up to 4 years to rear. Older juveniles and adults inhabit progressively deeper water and are benthopelagic on soft bottoms. Based on these habitat requirements, the MCR jetty areas would not provide habitat for sablefish. Consequently, rehabilitation of the jetties is not expected to affect sablefish EFH.

Butter Sole. Butter sole occurs from Alaska to southern California where they are common in shallow waters on muddy or silty bottoms. They utilize the waters off the Oregon Coast as a rearing area. Spawning occurs primarily in coastal areas from winter to spring. Larvae drift offshore and then settle to the bottom in the spring as young juveniles. They remain offshore as juveniles. Butter sole would not use the types of habitats associated with the MCR jetty work areas. Consequently, rehabilitation of the jetties is not expected to affect butter sole EFH.

Curlfin Sole. Curlfin sole occur from Alaska to Mexico in shallow waters less than 90 meters in depth over soft bottoms. Little else is known of their habitat requirements, but they apparently do not occur to any extent around rocky areas such as in the vicinity of the MCR jetties. Consequently, rehabilitation of the jetties is not expected to affect curlfin sole EFH.

English Sole. English sole are an inner shelf-mesobenthal species that occur to depths of 55 meters. Adults spawn in inshore waters and the eggs and larvae are pelagic settling to the bottom as young juveniles. Juveniles rear in the inshore areas and in the bays and estuaries. They move offshore as they grow older. English sole are distributed throughout the inshore area on soft bottom habitat. Based on these habitat requirements, English sole could occur in the vicinity of the MCR as either adults or juveniles migrating into or out of the estuary. Consequently, it is possible that English sole EFH could be impacted by rehabilitation of the MCR jetties. However, migratory habitat for English sole is abundant in the MCR area.

Flathead Sole. Flathead sole are mesobenthic, occurring on the continental shelf to depths of 550 meters, but usually are found at depths less than 366 meters. Spawning occurs at depths of 80 to 140 meters. Eggs and larvae are generally buoyant in seawater. The juveniles settle to the bottom and rear in the inshore areas and bays and estuaries. Larger juveniles and adults are usually found further offshore on soft, silty or mud bottoms. Based on these habitat requirements, the MCR jetties do not provide important habitat for flathead sole. Consequently, rehabilitation of the jetties is not expected to affect flathead sole EFH.

Pacific Sanddab. Pacific sanddab is an inshore sublittorial species that occurs in depths up to 306 meters, but are most abundant offshore of Oregon in depths from 37 to 90 meters. Juvenile pacific sanddab occur in shallow water coastal areas, bays, and estuaries on silty sand bottoms. Adults are found further offshore on coarser sandy areas. Based on these habitat requirements, the MCR jetties do not provide important habitat for Pacific sanddab. Consequently, rehabilitation of the jetties is not expected to affect Pacific sanddab EFH.

Petrale Sole. Petrale sole range from Alaska to Mexico where they occur primarily in deeper waters on the continental shelf. Juveniles and adults rear in estuaries in the summer where they are generally found on sand, sandy mud, or occasionally muddy bottoms. Petrale sole do not occur in rocky areas and would not be expected to be in the vicinity of the MCR jetties. Consequently, rehabilitation of the jetties is not expected to affect petrale sole EFH.

Rex Sole. Rex sole is a middle shelf-mesobenthal species occurring at depths from 0 to 850 meters. It is one of the mostly widely distributed sole on the shelf and upper slope, occurring in a variety of depths and sediment types. Spawning occurs at depths from 100 to 300 meters. Larvae are pelagic and are widely distributed offshore with a peak of abundance at about 46 kilometers offshore. Rex sole settle to the bottom at the outer continental shelf and rear in the outer continental shelf. Intermediate size rex sole move inshore to depths of 55 to 150 meters. Adults are distributed throughout the depth range but are more abundant inshore in the summer when feeding. Based on these habitat requirements, the MCR jetties do not provide important habitat for rex sole. Consequently, the proposed actions are not expected to affect rex sole EFH.

Rock Sole. Rock sole range from southern California to Alaska. Juveniles and adults are demersal and are found primarily in shallow water bays in the summer. They prefer sandy or gravel substrate or soft bottoms. Spawning occurs over a variety of substrates from rocky banks to sand and mud. In the winter they migrate to spawning grounds offshore on the edge of the continental slope. Eggs are demersal and adhesive while larvae are pelagic and found primarily in the upper 30 meters of the water column. Based on these habitat requirements, it is unlikely that rock sole would occur to any extent near the MCR jetties or that the jetties provide any important habitat. Consequently, the proposed actions are not expected to affect rock sole EFH.

Sand Sole. Sand sole range from southern California to Alaska. They are a shallow-water species that occur in estuaries as adults, larvae, and juveniles year around. Adults may move into shallow inshore waters to spawn in the winter then may move offshore in the summer to feed. Sand sole prefer sandy and muddy substrates all along the Pacific Coast. Sand sole may occur in the sandy habitat next to the MCR jetties during their migrations into and out of the Columbia River estuary. Consequently, this species may be impacted during rehabilitation of the jetties. Permanent habitat loss could occur with placement of rock on sandy bottom habitat. There is an abundance of sandy habitat in the vicinity of the jetties, however.

Starry Flounder. Starry flounder range from Alaska to the southern California where they are common in the shallow coastal areas. Adults and large juveniles can occur from the outer continental shelf to upstream into freshwater areas in major coastal rivers. Spawning occurs in estuaries or sheltered bays. Eggs and larvae are epipelagic and occur near the surface over water 20 to 70 meters deep. Juveniles are demersal and occur in the estuaries or in the lower reaches of the major coastal rivers. Based on these habitat requirements, this species could occur in the vicinity of jetties during their migration into and out of the Columbia River and could be impacted during the jetty rehabilitation. However, there is an abundance of migratory habitat at the MCR and it is likely that starry flounder would avoid the construction areas. Also, it is expected that EFH habitat for starry flounder would quickly recover following the completion of rehabilitation at each jetty. Permanent habitat loss could occur with placement of rock on sandy bottom habitat. However, there is an abundance of sandy habitat in the vicinity of the jetties.

Black Rockfish. Black rockfish occur from southern California to Alaska. They occur from near the surface to depths of 366 meters or greater, but are most abundant at depths to 54 meters. Adults generally occur near the surface and are frequently found associated with large kelp. Larvae and juveniles are pelagic but become benthic when they reach a larger size. Off the Oregon Coast, age 0 juveniles occur seasonally from June to October. The June transition from pelagic to benthic habitat is accompanied by a movement to estuaries, tide pools, and inshore areas with depths less than 20 meters. Larger juveniles up to 15 centimeters occur in rocky holes such as in the jetties or on sand bottoms associated with rocky areas. Black rockfish appear to migrate south from the central Washington Coast to the Columbia River and north from the northern Oregon Coast to the Columbia River during summer. Black rockfish spawn offshore and have internal fertilization. They release live young from January to March off the Oregon Coast. Rehabilitation of the MCR jetties has the potential to impact EFH for large juvenile black rockfish that may occur in the vicinity of the MCR jetties during the summer construction periods. Since there is an abundance of rocky habitat at the jetties, it is likely that individual black rockfish could avoid the construction activities. In addition, the habitat would quickly recover following project completion, and the rehabilitation would provide additional rocky habitat that would be beneficial to black rockfish.

Brown Rockfish. Brown rockfish range from California to Alaska where they are common in shallow water estuaries and bays. Adults are bottom dwellers living on hard bottoms of siltstone and sand. They also aggregate near rocks and other structures and are particularly attracted to artificial reefs. They set up home ranges of 30-400 square meters around these structures. Artificial reefs become less desirable in the summer and they exhibit considerable off reef movement. Juveniles usually inhabit shallower waters than adults and they utilize the estuaries as nursery areas. Brown rockfish may use the MCR jetty areas either as habitat or during their migrations into and out of the Columbia River estuary and may be impacted during the rehabilitation. Since there is an abundance of rocky habitat at the jetties, it is likely that individual brown rockfish could avoid the construction activities. In addition, the habitat would quickly recover following project completion, and the rehabilitation would provide additional rocky habitat that would be beneficial to brown rockfish.

China Rockfish. China rockfish range from California to Alaska where they occur both inshore and along the open coast in shallow water. They occur principally among rocks and reefs where they sit on the bottom often sheltering in crevices and likely occur around the MCR jetties. They also seem to prefer more exposed, high energy areas. Juveniles occur in the shallow subtidal areas in the summer and early fall. China rockfish are likely associated with the MCR jetties since these fish prefer high energy rocky habitat with an abundance of crevices, and may be impacted during the rehabilitation. Since there is an abundance of rocky habitat at the jetties, it is likely that individual China rockfish could avoid the construction activities. In addition, the habitat would quickly recover following project completion, and the rehabilitation would provide additional rocky habitat that would be beneficial to China rockfish.

Copper Rockfish. Copper rockfish range from Alaska to Mexico where they are predominately a shallow-water species. They occur commonly in rocky areas or on rock-sand bottoms in shallow areas. They are found on natural rock reefs, artificial reefs, and rock piles, typically near the bottom associated with the reefs or vegetation and likely occur at the MCR jetties. Copper rockfish spawn once a year and may move further inshore to release their young. Young are pelagic and then become associated with some type of structure as they mature into juveniles. Once adults find a rocky area they prefer they normally do not move to any extent. Copper rockfish likely occur associated with the jetties since they provide rocky habitat with an abundance of crevices and have the likelihood to be impacted during the rehabilitation. Since there is an abundance of rocky habitat at the jetties, it is likely that individual copper rockfish could avoid the construction activities. In addition, the habitat would quickly recover following project completion, and the rehabilitation would provide additional rocky habitat that would be beneficial to copper rockfish.

Quillback Rockfish. Quillback rockfish range from southern California to Alaska where they are a common shallow water reef dweller that lives close to the bottom. They may also be found over sand bottoms associated with rock reefs. They normally maintain small home ranges with off reef movement occurring in the summer. Young of the year are pelagic and settle to the bottom in vegetated area. Juveniles migrate between low relief and high relief reefs while adults migrate from artificial reefs to natural reefs in the summer when kelp is abundant. They return to the artificial reefs in the fall when the kelp disappears. They show a high homing instinct to their home reefs. Quillback rockfish likely occur associated with the jetties since they provide rocky habitat with an abundance of crevices and have the likelihood to be impacted during the rehabilitation. Since there is an abundance of rocky habitat at the jetties, it is likely that individual quillback rockfish could avoid the construction activities. In addition, the habitat would quickly recover following project completion, and the rehabilitation would provide additional rocky habitat that would be beneficial to quillback rockfish.

Vermilion Rockfish. Vermillion rockfish range from Mexico to Alaska where they are usually found in shallow waters over rocks along drop offs and hard bottoms associated with the bottom. They occur in shallow water as young and in deeper waters as adults. Newly hatched larvae are pelagic and remain near the surface for three to four months. Vermilion rockfish may be associated with the MCR jetties because the jetties provide rocky habitat with an abundance of crevices. However, vermilion rockfish prefer natural reef habitat so it is unlikely that they occur in any numbers in the jetty work areas. Vermilion rockfish may be associated with the MCR jetties since they provide rocky habitat with an abundance of crevices and have the likelihood to be impacted during the rehabilitation. Since there is an abundance of rocky habitat at the jetties, it is likely that individual vermilion rockfish could avoid the construction activities. In addition, the habitat would quickly recover following project completion, and the rehabilitation may provide additional rocky habitat that may be beneficial to vermillion rockfish.

DETERMINATION FOR ESSENTIAL FISH HABITAT

As described above, permanent negative impacts could be imparted on EFH for Chinook salmon, coho salmon, English sole, sand sole, and starry flounder. Short-term disturbances to EFH would result for lincod, English sole, sand sole, starry flounder, and black, brown, China, copper and quillback rockfish species. Permanent positive effects from addition of rock would increase the area of EFH for lincod and black, brown, China, copper and quillback rockfish species. The anticipated effects are summarized below.

1. The effects on EFH from pile installation and removal would be intermittent, only occurring for short periods of time followed by longer periods of no vibration or noise while the piles are being prepared for the next activity. Because vibratory drivers will be used for pile installation and removal, impacts will be minimal. Dredging will alter bottom topography, but the resulting bottom habitat is expected to be useable. It is likely that migratory species such as salmon and some groundfish could avoid the EFH effects from these activities. No long-term or significant effects to prey species or foraging base is expected as a result of stone placement, pile installation and removal, or dreding activities.

2. There will be permanent conversion of sandy bottom habitat from jetty and spur groin construction and temporary loss from offloading causeway construction in the vicinity of the jetty for certain groundfish species. Impacts to the rocky (jetty) habitat are expected to be temporary and new habitat is expected to be re-colonized by rockfish using existing jetty habitat. Additional EFH for some species of rockfish will be available with jetty rehabilitation and spur groin construction.

3. The proposed action at the MCR jetties may have a short-term, adverse effect on water quality for groundfish and salmon species due to localized increased concentration of suspended sediment and turbidity from installing piles, dredging, or the placement of jetty stones and larger rocks. The increases in suspended sediment and turbidity would generally be limited to the construction areas along the jetty bases and would be intermittent and of short duration. Suspended sediment would not be contaminated as sediment in the vicinity of the jetties is nearly pure sand.

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Endangered Species Act
Biological Assessment
For

Marbled Murrelet, Western Snowy Plover, Northern Spotted Owl, Short-Tailed Albatross, Columbian White-Tailed Deer, Bull Trout, Oregon Silverspot Butterfly, Nelson's Checker-mallow, and the Streaked Horned Lark

For the

Major Rehabilitation of the Jetty System at the Mouth of the Columbia River
In
Pacific County, Washington
And
Clatsop County, Oregon

Prepared by
U.S. Army Corps of Engineers
Portland District, Portland, Oregon

February 2011

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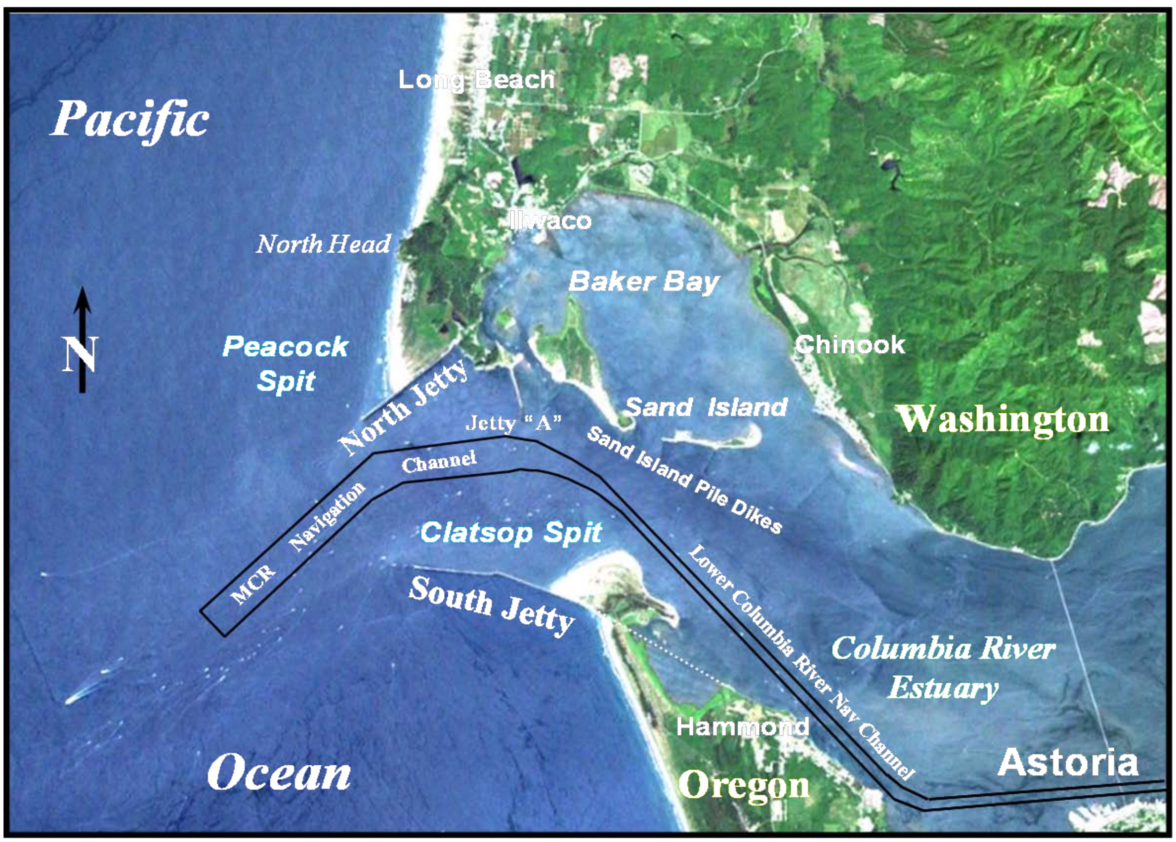
INTRODUCTION

The U.S. Army Corps of Engineers (Corps) prepared and is submitting this Biological Assessment (BA) to the U.S. Fish and Wildlife Service (USFWS) in compliance with the requirements of Section 7(c) of the Endangered Species Act of 1973, as amended. This BA evaluates effects to species listed on the Endangered Species Act (ESA) and their designated and proposed critical habitat for the Major Rehabilitation of the Jetty System at the mouth of the Columbia River (MCR). Federally listed fish, bird, mammal, invertebrate, and plant species and their Critical Habitat could be present in the vicinity of the proposed action. The Corps also requests a Conference Opinion regarding effects to streaked horned lark. The Corps did not request a species list from USFW. The Corps maintains this jetty system and navigational channels as appropriate based on necessity and appropriations. The Corps is currently proposing major repair and rehabilitation for the North Jetty, South Jetty, and Jetty A located at the MCR (Figure 1).

Figure 1. Location of the Jetty System at the MCR



PROJECT AUTHORITY

For the authorization for the actual construction of the MCR jetties, the present navigation channel and configuration of the inlet at the mouth of the Columbia River are the result of continuous improvement and maintenance efforts have been undertaken by the Corps Portland

District since 1885. Congress has authorized the improvement of the MCR for navigation through the following legislation. Senate Executive Document 13, 47th Congress, 2nd Session (5 July 1884) authorized the Corps to construct the South Jetty (first 4.5 miles) for the purpose of attaining a 30-foot channel across the bar at the MCR. House Document 94, 56th Congress, 1st Session (3 March 1905) authorized the Corps to extend the South Jetty (to 6.62 miles) and construct a North Jetty (2.35 miles long) for the purpose of attaining a 40-foot channel (0.5 mile wide) across the bar at the MCR. House Document 249, 83rd Congress, 2nd Session (3 September 1954) authorized a bar channel of 48 feet in depth and a spur jetty ("B") on the north shore of the inlet. Funds for Jetty "B" construction were not appropriated. Public Law 98-63 (30 July 1983) authorized the deepening of the northern most 2,000 feet of the MCR channel to a depth of 55 feet below mean lower low water (MLLW). The MCR federal navigation project was originally authorized (in 1884) before formulation of local sponsor cost sharing agreements; therefore, all navigation maintenance and improvements at MCR are borne by the Federal Government.

The authority for maintenance of the MCR jetties comes from the original authority for construction of the project and then with Corps' policies for the operations, maintenance, and management of a Corps' project (Chapter 11 of EP 1165-2-1). For navigation, completed projects like the MCR have established that operations and maintenance (O&M) is solely a federal responsibility to be accomplished at federal cost.

When maintaining a Corps' project, there is regular O&M, major maintenance, and major rehabilitation. Major rehabilitation consists of either one or both of two mutually exclusive categories, reliability or efficiency improvements.

- Reliability. Rehabilitation of a major project feature that consists of structural work on a Corps operated and maintained facility to improve reliability of an existing structure, the result of which will be a deferral of capital expenditures to replace the structure. Rehabilitation will be considered as an alternative when it can significantly extend the physical life of the feature (such as a jetty) and can be economically justified by a benefit/cost relationship. Each year the budget EC delineates the dollar limits and construction seasons (usually two construction seasons).
- Efficiency Improvements. This category will enhance operational efficiency of major project components. Operational efficiency will increase outputs beyond the original project design.

Thus, the authority for maintenance of the MCR jetties comes from the authorization documents for the project and/or the authority to operate and maintain the structures.

CONSULTATION HISTORY

As the project's preferred alternative has evolved, the Corps has been coordinating with USFW since 2005. Previously, the Corps submitted an earlier version of this Biological Assessment (BA) proposing a larger jetty rebuild. Subsequently, the BA was withdrawn later in January of 2008 due to significant changes in the project description.

Coordination with USFW and was reinstituted in the spring of 2010 after publication of the revised Draft Environmental Assessment in which a new proposed action with a smaller project footprint was determined to be the preferred alternative with which the Corps of Engineers would be moving forward. On May 20, 2010, the Corps and USFW Representatives conducted a Snowy Plover survey around the sandy beach portion of Clatsop Spit. Subsequently, though not specifically related to the MCR proposed action, the Corps has also signed a Memorandum of Agreement (MOA) which will affect implementation the Habitat Conservation Plan (HCP) developed by Oregon Parks and Recreation Department and proposed for portions of the Clatsop Spit.

The Corps has completed this Assessment and is requesting consultation based on current conditions, current listed species use, and currently designated critical habitat (as well as a Conference Opinion regarding the candidate species, streaked horned lark). However, given the duration of the project the Corps has proposed formation of an Adaptive Management Team (AMT) discussed further in the Proposed Action section. During the yearly check-in with the AMT – or more frequently if necessary – the Corps also proposes review of past and future project actions, species listings, and environmental conditions to determine if any re-initiation triggers arise. The Corps is also obligated at any time during implementation of the proposed action to re-initiate or supplement consultation in the event that new species are listed or that critical habitat is designated in the proposed action area.

The Corps has determined that the proposed action will have **no effect** on the following species: short-tailed albatross, northern spotted owls, Columbian white-tailed deer, Oregon silverspot butterfly, and Nelson's Checker-mallow. This Biological Analysis further demonstrates the Corps' determination that the proposed actions may affect but are **not likely to adversely affect** (NLAA) western snowy plovers, marbled murrelets, and bull trout.

BACKGROUND

The MCR project consists of a 0.5-mile wide navigation channel extending for about 6 miles (3 miles seaward and shoreward of the tip of the North Jetty) through a jettied entrance between the Columbia River and the Pacific Ocean on the border between Washington and Oregon. Figure 1 shows the navigation project and the three primary navigation structures, the North Jetty, South Jetty, and Jetty A. Those structures are shown in more detail in Figure 2. The North Jetty and Jetty A are located in Pacific County, Washington, near Ilwaco and Long Beach on the Long Beach Peninsula. The South Jetty is located in Clatsop County, Oregon near Warrenton/Hammond and Astoria.

Figure 2. Rubble-mound Jetties at the MCR

Top left photo shows the South Jetty looking east. The remnant feature shown disconnected from the primary structure is the concrete monolith that was constructed in 1941. The top right photo shows Jetty A. The bottom photo illustrates the North Jetty and the shoreline north of the MCR.

South Jetty

Jetty A

North Jetty

From 1885 to 1939, three rubble-mound jetties with a total length of 9.7 miles were constructed at the MCR on massive tidal shoals. The jetties were constructed to accelerate the flow of the river, which helps maintain the depth and orientation of the navigation channel, and to provide protection for ships of all sizes (both commercial and recreational) entering and leaving the Columbia River. The intention was to secure a consistent navigation channel through the coastal inlet, though morphology of the inlet currently remains in a dynamic, high-energy state. Under such conditions, the jetties have experienced significant deterioration since construction, mainly due to extreme wave attack and foundation instability associated with erosion of the tidal shoals on which the jetties were built.

The initial 4.5-mile section of the South Jetty was completed in 1895-1896. The Rivers and Harbor Act of 3 March 1905 authorized the extension of the South Jetty to 6.6 miles, with the 2.4-mile extension completed in 1913. Historical records show that six spur groins were constructed along the channel side of the South Jetty. Four of the groins were subsequently buried by accreted shoreline or sand shoal. Nine repairs to the South Jetty have been completed with the latest one in 2007. To date, jetty rock placement at the South Jetty totals approximately 8.8 million tons. In spite of these repairs and structural features, over 6,100 feet of head loss has occurred at the South Jetty.

The North Jetty was completed in 1917. Three repairs to the North Jetty have been made with the last one completed in 2005. To date, jetty rock placement totals approximately 3.4 million tons. Since initial construction, about 0.4 miles of the North Jetty head has eroded and is no longer functional.

Jetty A was constructed in 1939 to 1.1 miles in length in connection with rehabilitation of the North Jetty for the purpose of channel stabilization. Its purpose was to assist in controlling the location and direction of the ebb tidal flow through the navigation entrance. Improvements made from 1930 to 1942 (including addition of Jetty A and Sand Island pile dikes) produced the present entrance configuration.

The construction and repair history of the MCR jetties is summarized in Table 1.

The Corps' dredging and in-water disposal of dredged sediments to maintain the above referenced authorized navigation channel is conducted under the provisions of sections 102 and 103 of the Marine Protection Reserve and Sanctuaries Act of 1972, sections 401 and 404 of the Clean Water Act of 1977, and in accordance with Regulations 33 CFR parts 335-338.

Table 1. Construction and Repair History for the MCR Jetties

1881: Proposed project to build a strong pile-dike, 3 feet high about at low tide, 8,000 feet long and 20 feet wide along a line previously established on the south side. The structure to start near the northeast corner of Fort Stevens, following the 12-foot curve, dike will be directed a little westward of the outer part of headland of Cape Hancock. It was stated that work commence soon (during summer and autumn) because channel maintenance is dependent upon building up Clatsop Spit.

1883: A jetty plan approved by the Board of Engineers from the south cape of the entrance on the spit. A survey was conducted in October-November of the south cape, Point Adams, to extreme low water. The jetty extends from Point Adams and makes the distance between the outer end of the jetty and Cape Disappointment the same as the distance between Chinook Point and Point Adams. The Board stated that any structures placed in-river should not harm the river and should keep the channel open using the tide; therefore, the jetty should not obstruct the entry of the flood tide. The jetty design called for a crest elevation at low water level. Estimated depths of various jetty sections from the landward end are: 5,000 feet - less than +6 feet; 7,500 feet – +6 to +11 feet; 4,000 feet – +11 to +16 feet; and 7,500 feet – +16 to +21 feet. Jetty crest elevation was designed to be at low water level because of wave violence that could harm a higher jetty. The logic was that a higher jetty could be built, if needed later, by placing more stone on the existing jetty. A jetty height to mid-tide level was suggested but not recommended because the lower jetty would be quite effective in directing the ebb tide and would interfere less with the flood tide. A higher jetty would result in higher maintenance costs due to the jetty being more exposed to wave action.

1884: The improvement plan for MCR was approved by the Rivers and Harbors Act of July 5, 1884 to maintain a channel 30 feet deep at mean low tide by constructing a low-tide jetty, about 4.5 miles long, from near Fort Stevens on the South Cape to a point about 3 miles south of Cape Disappointment.

1886-1896: Original construction South Jetty from Fort Stevens (station 25+80) across Trestle Bay and Clatsop Spit to station 250+20. Rock placed with a natural slope to an elevation from 4 to 12 feet, crest width roughly 10 feet. "The jetty, of a brush-mattress and stone ballast, was built for 1,020 feet from ordinary highest tide-line, and minor constructions added." Material has filled along the jetty's south side, moving the shoreline seaward. Highest tide-line is located at tramway station 30+50. A 115 feet long spur was built landward of the jetty for shore protection. A 510 feet long sand-catch, consisting of heavy beach drift and loose brush, was built on the south side of landward end of the jetty to continue filling the old outlet of a lagoon at extreme end of Point Adams. Jetty stone was originally dumped in ridges, but waves flattened and compacted the rocks to a width of 50 feet. The report indicated urgency to extend the jetty to prevent further deterioration of the bar channel.

1889: The South Jetty now under construction for 1.5 miles. Clatsop Spit has more material visible at low water and the river channel has a tendency towards a straight course out to sea. Tillamook Chute being closed. Sand building up south of the jetty adjacent to and in front of the mattresses as they are constructed.

1890: South Jetty construction is 3.25 miles underway. Jetty elevation at MLLW for about 3 miles. 1.25 miles of tramway to be constructed. Clatsop Spit building up, the outflowing waters being concentrated over the channel bar. Station 25+80 considered the beginning of the jetty. The jetty mattress has advanced from stations 99+04 to 194+08. The jetty elevation is at MLLW to station 170+00. From Station 170+00 to the end of mattress work, there is about 9 feet of rock on top of the mattress. At station 65+00, there were signs of sinking and a large amount of rock was dumped in place.

1903-1913: Extension of South Jetty. Crest elevation of jetty raised to 10 feet MLLW from stations 210+35 to 250+20, and rock placed from stations 250+20 to 375+52, elevation increasing in steps to 24 feet MLLW. Crest width is 25 feet and side slopes are natural slope of rock. Seaward bend in the jetty is added and called the "knuckle."

1913-1917: Original construction of North Jetty from stations 0+00 to 122+00. Side slopes are 1 vertical by 1.5 horizontal (1:1.5) and crest width is 25 feet. Crest elevation varies from 15 to 32 feet.

1931-1932: Repair South Jetty from stations 175+00 to 257+68.7 (shoreline to knuckle), side slopes 1:1.5, crest elevation 24 feet MLLW, and crest width 24 feet. This is first maintenance for South Jetty. The jetty had been flattened to about low water level. 2.2 million tons of stone placed in super-structure. The work completed in 1936. The end of jetty would unravel 300 feet or more, so a solid concrete terminal was constructed above low water level. The terminal was located 3,900 feet shoreward of the original jetty end that was completed in 1913.

1933-1934: Repair of South Jetty from stations 257+68.7 to 305+05 (knuckle to middle of outer segment). Two level cross section with crest elevations of 17 and 26 feet. Crest width of each level is 24 feet. Side slopes are 1:1.5 on channel side and vary from 1:1 to 1:1.75 to 1:2 on ocean side.

1935-1936: Repair South Jetty from stations 305+05 to 353+05 (middle of outer segment to existing end). Similar design to 1933-1934 repair.

Table 1 (continued). Construction and Repair History for the MCR Jetties

1936: Stone/asphalt cone-shaped terminal constructed on South Jetty from stations 340+30 to 344+30. Crest width of approximately 50 feet and elevation varied from 23 to 26 feet. Side slopes are 1:2.

1937-1939: Repair of North Jetty from stations 68+35 to 110+35. Crest elevation 26 feet and crest width 30 feet. Side slope 1:1.25 on ocean side and 1:1.5 on channel side.

1939: Original construction of Jetty A from stations 40+93.89 to 96+83. Crest width is 10 feet from beginning to station 53+00, 30 feet in width, and elevation at 20 feet from this point on. Four pile dikes completed at Sand Island.

1940: Repair of South Jetty with replacement rock in locations as needed.

1940-1942: South Jetty repair from stations 332+00 to 343+30. Concrete terminal/stone foundation added. Crest elevation from 8-20 feet and crest width from 50-75 feet, 10 inches. Side slopes determined by concrete terminal shape.

1945-1947: Repair Jetty A from stations 78+00 to 96+00. Crest elevation to 20 feet with crest width of 40 feet.

1948-1949: Repair 300 feet of Jetty A from stations 92+35 to 95+35 with a crest elevation of 20 feet, a crest width of 30 feet, and side slopes of 1:1.25.

1951: Repair Jetty A from stations 91+50 to 93+00 with a crest elevation of 20 feet MLLW, a crest width of 30 feet, and side slopes of 1:1.5.

1952: Repair of Jetty A from stations 90+00 to 94+00 with a crest elevation of 20 feet, a crest width of 30 feet, and side slopes of 1:1.5.

1958: Repair of Jetty A from Stations 41+00 to 79+00. Crest elevation raised to 20 feet and a crest width of 20 feet from Stations 41+00 to 56+00. Crest width is 30 feet from Stations 61+00 to 79+00.

1961-1962: Repair Jetty A from stations 50+00 to 90+50, with no repairs from Stations 68+00 to 76+50. Crest elevation built with a 10% grade from 20 feet to 24 feet from stations 50+00 to 68+00. The crest elevation was raised to 24 feet from stations 76+50 to 90+50.

1961: South Jetty repair from stations 194+00 to 249+00 (before knuckle, current stationing). Crest elevation varies from 24 to 28 feet and crest width is 30 feet. Channel side slope 1:1.25 and ocean side slope 1:1.5. Repairs from stations 38+00 to 93+00 (old stationing). Elevation at station 38+00 is +24 feet and then increased with a 0.5% grade up to +28 feet for the remainder of repair section. The repair centerline is located 13 feet north of the centerline of the original jetty design. The design crest width is 30 feet. North slope is 1:1.25 and south slope is 1:1.5.

1962-1965: South Jetty repair from stations 249+00 to 314+05 (beyond knuckle). Crest elevation begins at 28 feet and transitions to 25 feet for most of section. Side slopes vary from 1:1.5 to 1:2 and crest width is 40 feet (this appears to be the furthest seaward intact portion of current jetty). Repairs made from stations 93+00 to 157+50 (old stationing). The crest elevation is +28 feet at station 93+00, then decreases to +25 feet at station 95+00, and then continues with this elevation to end of the repairs. The crest width is 40 feet and has a slope of 1:1.5 from stations 93+00 to 152+00. Slope then transitions to 1:2 from stations 152+00 to 154+00. The centerline of the repair is 15 feet south of the trestle centerline.

1965: Repair North Jetty from stations 89+47 to 109+67 with a crest elevation of 24 feet and crest width is 30 feet. Side slopes vary from 1:1.5 to 1:2.

1982: Repair South Jetty from stations 194+00 to 249+00 (segment before knuckle). Crest elevation varies from 22 to 25 feet MLLW. Crest width varies from 25-30 feet and side slopes 1:1.5. Crest elevation varies from +22 feet at station 38+00 to +25 feet at station 80+35 (old stationing). From stations 44+50 to 80+35, crest width is 30 feet and slope is 1:1.5. Centerline of repairs has 10 feet maximum variance to the north for the South Jetty control line. From stations 80+35 to 93+00, centerline of repairs is the same as South Jetty control. Crest elevation +25 feet, width varies from 25-30 feet, side slope is 1:1.5.

2005: Interim repair of North Jetty (stations 55+00 to 86+00). Crest elevation +25 feet with side slope of 1:1.5.

2006: Interim repair of South Jetty (stations 223+00 to 245+00). Crest elevation +25 feet with side slope of 1:2.

2007: Interim repair of South Jetty (stations 255+00 to 285+00). Crest elevation +25 feet with side slope of 1:2.

DESCRIPTION OF THE PROPOSED ACTION

OVERVIEW

The Corps proposes to perform modifications and repairs to the North and South Jetties and Jetty A at the MCR that would strengthen the jetty structures, extend their functional life, and maintain deep-draft navigation.

Proposed actions are generally comprised of four categories applicable to each jetty: (1) engineered designs elements and features of the physical structures; (2) construction measures and implementation activities; (3) proposed 7(a)(1) habitat improvement measures and wetland mitigation actions to improve habitat for the benefit of listed species and to offset wetland fill, and (4) proposed establishment of and coordination with an Adaptive Management Team (AMT) comprised of Corps' staff and representatives from appropriate Federal and State agencies.

It is notable that the duration of the construction schedules is 20 years, with a 50-year operational lifetime for the MCR jetty system. Therefore, an inherent level of uncertainty exists regarding dynamic environmental conditions and actual conditions of and at each of the jetties. For this reason, in all cases where areas, weights, and volumes (tons, acres, cubic yards, etc.) or other metrics are indicated, these are best professional estimates and may vary by greater or lesser amounts within a 20% range when final designs are completed. These amounts represent Corps' and staff's best professional judgments of what the range of variability could entail as the design is further developed and as on-the-ground conditions evolve over the 20-year construction schedule. The Corps maintains an active jetty monitoring and surveying program that will further inform the timing and design of the proposed action in order to facilitate efficient completion of the project and whenever possible to avoid emergency repair scenarios.

(1) Design elements and structural features specific to each jetty include the following:

- North Jetty – Scheduled repairs addressing the existing loss of cross section and the addition of engineering features designed to minimize future cross section instability are planned. The cross section repairs are primarily above MLLW, with a majority of stone placement not likely to extend beyond -5 ft below MLLW. In order to address the structural instability of the jetty cross-section, four spur groins will be added and the jetty head (western-most section) will be capped with large stone. Groins will be constructed primarily on existing relic stone and the head capping will be placed on relic as well as jetty stone that is above MLLW. The shore-side improvements that have been identified are culvert replacement and lagoon fill. These actions are designed to stop the current ongoing erosion of the jetty root.

- South Jetty – Scheduled repairs addressing the existing loss of cross section and the addition of engineering features designed to minimize future cross section instability are planned. The cross section repairs are primarily above MLLW, with a majority of stone placement not likely to extend beyond -5 ft below MLLW. In order to address the structural instability of the jetty cross-section, five spur groins will be added and the jetty head (western-most section) will be capped with large stone. Groins will be constructed primarily on existing relic stone and the head capping will be placed on relic as well as jetty stone that is above MLLW. Augmentation of the dune at the western shoreline extending south from the jetty root has been included in the repair plan. This action is intended to prevent the degradation of the jetty root and prevent the potential breaching of the fore dune.

- Jetty A – Scheduled rehabilitation addressing the existing loss of cross section and the addition of engineering features designed to minimize future cross section instability are planned for Jetty A. The cross section repairs are primarily above MLLW, with a majority of stone placement not likely to extend beyond -5 ft below MLLW. In order to address the structural instability of the jetty cross-section, two spur groins will be added and the jetty head (southern most section) will be capped with large stone. The groins will be constructed primarily on existing relic stone and the head capping will be placed on relic as well as jetty stone that is above MLLW. Immediate rehabilitation with small cross section, two spur groins, and head capping.

(2.) Construction measures and implementation activities for all three jetties include the following:

- Storage and staging areas for rock stockpiles and all associated construction and placement activities such as: roadways, parking areas, turn-outs, haul roads, weigh stations, yard area for sorting and staging actions, etc.
- Stone delivery from identified quarries either by barge or by truck. Possible transit routes have been identified. This also includes the construction and use of permanent barge offloading facilities and causeways with installation and removal of associated piles and dolphins.
- Stone placement either from land or water, which includes the construction, repair, and maintenance of a haul road on the jetty itself, crane set-up pads, and turnouts on jetty road. Placement by water could occur via the use of a jack-up barge on South Jetty, but will not occur by other means or on North Jetty to avoid impacts to crab and juvenile salmon migration.
- Regular dredging and disposal of infill at offloading facilities with frequency dependent on a combination of the evolving conditions at the site and expected construction scheduling and delivery. Disposal will occur at existing approved in-water sites.

(3.) A suite of potential projects to provide 7(a) (1) habitat improvement and wetland mitigation actions have been identified as beneficial to listed species. Depending on further development of alternatives within this list, a specific project or combination of projects will be selected and constructed concurrently to provide environmental benefits as portions of the proposed action are completed over time. Estimates for wetland impacts are preliminary and may be reduced when final delineations are completed; therefore wetland restoration may be less than approximations noted, but will be commensurate with impacts from construction activities. These restoration and habitat improvement measures will therefore require additional consultations, and it is anticipated that the proposed AMT will be of assistance in this process. It is anticipated that a programmatic opinion similar to SLOPES Restoration or Limit 8 may be useful to fulfill clearance requirements. Possible restoration measures could include an individual project or a combination of projects and actions such as:

- Excavation and creation of wetlands to restore and improve wetland functions including water quality, flood storage, and salmonid refugia.
- Culvert and tide gate replacements or retrofits to restore or improve fish passage and access to significant spawning, rearing, and resting habitat.
- Dike breaches to restore estuarine brackish intertidal shallow-water habitat for fish benefits.
- Beneficial uses of dredged material from MCR hopper dredge to replenish littoral cells.
- Invasive species removal and control and revegetation of native plants to restore ecological and food web functions that benefit fisheries.

(4.) Due to the long duration of the MCR Jetty Rehabilitation schedule, the Corps proposes formation of a modified Adaptive Management Team (AMT). The Corps suggests annual meetings to discuss relevant design and construction challenges and modifications, technical data, new species listings or critical habitat designations, evolving environmental conditions, and adaptive management practices as needed. The primary purpose of the proposed AMT and its implementation is to ensure construction, operation, and maintenance actions have no greater impacts than those described in the Biological Assessments, and that terms and conditions of the Biological Opinions are being met. This will also allow confirmation that any necessary construction or design refinements remain within the range and scope of effects described during Consultations. This forum will provide and opportunity for periodic evaluation as to whether or not the proposed actions, ESA listings, or environmental conditions result in any re-initiation triggers. It will also facilitate continued coordination and updating and allow the Corps to inform agency partners when unforeseen changes arise. Results regarding marine mammal and fish monitoring, wetland mitigation and habitat improvement monitoring, as well as water quality monitoring will also be made available to the AMT in order to fulfill reporting requirements and to address any unexpected field observations. Results of jetty monitoring surveys will also inform the AMT of the repair schedule and design refinements that become necessary as the system evolves over time. This venue will provide greater transparency and allow opportunities for additional agency input. Final selection and design of the habitat improvement and wetland mitigation proposal will be vetted through this forum to facilitate obtaining final environmental clearance documents for this component of the MCR proposed action. Potential principal partners include federal (National Marine Fisheries Service, U.S. Fish and Wildlife

Service) and State (Washington and Oregon) resource management agencies. The strategy is designed to be consistent with the guidance provided in 65 Federal Register (FR) 35242.

GENERAL TERMS AND FEATURES

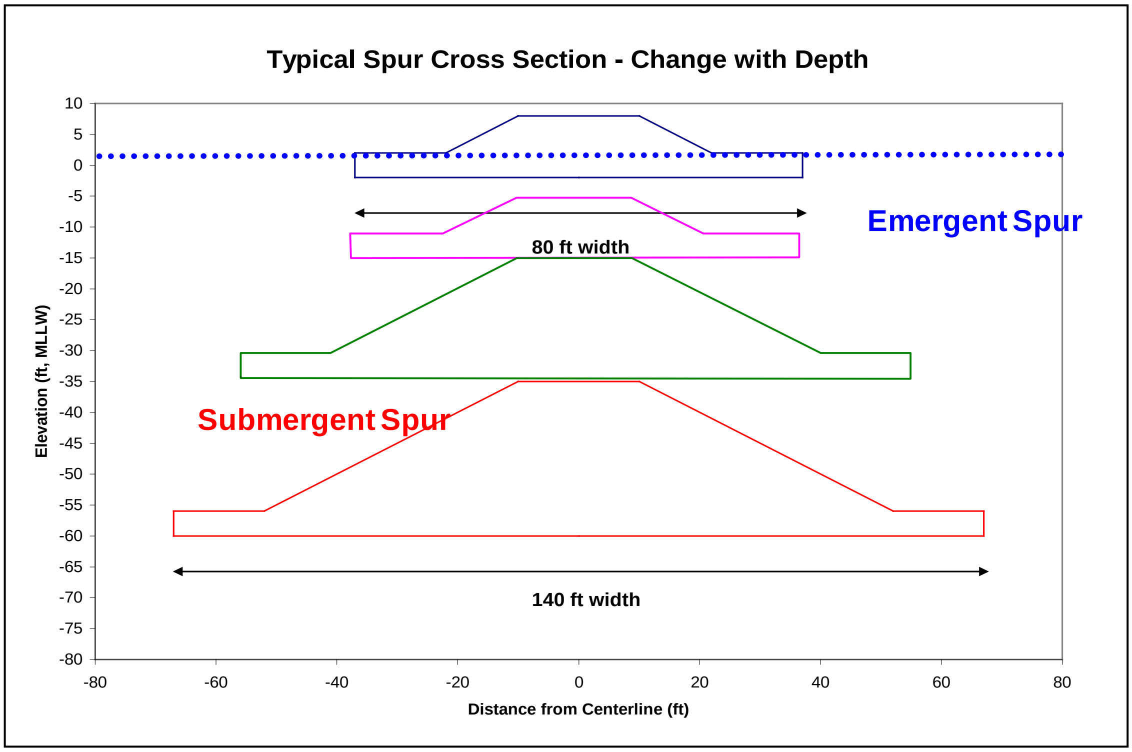
Previously during earlier design phases of the proposed action, the U.S. Geological Survey (USGS) in Menlo Park, California assisted the Corps with evaluating potential improvements and impacts of rebuilding and repairing the lengths of the MCR jetties. The USGS efforts focused on using the Delft-3D model of the Columbia River estuary and adjacent coast (Delft3D 2006) to identify potential changes in circulation, salinity and sediment transport that could result from the offshore re-build of the three jetties. Increased jetty lengths were investigated to determine if they could provide a more sustainable jetty system over the long term. Although rebuild of the jetties is no longer proposed, Corps' engineering staff has also indicated modeling results remain relevant and valid for evaluating jetty performance in the current proposed action, which caps jetty lengths in their current locations (Moritz 2010).

The Corps' Engineering Research and Development Center (ERDC) in Vicksburg, Mississippi was also contracted to conduct a physical model of the jetty cross-section design. The range of structural repair types addressed in the model included crest elevation and crest widths variations, side-slope variations, underwater berms, armor stone, and concrete armor unit options. Both the North Jetty and South Jetty were tested under low and high water conditions. Physical modeling results showed that the primary failure modes for the North and South jetties were high water wave attack and overtopping. These results were used to determine cross-section design options for the jetties that achieve varying levels of structure reliability. The following design components are a result of a combination of these models and other modeling and engineering staff efforts (Moritz and Moritz 2010).

Each MCR jetty consists of three parts. The <u>head</u> is the seaward terminus and is exposed to the most severe wave action. Jetty head design is much more substantial than a typical jetty trunk section due to its increased exposure to wave attack and its critical protective function for the rest of the structure. The <u>trunk</u> forms the connection from jetty head to shore, retains sub-tidal shoals, and confines circulation in the navigation inlet. The <u>root</u> forms the connection from the jetty trunk to shore and prevents accreted landforms from migrating into the navigation channel.

A spur groin is a relatively short structure (in comparison to jetty length) usually extending perpendicular from the main axis of a jetty. Spur groins are constructed: (1) on the ocean or beach side of a jetty to deflect the long-shore (rip) current and related littoral sediment away from the jetty and prevent littoral sediment from entering the navigation channel; and (2) on the channel side of a jetty to divert the tidal or river current away from the channel side toe of the jetty. Spur groins also act to reduce the scour affecting the foundation while increasing the current in the navigation channel, thus reducing the deposition in the channel. In areas where foundation scour threatens the overall stability of the MCR jetties, spur groins constructed perpendicular to the structure facilitate stabilization by the accumulation of sediment along the jetty's foundation. Each spur groin will have a crest width of about 20 feet, and will be constructed using a bedding layer (mixture of gravel and rock) that will be covered with large stone sized for the location and exposure. Submergent spur groins that located at greater depths also typically have wider bases than shallower, emergent groins (Figure 3).

Figure 3. Typical Spur Cross Section - Change with Depth



The ERDC analyzed the hydrodynamics and circulation patterns in the MCR entrance, as well as the potential impacts and effectiveness of placing spur groins on the jetties. This analysis was conducted with the coastal modeling system and other models to select the type, depth, and length of spur groins necessary to protect the each jetty from the processes causing increased scour (e.g., rip currents, eddies). Although the models were also evaluating a potential restoration of the jetties' former lengths, proposed construction of spur groins at each jetty has not changed since modeling was completed. Therefore, Corps' engineering staff has indicated that modeling results remain relevant and valid in their assessment of spur groin performance.

Two potential construction methods could be used for spur groins, either land-based or marine-based depending on location. Barges or similar equipment could be used to dump the bedding layer rock into place and a clamshell would be used to place larger stone on top of the bedding rock layer in locations with sufficient water depth. This type of marine placement activity will not require installation of additional piles or dolphins. Material could also be placed using land-based equipment from on top of the jetty. Land-based construction may require a wide turnout crane placement with over-excavation down to grade as the crane walks back onto the main jetty axis. In addition, the emergent spur groins may be used as turnouts for construction equipment. The land-based construction method could be used for all but the deepest spur groins.

Head capping involves placing much larger armor stone at the terminus of the jetty where the highest degree of enforcement is necessary to withstand conditions. Enforcement could also include the use of concrete armor units (CAU). These will be fabricated off-site and then transported to the head via truck or barge. The armor stone at the head helps avoid recession and loss of length and by protecting the rest of the jetty from unraveling back towards the root.

Repair and rehabilitation are two proposed approaches that specifically describe construction and stone placement actions for the cross-sections and engineered features along the trunks and roots of the jetties. The economics and design model used to select Schedule Repair as the proposed action at the North and South jetties predicts a certain number of repair actions that will be needed to avoid a breaching scenario during the 20-year construction schedule and 50-year operational lifetime of the jetties.

Along certain sections of each jetty, wave cast and erosional forces have in some cases flattened the jetty prism and left a bedding of relic stone with little or only a partially complete jetty prism remaining. The Scheduled Repair approach prioritizes work on specific portions of the jetty so that sections in a greater degree of deterioration will be repaired with rock according to a programmed sequence developed as a result of regular jetty monitoring and inspections. Proposed <u>repair</u> alternatives involve adding limited amounts of stone to trunk, head, and root features in order to restore the damaged cross-sections back to a standard repair template. A repair action is generally triggered when the upper cross-sectional area falls below 30%-40% of its standard jetty template profile (only 30% or 40% of the current jetty structure remains; 60%-70% of the previously existing prism is gone). Then a standard repair template is implemented. For each repair action, a majority of stone placement will occur above MLLW. However, depending on conditions at specific jetty cross-sections, stone could extend deeper than -5 ft below MLLW in order to restore the reach back to the standard repair template. Therefore, repair actions could be slightly greater or smaller depending on the condition of the cross-section being repaired. Stone placement will remain mostly within the prism of the existing jetty and relic stone structures; though it is possible that wave actions and slope angles could result in a small percentage of further rock slipping off the relic slope.

Proposed <u>rehabilitation</u> alternatives generally incorporate engineering components and rock placement along the cross-section of the entire root and trunk. The construction and placement sequence for Immediate Rehabilitation at Jetty A means stone placement activities are initiated at one end of the jetty and are completed continuously in succession without prioritization based on conditions at any particular jetty section. The proposed rehabilitation action on Jetty A is more robust than a repair action and includes a <u>small</u> cross section along the entire length of the jetty. Sections in a greater state of deterioration may receive a relatively larger amount of rock compared to sections with less damage. The rehabilitation cross-section template is expanded slightly beyond the existing prism template. This generally involves stone placement that primarily fits within the existing footprint of the jetty structure or relic stone, but may extend slightly beyond the existing prism. It also generally involves the bulk of the rock placement above MLLW, though it could extend below in some sections, again depending conditions in each reach.

The following discussions also mention station numbers on each jetty. These stations indicate lineal distance along the jetty relative to a fixed reference point (0+00) located at the landward-most point on the jetty root. Numbering begins at the reference point (0+00) and increases seaward such that each station number represents that distance in feet, multiplied by 100, plus the additional number of feet indicated after the station number. For instance, station 100+17 would be 10,017 feet seaward from the reference point. A summary of design parameters for the preferred plan at each jetty is shown in Table 2.

Table 2. Preferred Plan Design Metrics Summary for MCR Jetties

Note: volumes, lengths and areas may vary by ± 20% upon final design.

North Jetty Scheduled Repair with Engineering Features

Jetty Crest Elevation	Estimated Stone Density	Total Repair Length	Jetty Crest Width	Jetty Sideslope		Jetty Head Station	Head Length	Spur Groin Sta.	Spur Groin Tons
				Channel	Ocean				
25' above MLLW	167 #/ft3	8,100'	30'	1v:1.5h	1v:1.5h	99+00 to 101+00	200'	Sta 50-C Sta 70-C Sta 80-O Sta 90-C	3,895 12,870 2,340 33,960

South Jetty Scheduled Repair with Engineering Features

Jetty Crest Elevation	Estimated Stone Density	Total Repair Length	Jetty Crest Width	Jetty Sideslope		Jetty Head Station	Head Length	Spur Groin Sta.	Spur Groin Tons
				Channel	Ocean				
25' above MLLW	167 #/ft3	15,800'	30'	1v:1.5h	1v:2h	311+00 to 313+00	200'	Sta 165-O Sta 210-C Sta 230-C Sta 265-C Sta 305-O	1,496 2,095 2,095 2,841 16,747

Jetty A Rehab with Engineering Features

Jetty Crest Elevation	Estimated Stone Density	Total Repair Length	Jetty Crest Width	Jetty Sideslope		Jetty Head Station	Head Length	Spur Groin Sta.	Spur Groin Tons
				Estuary	Ocean				
20' above MLLW	167 #/ft3	5,300'	40'	1v:2h	1v:2h	91+00 to 93+00	200'	Sta 84-O Sta 90-E	12,272 12,272

DESIGN ELEMENTS AND STRUCTURAL FEATURES OF PROPOSED ACTION

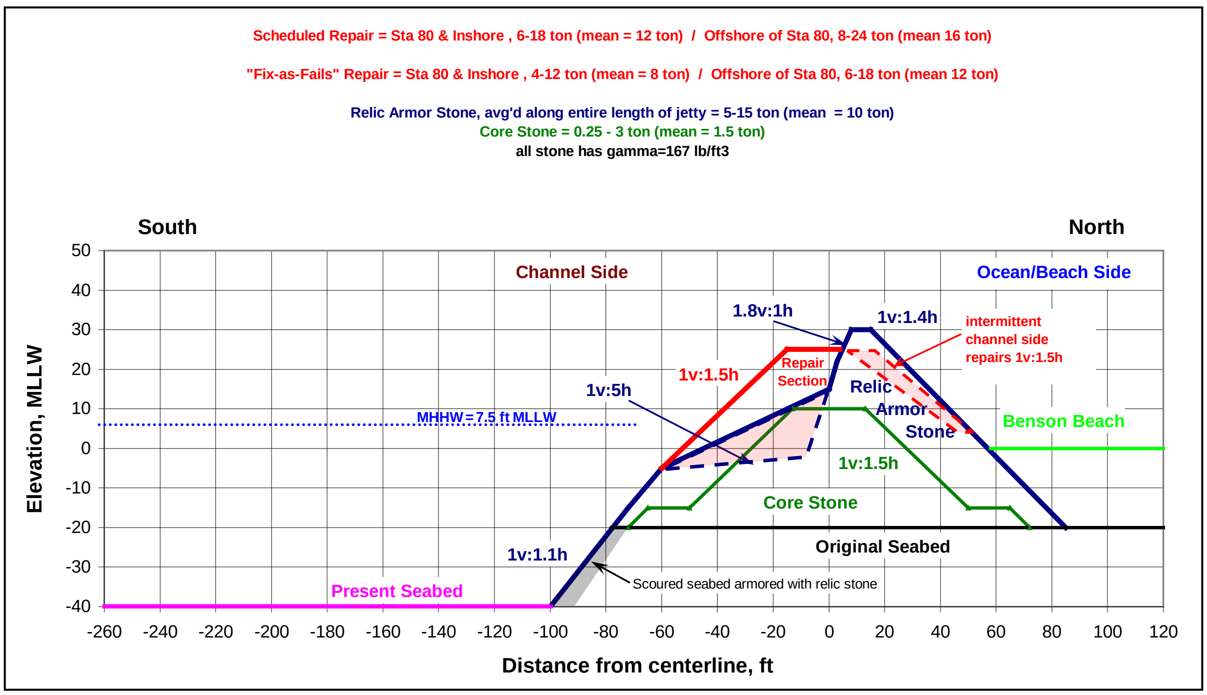
MCR North Jetty

The proposed action for the North Jetty is Scheduled Repair and construction of engineered features including four spur groins and head capping, culvert replacement, and lagoon fill to stop erosion of the jetty root (Figures 4 and 5). The jetty head and foundation at the most exposed portion of jetty will be stabilized.

North Jetty Trunk and Root

The cross-section design from stations 20+00 to 99+00 will have a crest width of approximately 30 feet and will lie essentially within the existing jetty footprint based on the configuration of the original cross section, previous repair cross sections, and redistribution of jetty rock by wave action. About 460,000 tons (~287,500 cy) of new rock will be placed on relic armor stone, with the majority of stone placement above MLLW. About four repair events were predicted over the next 20 years. Each repair action is expected to cover a length range of up to 1,700 feet and include stone volumes in the range of 45,000 to 100,000 tons (~28,125-62,500 cy) per season.

Figure 4. North Jetty Cross Section for Existing Condition and Scheduled Repair Template



At the time of repair, it is expected that 60%-70% of the standard jetty template cross-section has been displaced. Therefore, each repair event will increase the degraded cross-section from 30%-40% back to 100% of the desired standard cross-section template. This means the overall added rock will essentially triple what exists immediately prior to the time of repair. This could be described as a ~300% increase in rock relative to the existing jetty rock volume. However, this will not increase the jetty prism or footprint beyond the scope and size of the historic structure, and does not include any modification that changes the character, scope, or size of the original structure design.

With placement divided into elevation zones per representative repair event, about 21,550 cy of rock will be placed above mean higher high water (MHHW). This represents 58% of the overall stone placement on these portions of the jetty and 376% change from the existing jetty prism. This means that currently only a small portion of the original profile remains in this zone and over three times as much stone must be placed compared to what presently remains. As described, above, this same concept applies characterizations about the rest of the zones. About 9,230 cy of rock will be placed between MHHW and MLLW. This represents 25% of the overall stone placement on these portions of the jetty and a 192% change from the existing jetty prism. About 6,675 cy of rock will be placed below MLLW. This represents 18% of the overall stone placement on these portions of the jetty and a 150% change from the existing jetty prism. The footprint of the trunk and root of the North Jetty will remain on relic stone and within its current jetty dimensions.

North Jetty Spur Groins

Three submergent spur groins will be placed on the channel side and one emergent spur groin will be placed on the ocean side of the North Jetty to stabilize the foundation (Figures 6 to 9). The approximate dimensions and other features of the spur groins are shown in Table 3. If possible, in order to avoid and minimize impacts to species and habitats, either one of the spur groins located around stations 50 or 70 may also serve a dual purpose as an offloading facility for stone delivery. This will occur at the contractor's discretion depending on channel current and wave conditions. Otherwise, a separate offloading facility will be constructed in the vicinity between these stations to take advantage of calmer waters. There is a dredge material disposal site along the North Jetty and adjacent disposal cells closest to the jetty and spur groins will be precluded from use to avoid interference with jetty construction and to ensure barge safety during disposal. Barge offloading structures and dredge activities are discussed in more detail later in this assessment.

Representing rock volume estimated totals divided into elevation zones for all newly constructed spurs on the North Jetty, about 25 cy of rock will be placed above MHHW. This represents 0.1% of the overall stone placement on these portions of the North Jetty spur groins and there is very little or no existing jetty stone expected to be present within this elevation range. About 1,146 cy of rock will be placed between MHHW and MLLW. This represents 4% of the overall stone placement on these portions of the North Jetty spur groins and there is very little or no existing jetty stone expected to be present within this elevation range. About 27,760 cy of rock will be placed below MLLW. This represents 95.9% of the overall stone placement on these portions of the North Jetty spur groins and there is very little or no existing jetty stone expected to be present within this elevation range. The footprint of the North Jetty spurs will increase from 0 acres to 1.55 acres. In the relevant figures, note that the difference in the vertical and horizontal scales causes a slight representational distortion along the axes.

Figure 5. Proposed Action for the MCR North Jetty

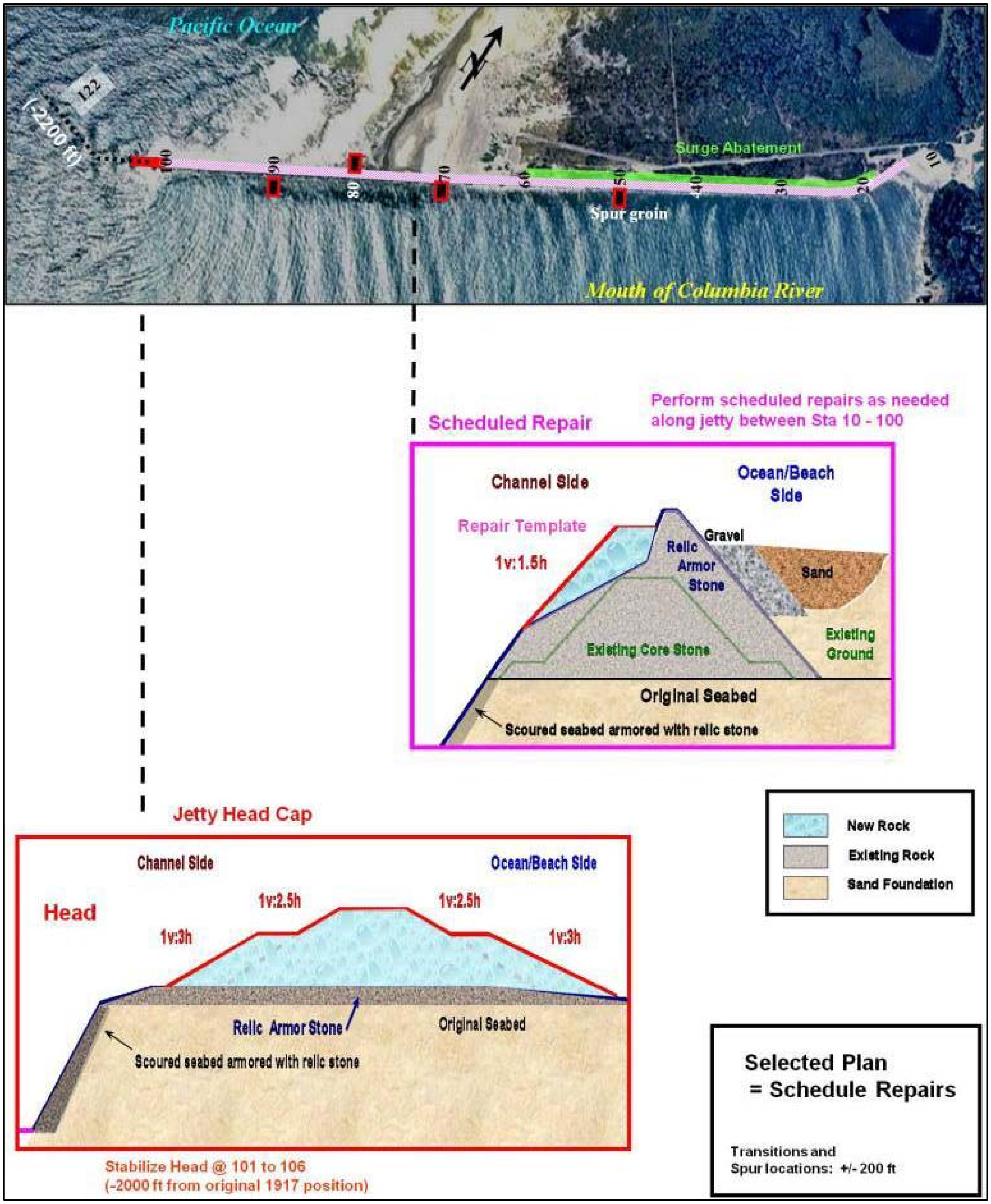
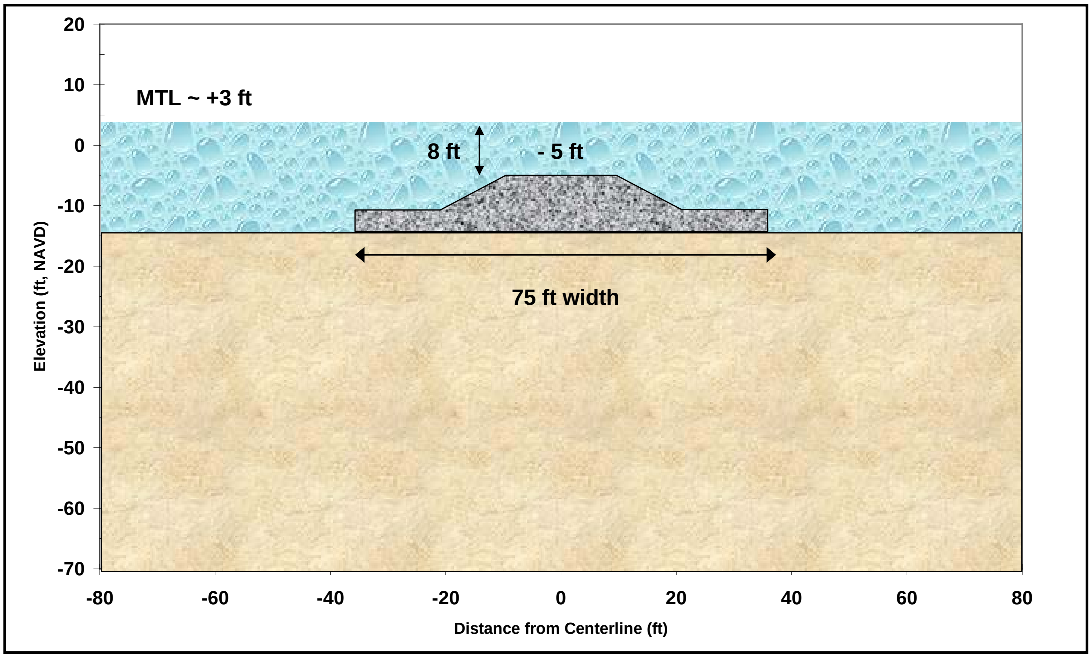


Table 3. North Jetty Spur Groin Features

Spur Groin Features	North Jetty
Number of spurs on channel side	3
Number of spurs on ocean side	1
Approximate total rock volume per spur (+/- 20%)	NJ1C: 3,350 tons (~2,094 cy) NJ2C: 11,090 tons (~6,931 cy) NJ3O: 2,010 tons (~1,256 cy) NJ4C: 29,250 tons (~18,281 cy)
Approximate total rock volume (all spurs) (+/- 20%)	53,000 tons (~33,125 cy)
Approximate area affected by each spur	NJ1C: 0.18 acres NJ2C: 0.45 acres NJ3O: 0.11 acres NJ4C: 0.80 acres
Approximate total area affected (all spurs)	1.55 acres
Approximate area of spurs above MLLW	NJ1C: 0% NJ2C: 0% NJ3O: 24% NJ4C: 0%
Approximate area of spurs below -20 MLLW	NJ1C: 0% NJ2C: 88% NJ3O: 0% NJ4C: 100%
Approximate dimension of spurs: length x width x height (feet)	NJ1C: 100 x 80 x 10 NJ2C: 170 x 115 x 19 NJ3O: 60 x 80 x 10 NJ4C: 170 x 115 x 19

Figure 6. North Jetty Spur Groin NJ1C

Note difference in scale between vertical and horizontal axes.



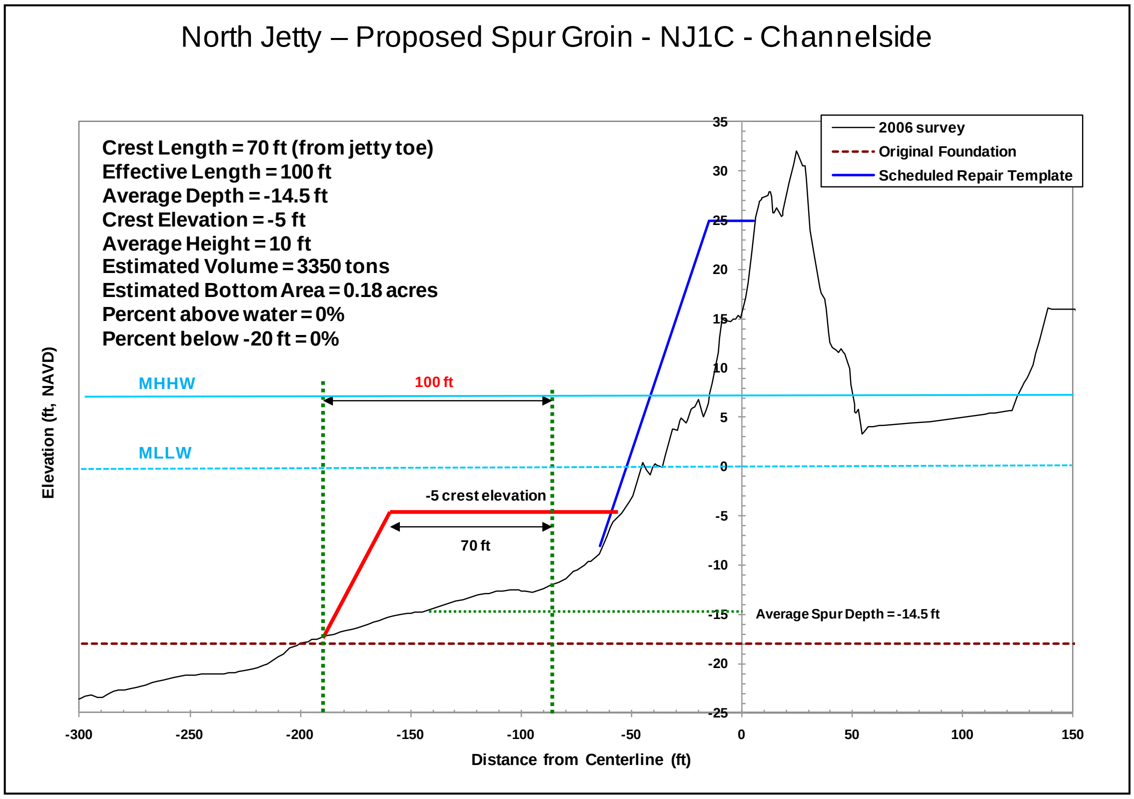
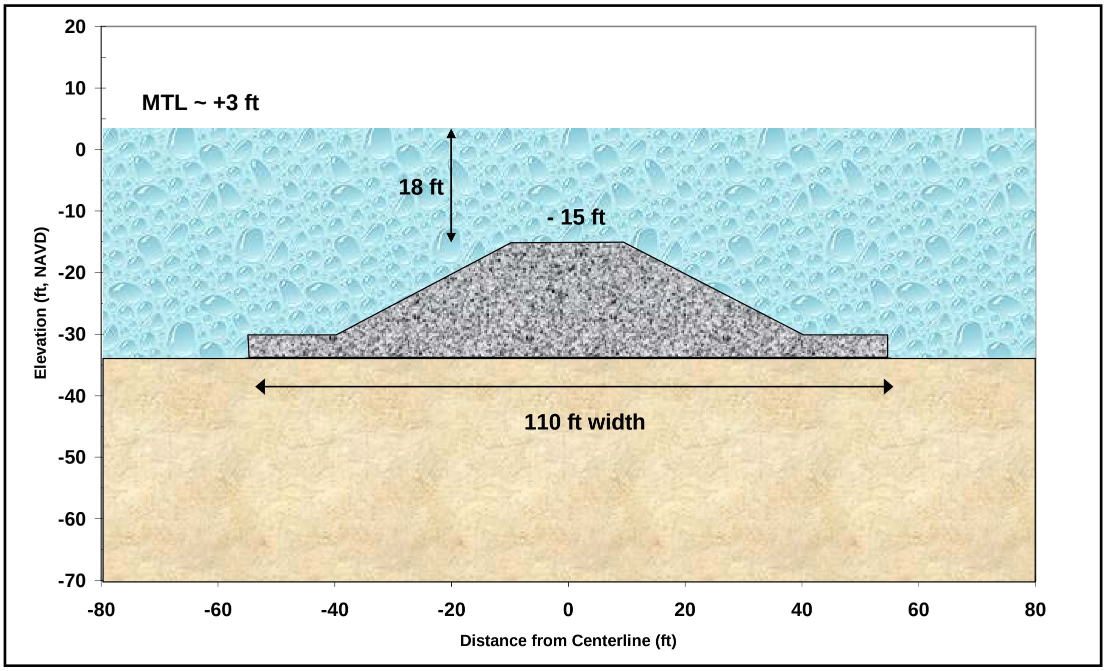


Figure 7. North Jetty Spur Groin NJ2C

Note difference in scale between vertical and horizontal axes.



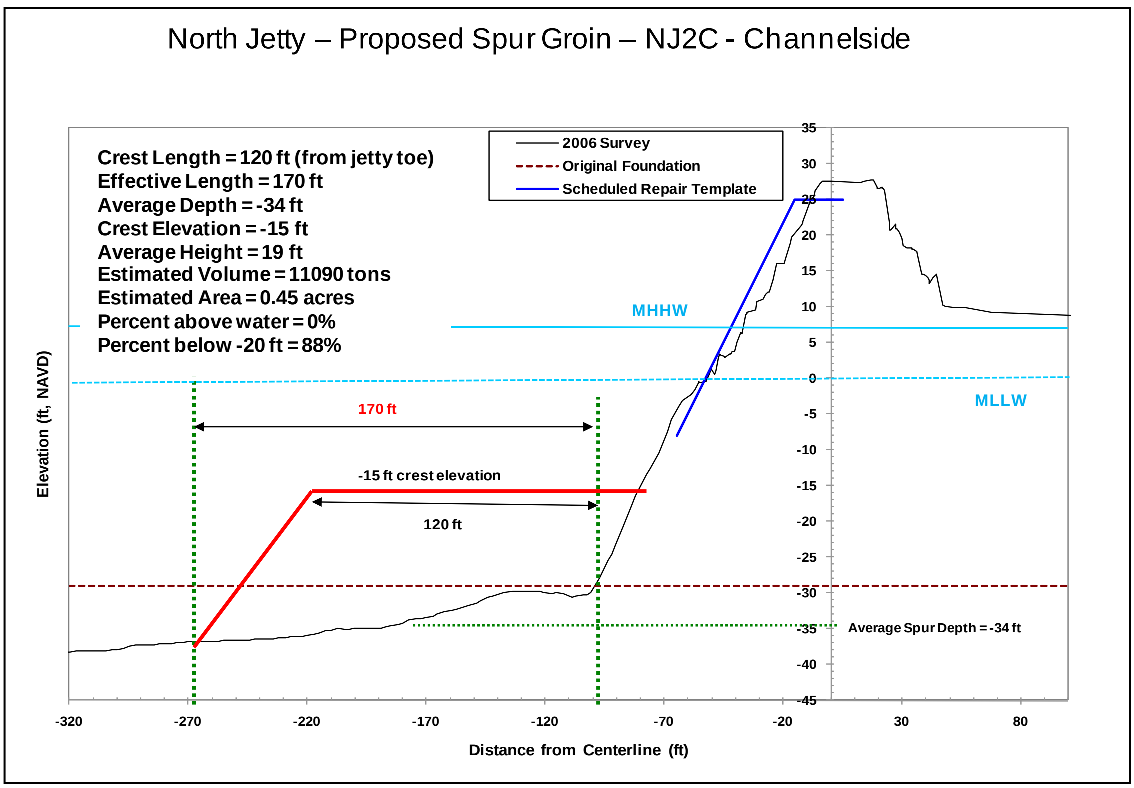
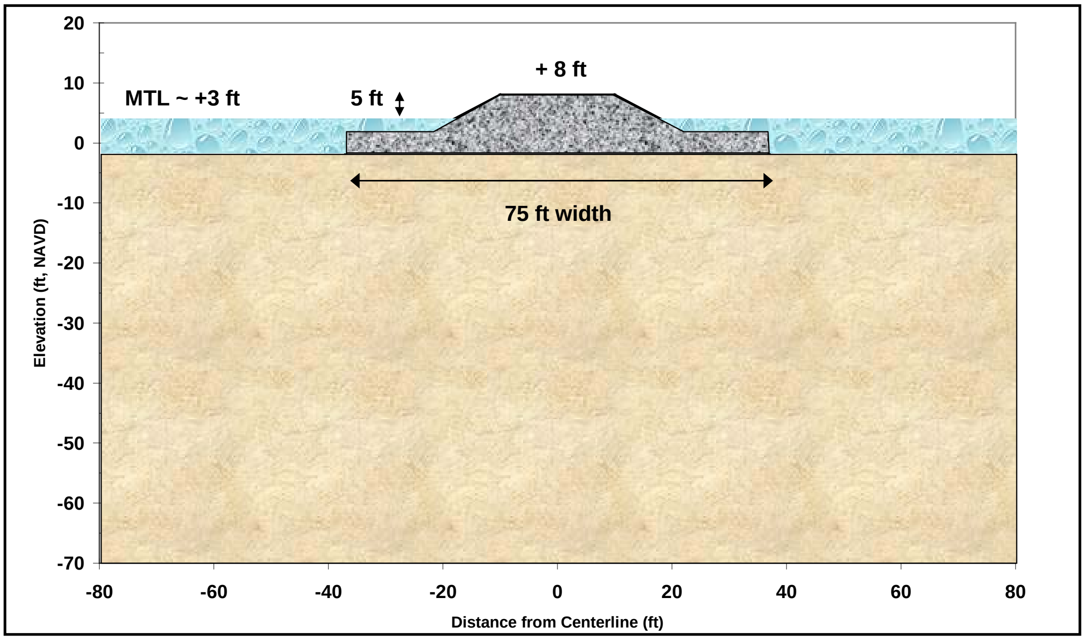


Figure 8. North Jetty Spur Groin NJ3O

Note difference in scale between vertical and horizontal axes.



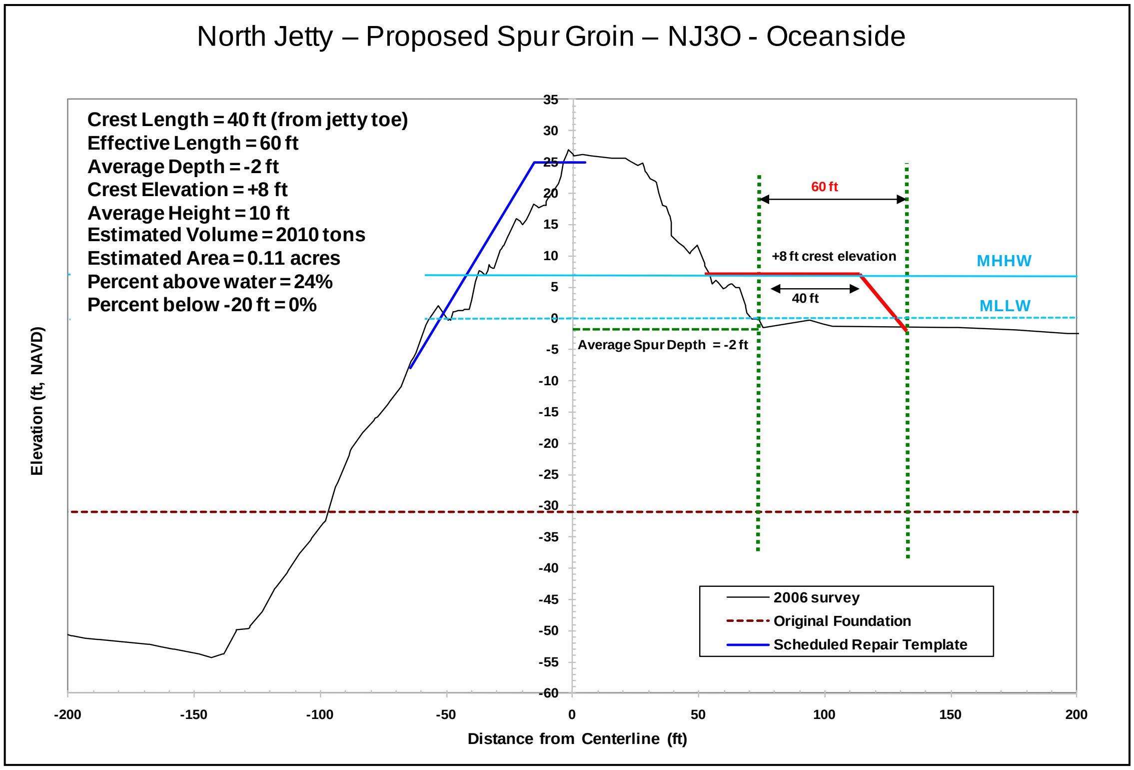
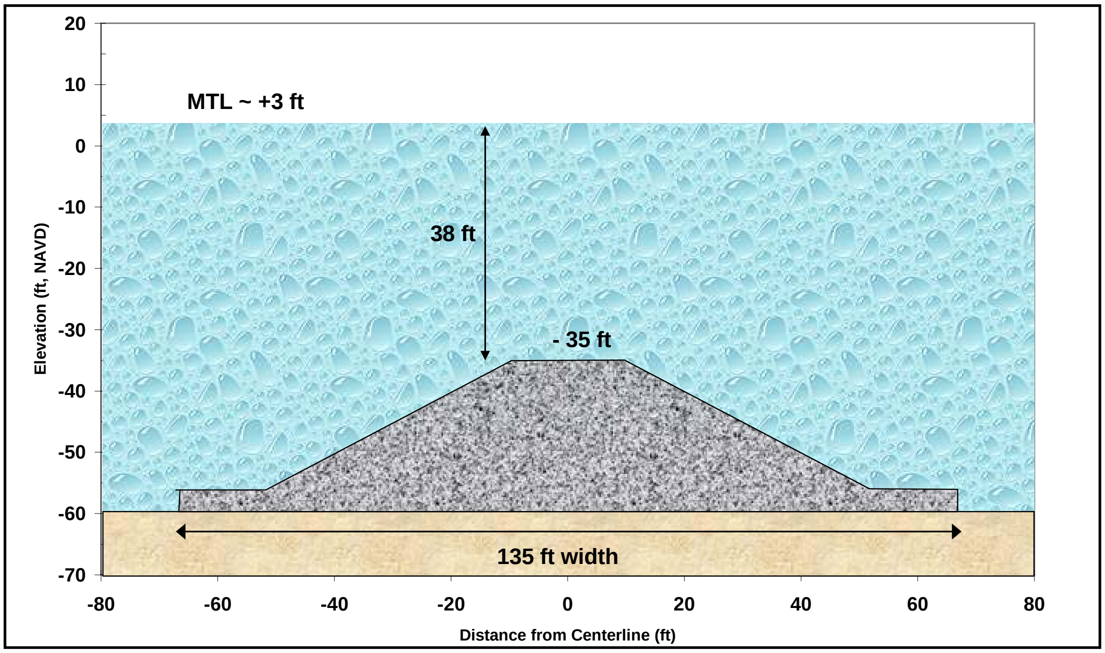
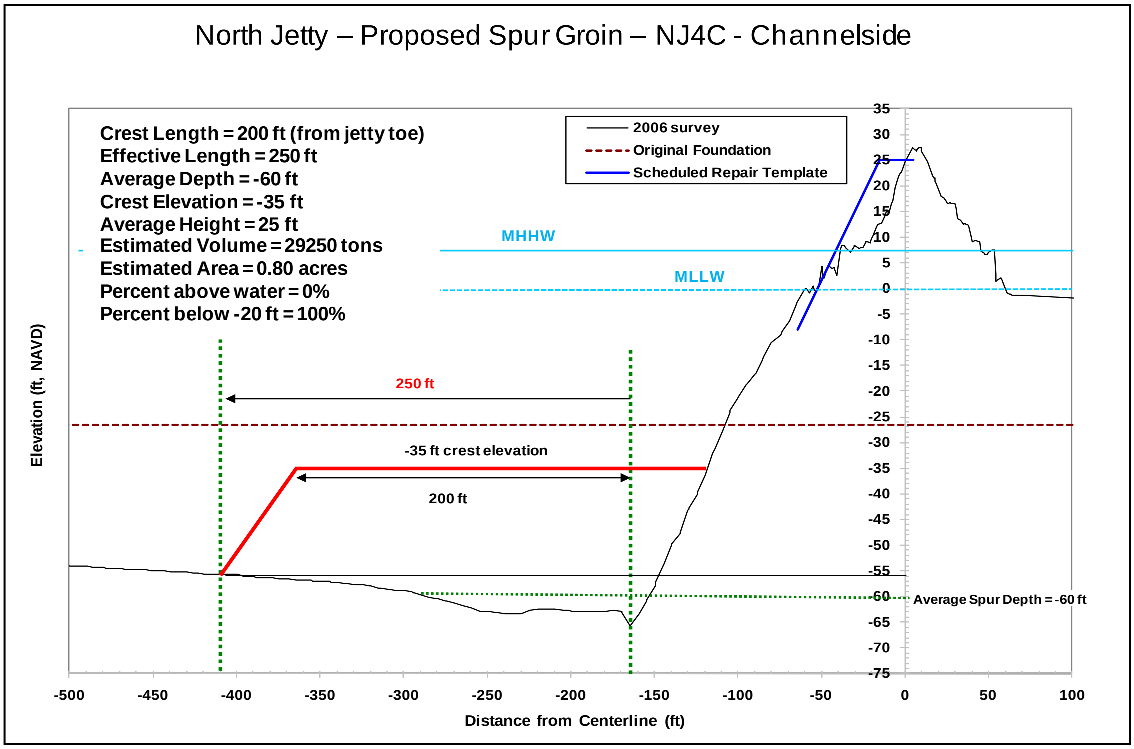


Figure 9. North Jetty Spur Groin NJ4C

Note difference in scale between vertical and horizontal axes.





North Jetty Head Capping

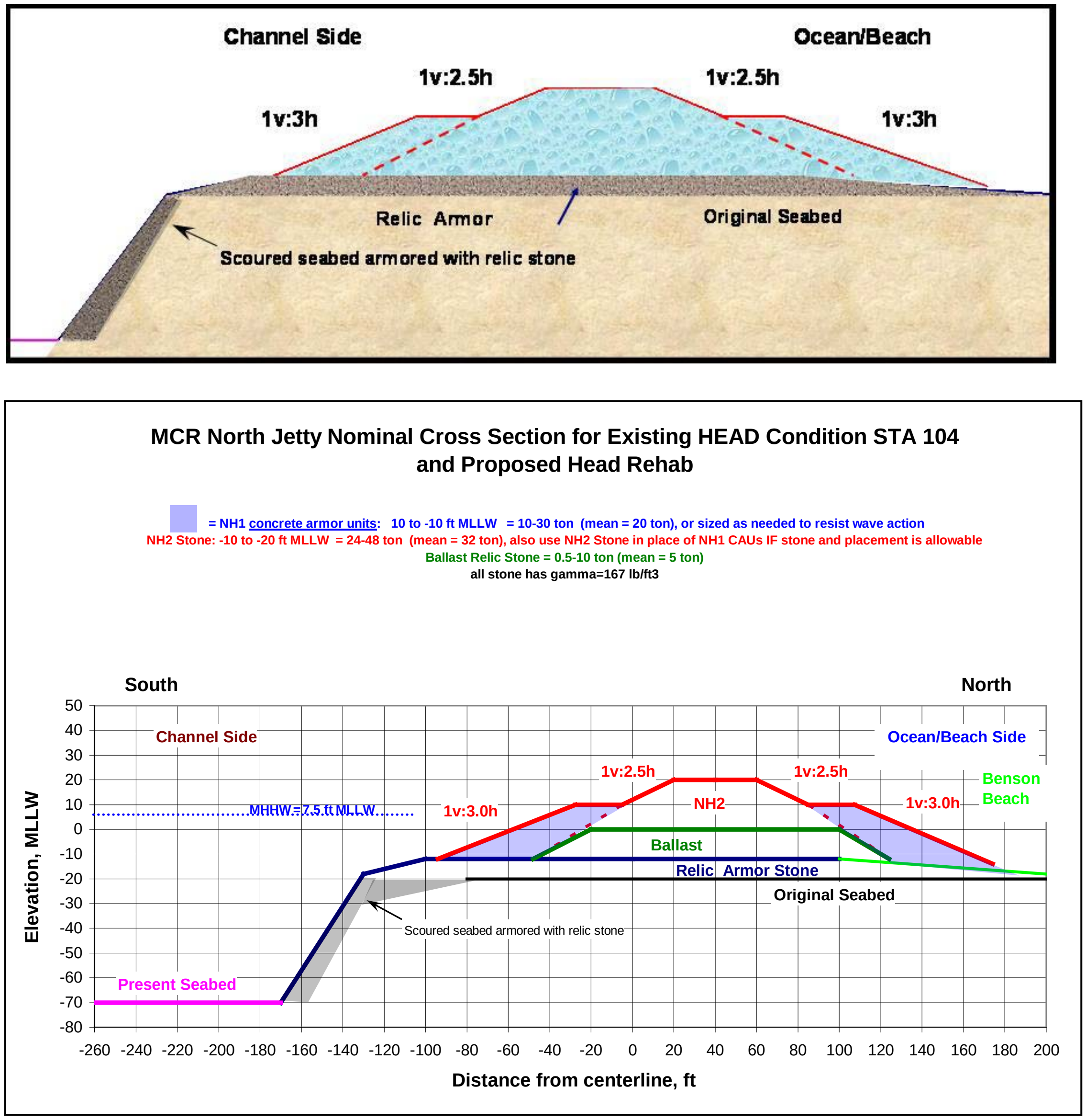
An armor stone cap or concrete armor units (CAU) will be placed on the head of the North Jetty to stop its deterioration (Table 4 and Figure 10). Approximately 38,000 tons (~23,750 cy) of stone or functionally equivalent CAUs will be placed on the relic stone to cap the jetty head. Future physical modeling will refine head capping features.

Table 4. North Jetty Head Cap Features

Head Cap Features	North Jetty
Location of cap	stations 99 to 101
Timing of construction	2015
Approximate dimensions of cap: length x width x height (feet)	350 x 270 x 45 (2.17 acres)
Stone size	30 to 50 tons
Area affected (outside relic stone)	None
% of cap constructed on relic stone	100%
Construction method	Cranes set on the jetty

For capping of the head, when stone placement is divided into elevation zones about 13,425 cy of rock will be placed above MHHW. This represents 49% of the overall stone placement on this portion of the jetty, and there is very little or no existing mounded jetty stone expected to be present within this elevation range. About 6,490 cy of rock will be placed between MHHW and MLLW. This represents 24% of the overall stone placement on this portion of the North Jetty, and there is very little or no existing jetty stone expected to be present within this elevation range. About 7,280 cy of rock will be placed below MLLW. This represents 27% of the overall stone placement on this portion of the North Jetty head, and a 2684% change from the existing jetty prism on this portion, as there is very little or no existing mounded jetty stone expected to be present within this elevation range. In all zones, all proposed stone placement will occur on existing base relic stone that formed the original jetty cross-section and was displaced and flattened by wave action, and does not include any modification that changes the character or increases the scope, or size of the original structure design. The terminus of the head is simply closer to shore on a shorter jetty structure. The footprint of the existing jetty mound on the flattened relic stone is approximately 1.37 acres, and the additional capping on the relic stone increases the width of the prism approximately 0.80 acres, for a total footprint of 2.17 acres, all of which will remain on the existing relic stone.

Figure 10. North Jetty Head Cap



North Jetty Lagoon and Wetland Fill and Culvert Replacement

Approximately 109,000 tons (~68,125 cy) of gravel and sand will be added to the jetty's beach side as lagoon fill to eliminate the tidal flow through the jetty that is destabilizing the foundation. A recent berm repair action now precludes lagoon inundation by tidal waters. Scouring has taken place on the north side of the North Jetty resulting in formation of a backwater area (lagoon) that was previously inundated both by tidal waters that come through the jetty and by freshwater that drains from the O'Neil Lake-McKenzie Head Lagoon and wetland complex area through the accreted land to the north of the jetty and North Jetty Road. This area drains through a culvert under the road and provides some of the freshwater flow to the lagoon. The surrounding lagoon resembles a scoured-out tidal channel and is a non-vegetated (and non-wetland) area of bare sand comprising approximately 4.71 acres. These wetland and waters will be filled to protect and stabilize the foundation of the North Jetty and to serve as a location for rock stockpiles and construction staging activities. The features of this work are shown in Table 5.

Table 5. North Jetty Lagoon and Wetland Fill Features

Features	North Jetty
Timing of construction	2014
Material used for fill	Sand, gravel, quarry stone
Short-term and long-term use	Stockpile area, long-term stabilization of root
De-watering	Culvert feeding into area will be re-placed
Impact on wetlands	1.78 acres
Impact on Section 404 waters	4.71 acres

After further hydraulic and hydrologic design, the aging culvert draining south from the wetland complex north of the roadway will be replaced, as it provides required drainage under the roadway. The design of the inlet, elevation, and culvert size will be determined so that hydrologic function in the adjacent wetland system is not negatively impacted. The outlet channel downstream of the culvert will not be filled. This area may provide an opportunity for minor stream and bank enhancement which will be evaluated when the culvert design is finalized, but this is uncertain until possible benefits can be further assessed. Under the proposed action, the existing channel will outlet to an engineered sump area comprised of newly placed lagoon fill material. In addition to infiltration through the jetty structure, this small portion of the creek currently connects the wetland to the lagoon and likely also receives some backwater flow from jetty infiltration. The current culvert is perched, and the regularly disconnected nature of the lagoon system does not appear to support anadromous fish use. Fish surveys were not completed for the stream inlet leading into this wetland complex and creek. The Corps proposes to conduct an initial sampling survey during peak juvenile salmon outmigration to determine whether or not fish salvage and fish exclusion efforts for listed species is warranted. The Corps will coordinate with NMFS if listed species are identified. Redesign of this system may provide an opportunity to accommodate improved hydrology to newly created wetlands excavated adjacent to the existing wetland complex. This will be further investigated during the hydraulic/hydrologic design analysis.

MCR South Jetty

The proposed action for the South Jetty includes scheduled repairs addressing mostly above MLLW water structural instability, five spur groins, head capping, and improving the jetty shoreline near the root (Figure 11). Seven Scheduled Repair events over the next 20 years were predicted at the South Jetty.

<u>South Jetty Trunk and Root</u>

The cross-section design from stations 155+00 to 311+00 will have a crest width of approximately 30 feet and will lie essentially within the existing jetty footprint based on the configuration of the original cross section, previous repair cross sections, and redistribution of jetty rock by wave action (Figure 12). The majority of the stone placement will be conducted above the MLLW. Each repair action is expected to cover a length up to 2,100 feet and include stone volumes in the range of 30,000 to 118,000 tons per season (18,750 - 73,750 cy).

As with the North Jetty repair action, it is expected that 60%-70% of the South Jetty's overall standard jetty template cross section has been displaced. Therefore, each repair event will increase the existing degraded cross section from 30%-40% back to 100% of the desired standard cross-section template. This means overall, the added rock will essentially triple what exists immediately prior to the time of repair. This could be described as a ~300% increase in rock relative to the existing jetty rock volume. However, this will not result in an increase the jetty prism or footprint beyond the scope and size of the historic structure, and does not include any modification that changes the character, scope, or size of the original structure design.

Per repair event, when divided into elevation zones, about 37,640 cy of rock will be placed above MHHW. This represents 68% of the overall stone placement on these portions of the South Jetty and a 1023% change from the existing jetty prism, as very little stone currently remains in the zone and a larger amount of stone must be placed compared to what presently remains. As described, above, this same concept applies characterizations about the rest of the zones. About 10,420 cy of rock will be placed between MHHW and MLLW. This represents 19% of the overall stone placement on these portions of the South Jetty and a 225% change from the existing jetty prism. About 6,940 cy of rock will be placed below MLLW. This represents 13% of the overall stone placement on these portions of the South Jetty and a 150% change from the existing jetty cross section. However, in all zones, all proposed stone placement will occur on existing base relic stone that formed the original jetty cross section. The footprint of the trunk and root of the South Jetty will remain within its current jetty dimensions and on relic stone.

Figure 11. Proposed Action for the MCR South Jetty

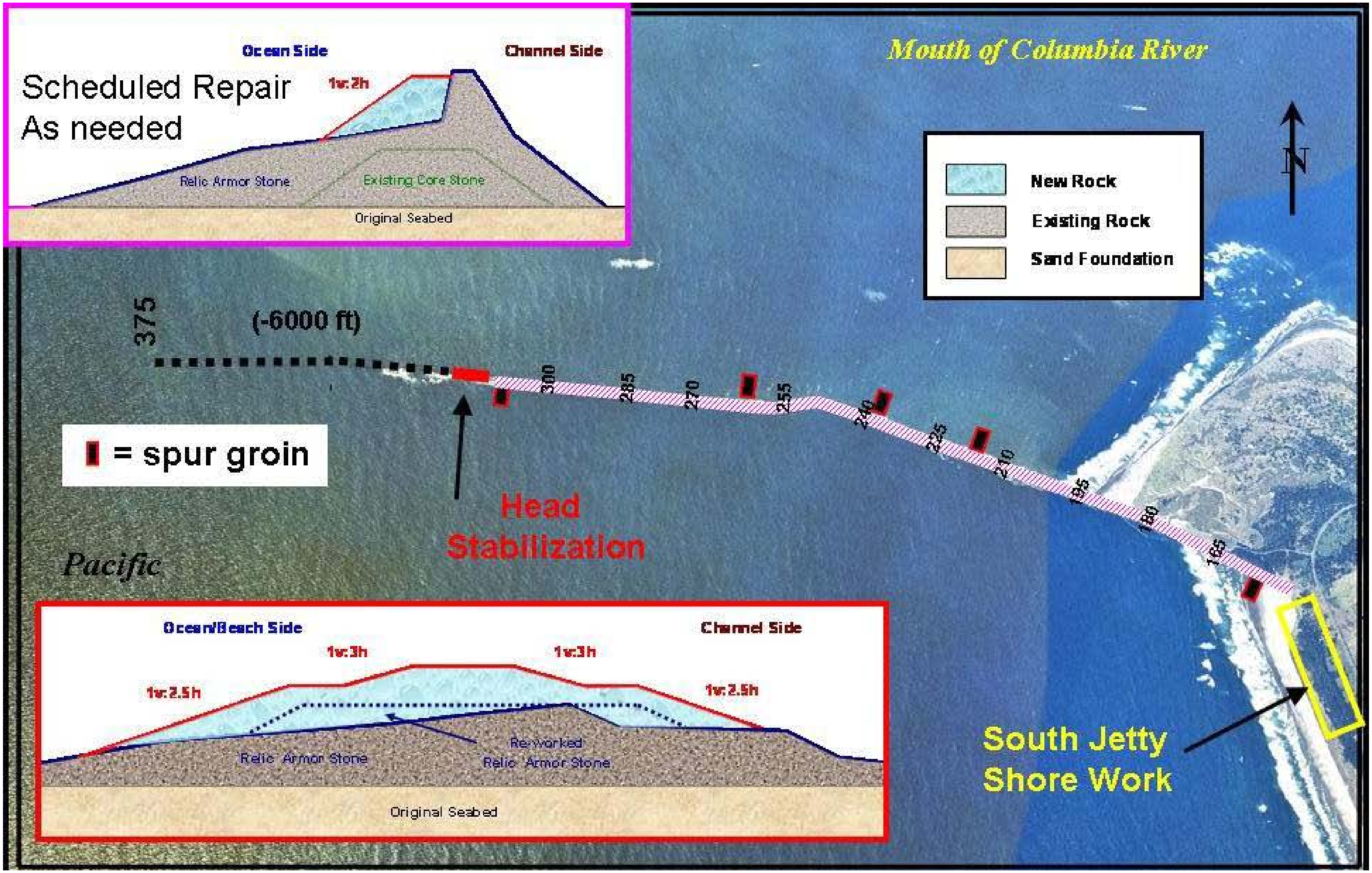
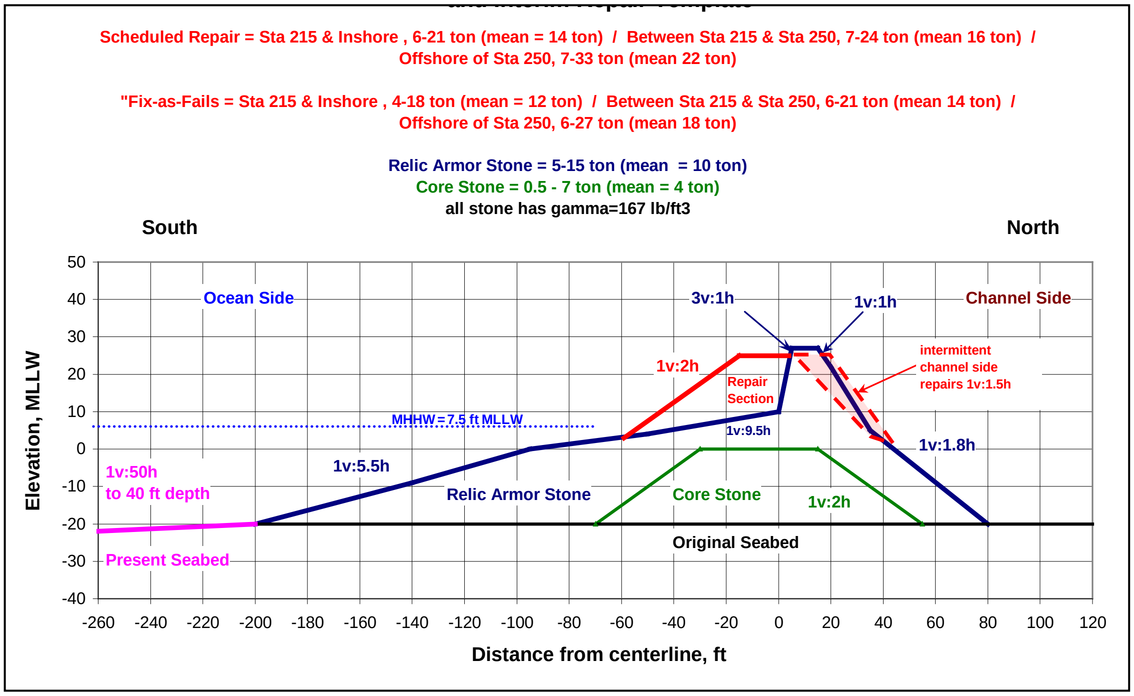


Figure 12. South Jetty Cross Section for Existing Condition and Scheduled Repair



<u>South Jetty Spur Groins</u>

Three emergent and two submergent spur groins will be constructed to stabilize the jetty's foundation (Figures 13 to 17). The dimensions and other features of the spur groins are shown in Table 6.

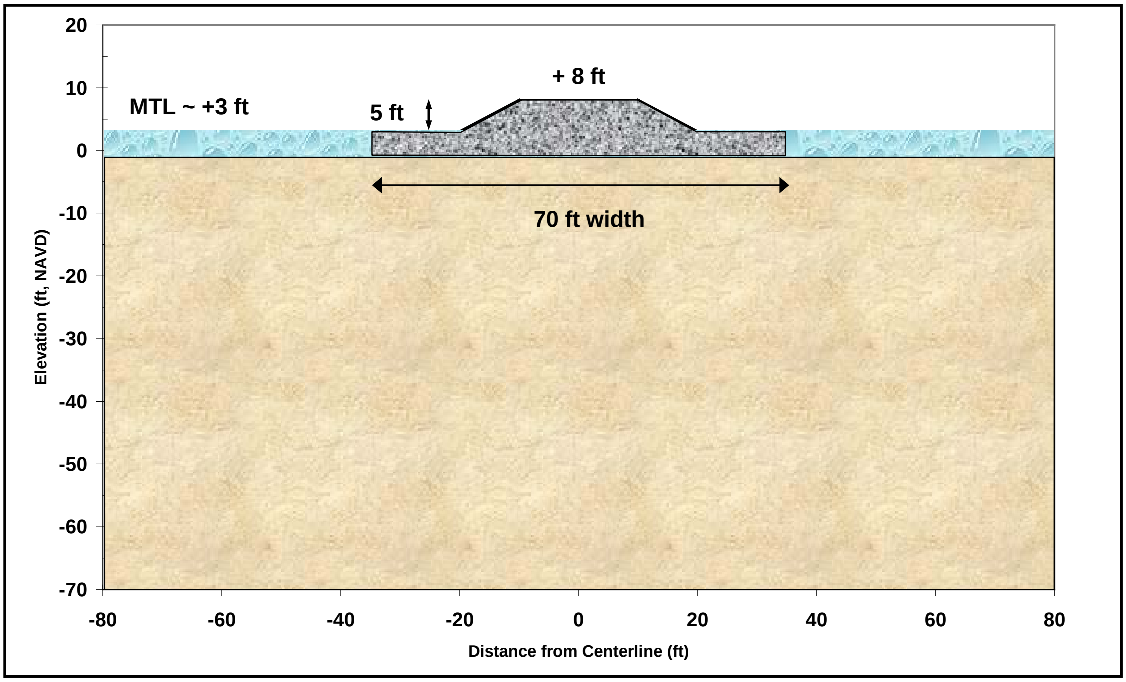
Representing estimated rock volume totals divided into elevation zones for all spurs on the South Jetty, about 21 cy of rock will be placed above MHHW. This represents 0.1% % of the overall stone placement on these portions of the South Jetty, and there is very little or no existing jetty stone expected to be present within this elevation range. About 2,190 cy of rock will be placed between MHHW and MLLW. This represents 12.3% of the overall stone placement on these portions of the South Jetty, and there is very little or no existing jetty stone expected to be present within this elevation range. About 15,700 cy of rock will be placed below MLLW. This represents 87.6% of the overall stone placement on these portions of the South Jetty, and there is very little or no existing jetty stone expected to be present within this elevation range. The footprint of the spurs on the South Jetty will increase from 0 acres to 1.10 acres. In the relevant figures, note that the difference in the vertical and horizontal scales causes a slight representational distortion.

Table 6. South Jetty Spur Groin Features

Spur Groin Feature	South Jetty
Number of spurs on channel side or downstream	3
Number of spurs on ocean side or upstream	2
Approximate total rock volume per spur (+/- 20%)	SJ1O: 1,680 tons (~1,050 cy) SJ2C: 2,350 tons (~1,469 cy) SJ3C: 2,350 tons (~1,469 cy) SJ4C: 3,180 tons (~1,988 cy) SJ5O: 18,750 tons (~11,719 cy)
Approximate total rock volume (all spurs) (+/- 20%)	25,000 tons (~15,625 cy)
Approximate area affected by each spur	SJ1O: 0.11 acres SJ2C: 0.13 acres SJ3C: 0.13 acres SJ4C: 0.19 acres SJ5O: 0.55 acres
Approximate total area affected (all spurs)	1.10 acres
Approximate area of spurs above water	SJ1O: 29% SJ2C: 7% SJ3C: 7% SJ4C: 0% SJ5O: 0%
Approximate area of spurs below -20 MLLW	SJ1O: 0% SJ2C: 0% SJ3C: 0% SJ4C: 0% SJ5O: 92%
Approximate dimension of spurs: length x width x height (feet)	SJ1O: 60 x 80 x 9 SJ2C: 70 x 80 x 10 SJ3C: 70 x 80 x 10 SJ4C: 90 x 90 x 12 SJ5O: 190 x 125 x 22

Figure 13. South Jetty Spur Groin SJ1O

Note difference in scale between vertical and horizontal axes.



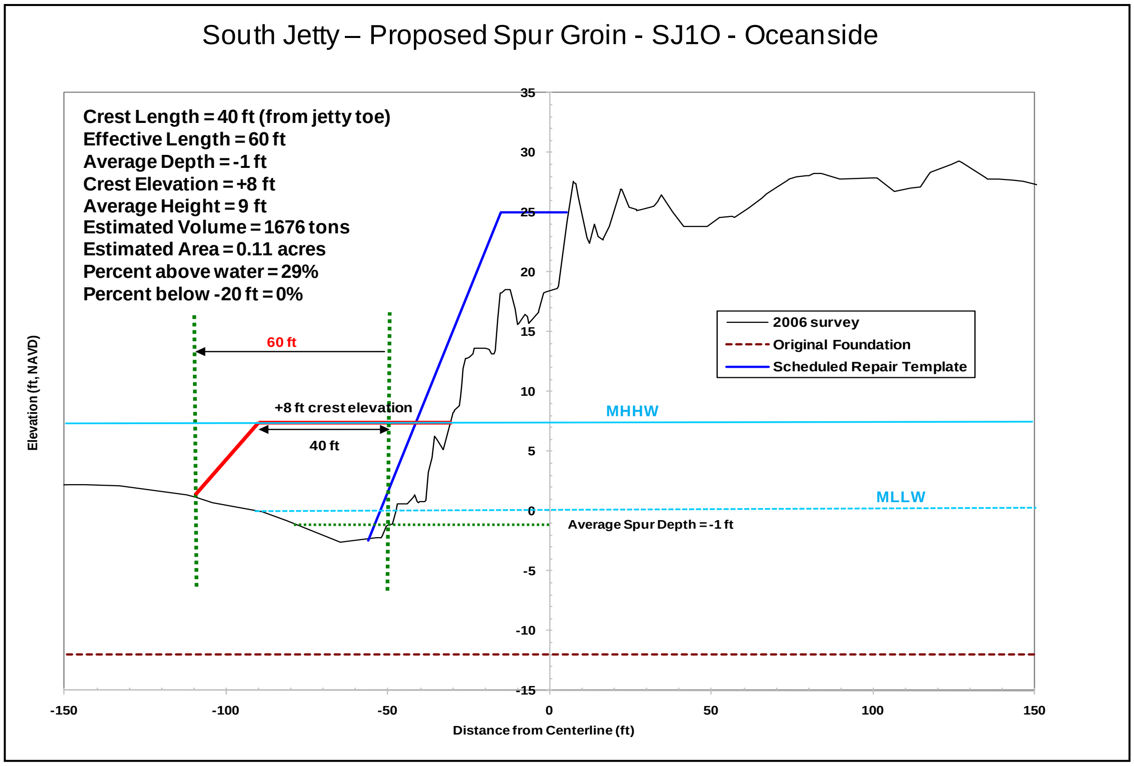
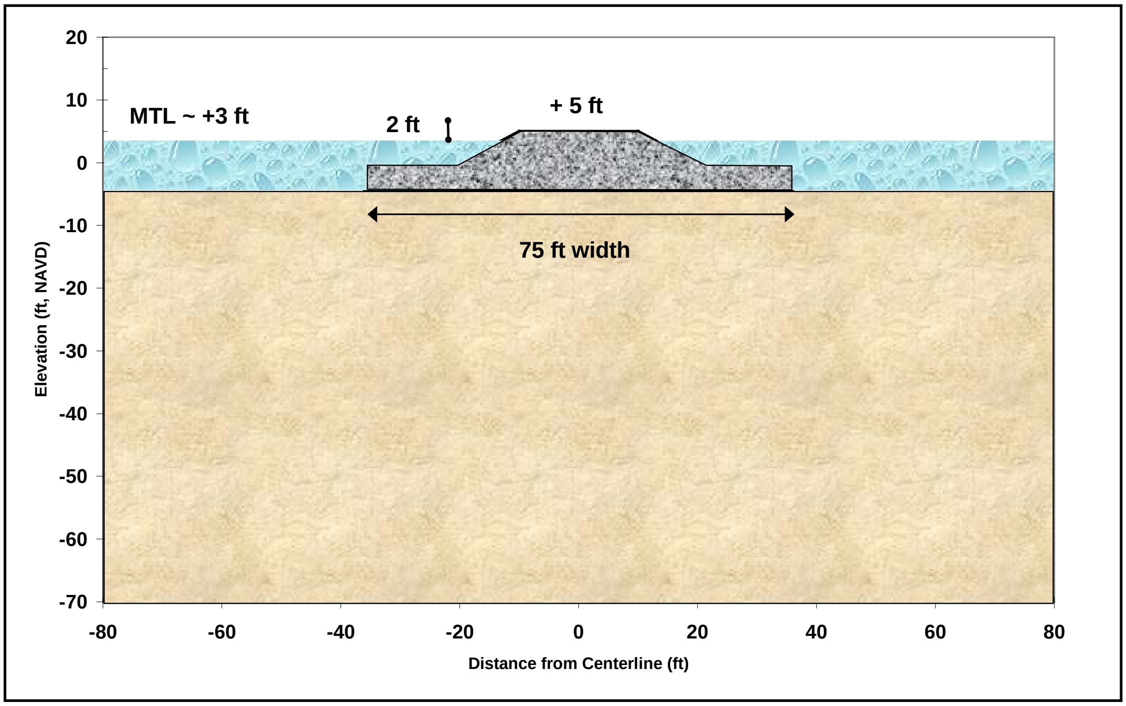


Figure 14. South Jetty Spur Groin SJ2C

Note difference in scale between vertical and horizontal axes.



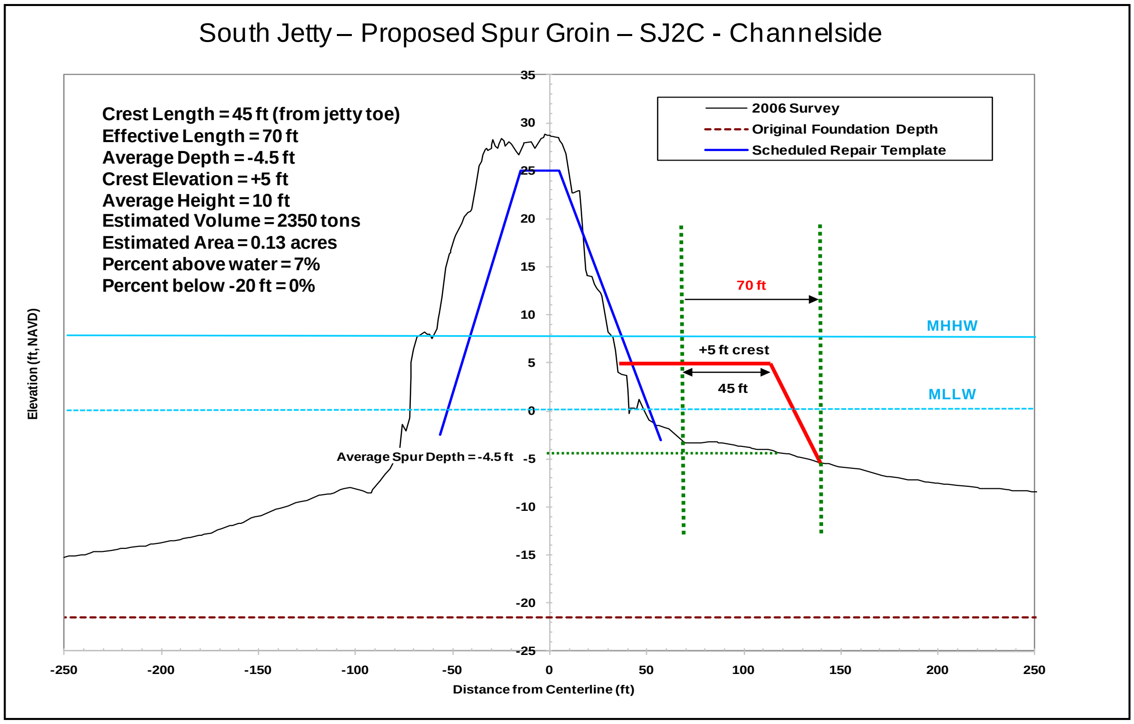
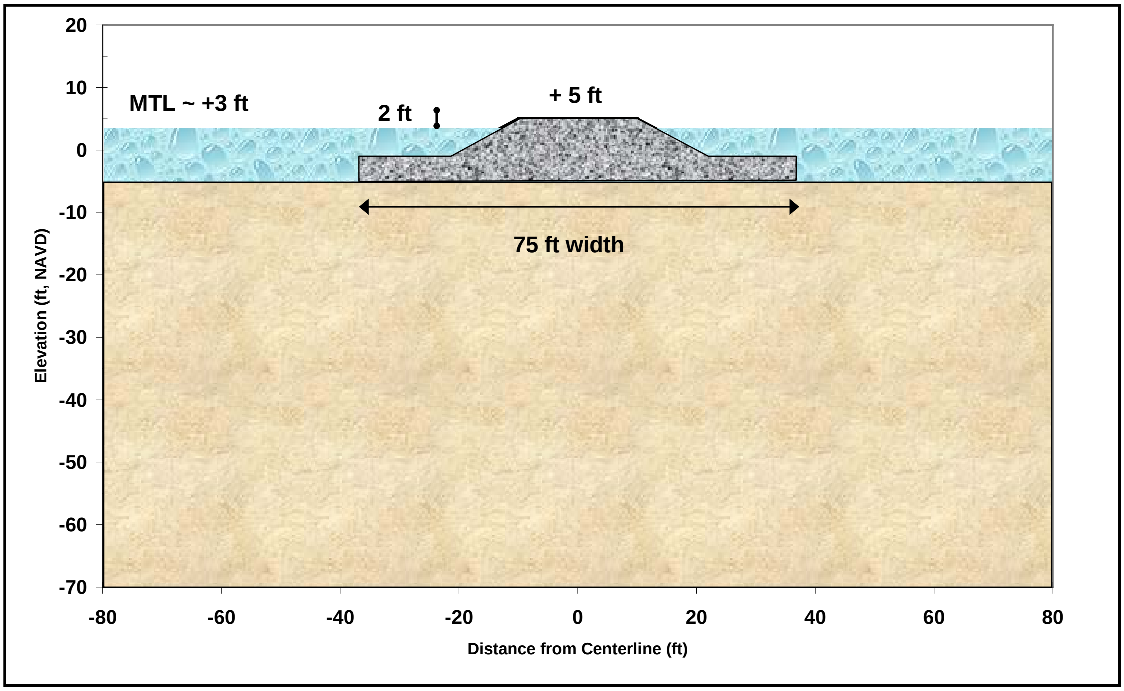


Figure 15. South Jetty Spur Groin SJ3C

Note difference in scale between vertical and horizontal axes.



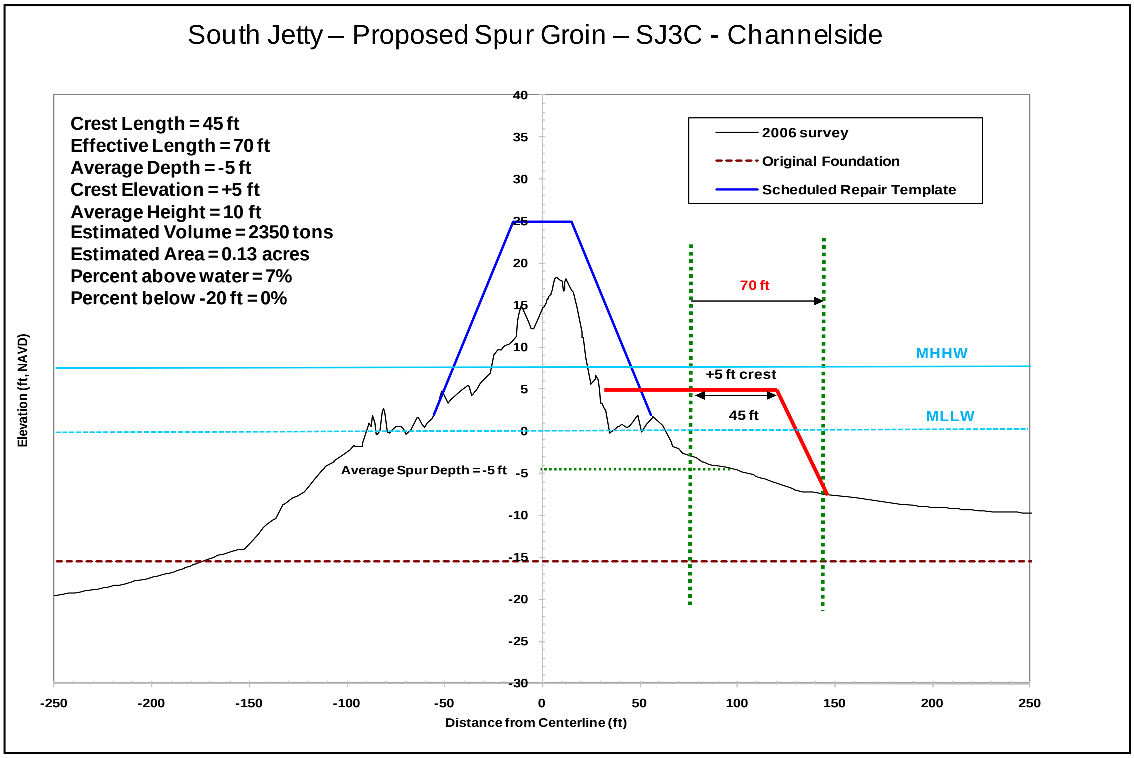
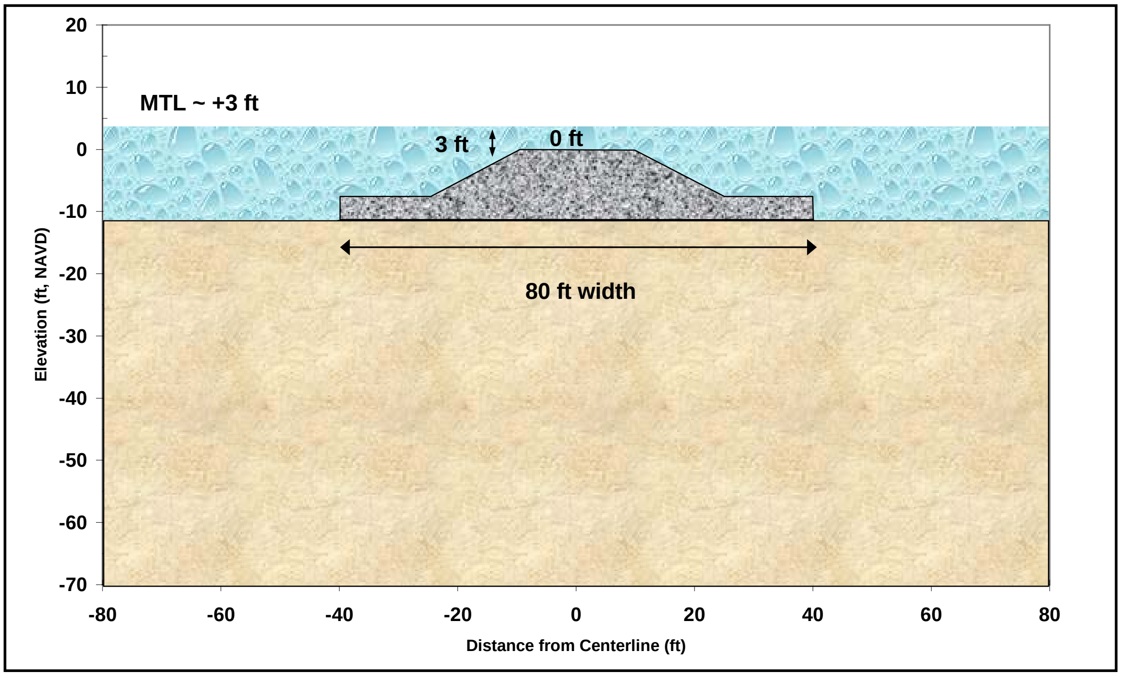


Figure 16. South Jetty Spur Groin SJ4C

Note difference in scale between vertical and horizontal axes.



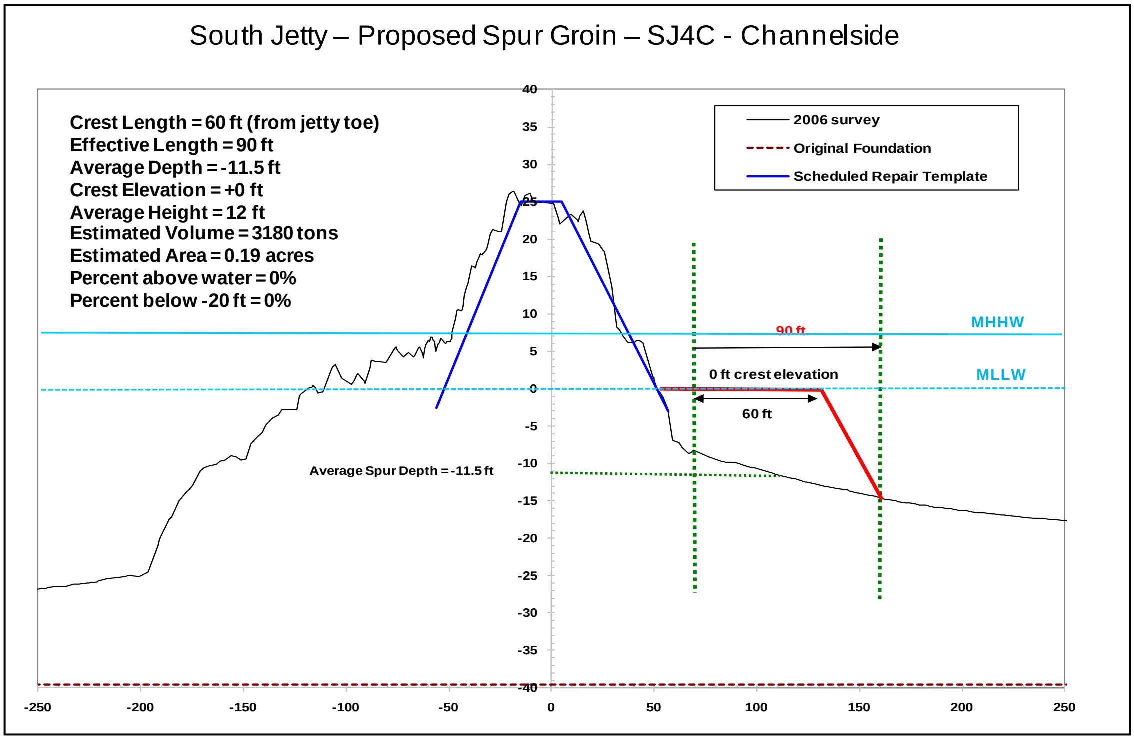
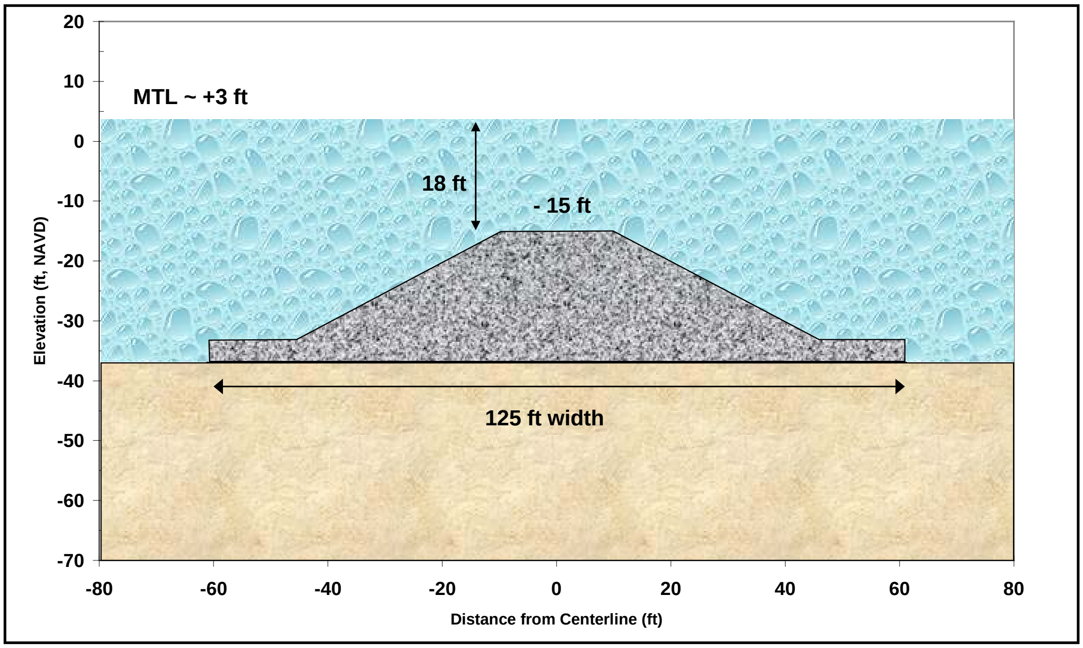
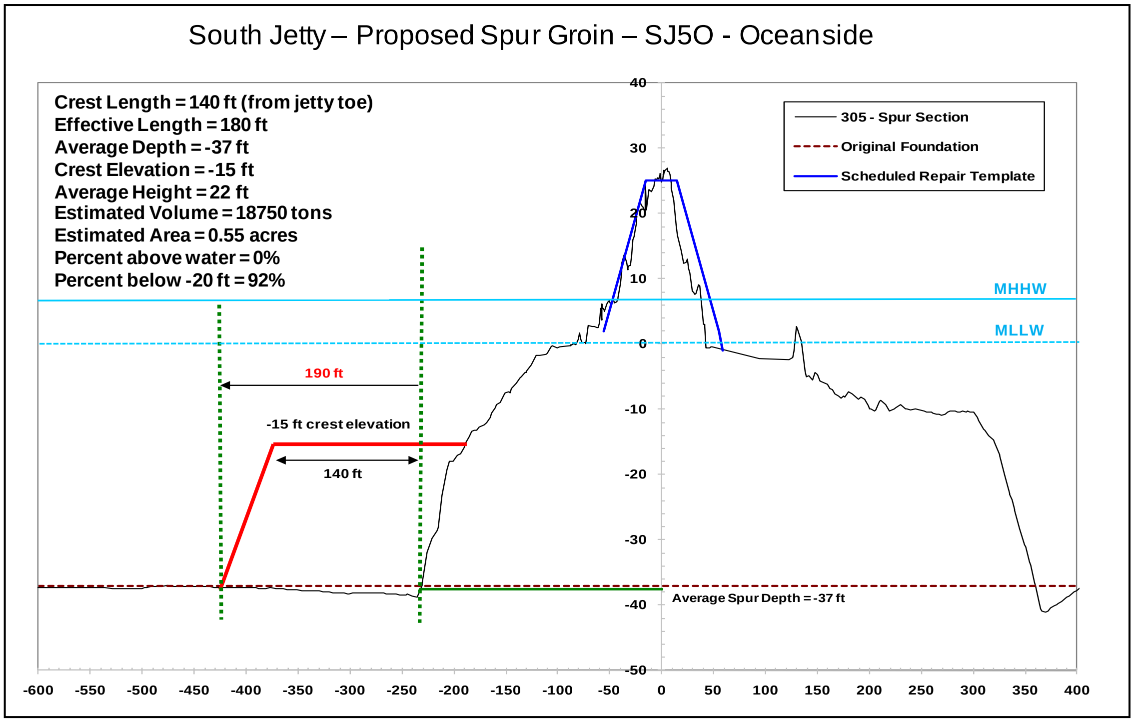


Figure 17. South Jetty Spur Groin SJ5O

Note difference in scale between vertical and horizontal axes.





South Jetty Head Capping

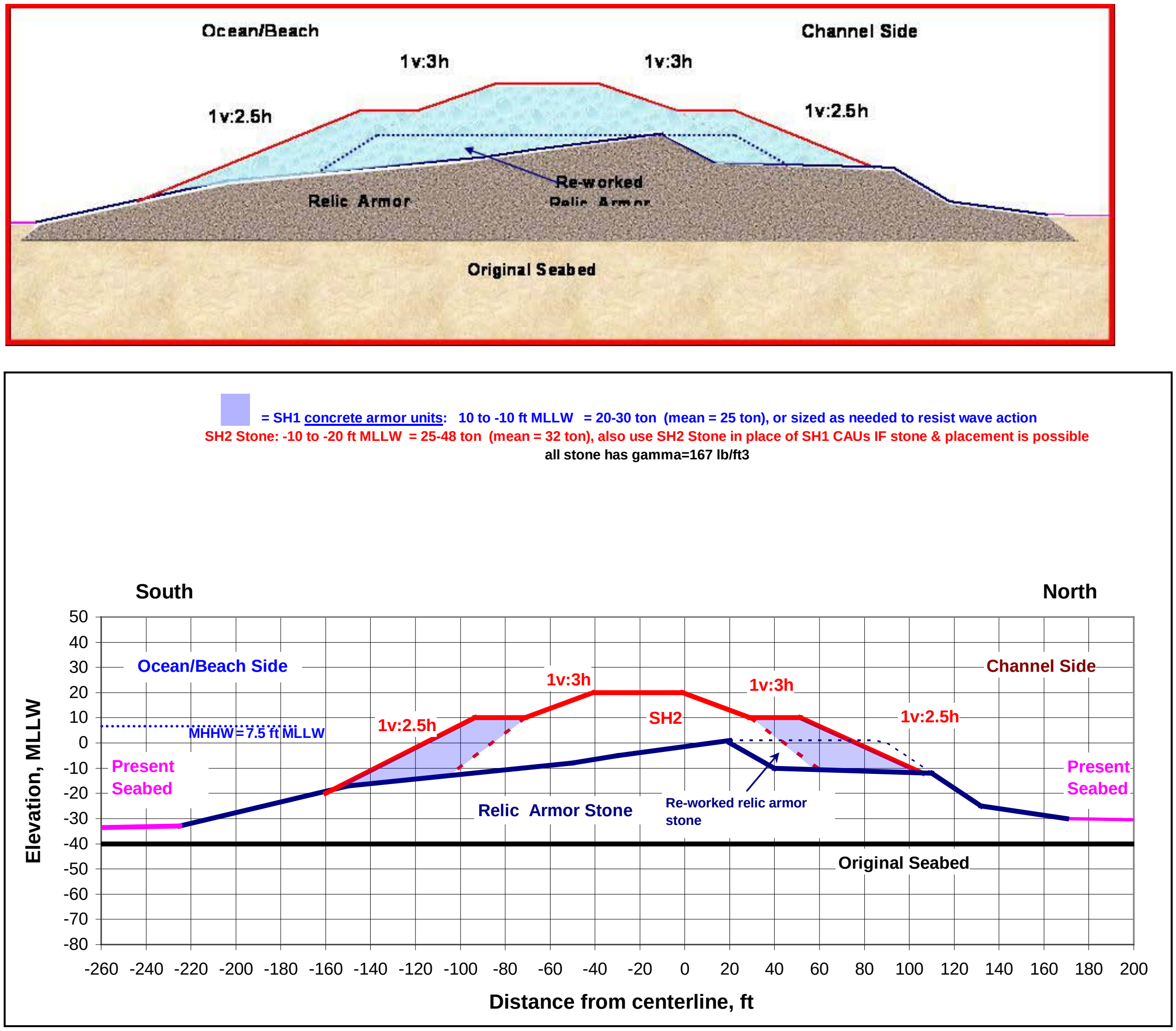
An armor stone cap with approximately 40,000 to 74,000 tons (~25,000 - 46,250 cy) of stone or equivalent concrete armor units will be placed on the head of the South Jetty to stop its deterioration (Figure 18). The features of this work are shown in Table 7.

For capping of the head, divided into elevation zones about 13,425 cy of rock will be placed above MHHW. This represents 52% of the overall stone placement on this portion of the South Jetty and there is very little or no existing jetty stone expected to be present within this elevation range. About 6,490 cy of rock will be placed between MHHW and MLLW. This represents 25% of the overall stone placement on this portion of the South Jetty and there is very little or no existing jetty stone expected to be present within this elevation range. About 6,050 cy of rock will be placed below MLLW. This represents 23% of the overall stone placement on this portion of the South Jetty and 1150% change from the existing base condition as there is very little or no existing mounded jetty stone expected to be present within this elevation range. In all zones, all proposed stone placement will occur on existing base relic stone that formed the original jetty cross section and was displaced and flattened by wave action, and does not include any modification that changes the character or increases the scope or size of the original structure design. The terminus of the head is simply closer to shore on a shorter jetty structure. The footprint of the existing jetty mound on the flattened relic stone is approximately 1.69 acres, and the additional capping on the relic stone increases the width of the prism approximately 0.64 acres, for a total footprint of 2.33 acres, all of which will occur on existing relic stone.

Table 7. South Jetty Head Capping Features

Capping Feature	South Jetty
Location of cap	stations 311 to 313
Timing of construction	2019-2020
Dimensions of cap: length x width x height (feet)	350 x 290 x 45 (2.33 acres)
Stone size	30 to 50 tons
Area affected (outside relic stone)	None
% of cap constructed on relic stone	100%
Construction method	Land-based cranes or jack-up barge

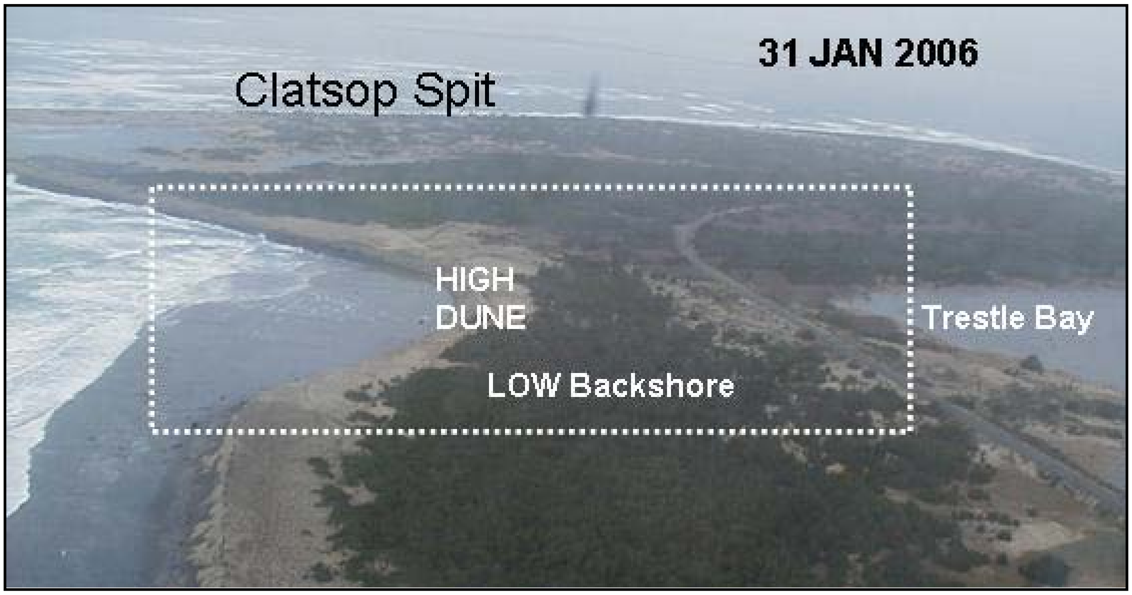
Figure 18. South Jetty Head Cap



South Jetty Root Erosion and Dune Augmentation

Currently, the coastal shore interface along the South Jetty is in a condition of advanced deterioration (Figure 19). The foredune separating the ocean from the backshore is almost breached. The backshore is a narrow strip of a low-elevation, accretion area that separates Trestle Bay from the ocean by hundreds of yards. The offshore area along the South Jetty (and to the south) continues to erode, promoting larger wave action to affect the shoreline along the South Jetty root. The back dune of Trestle Bay has continued to advance westward due to increased circulation in the bay, seasonal wave chop, and hydraulic surcharging. Under existing conditions, the shoreline at the root of the South Jetty will continue to erode and recede, resulting in a possible shoreline breach into Trestle Bay in about 8-16 years. If this sand spit breach occurs, the result would be catastrophic. The MCR inlet would establish a secondary flow way from the estuary to the ocean along this area (south of South Jetty). This condition would profoundly disrupt navigation at the MCR and bring lasting changes to the physical nature of the inlet.

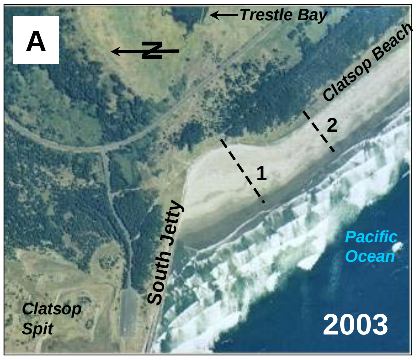
Figure 19. Clatsop Spit and South Jetty Root Erosion



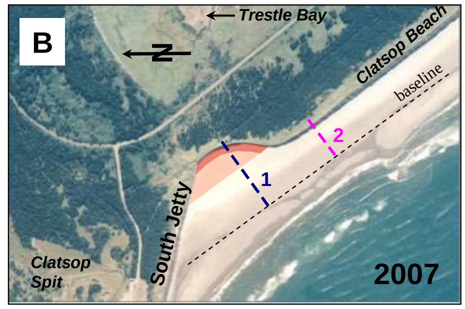
About 40,000 to 70,000 cy of cobble in the shape of angular or rounded graded stone is proposed at the South Jetty root in order to fortify the toe of the foredune and to improve the foreshore fronting to resist wave-induced erosion/recession (Figure 20). Maximum crest width of the template is estimated to extend 70 feet seaward from the seaward base of the present foredune. Construction of the berm augmentation would require 2 to 6 weeks. To adequately protect the foredune during storm conditions, this requires that the top of the stone berm (crest) extend vertically to approximately 25 feet NAVD and have an alongshore application length of approximately 1,100 feet, extending southward from the South Jetty root. This is equivalent to about 3 acres. The constructed template crest would be 10 to 15 feet above the current beach grade and have a 1 vertical to 10 horizontal slope aspects from crest to existing grade. Cobble is not expected to extend below MHHW. An additional layer of sand may be placed over this berm, or natural accretion may facilitate sand recruitment after construction of the adjacent spur groin.

Cobble material would be procured from upland sources and placed using haul trucks and dozers. The material would be transported on existing surface roads and through Fort Stevens State Park to a beach access point at the project site. There is an existing relic access road along the jetty root that will be refurbished and used to transport stone to the dune augmentation area. Though there is an existing razor clam bed adjacent to the vicinity of the proposed dune augmentation, species impacts are not expected because all of the stone placement will occur above MHHW, and haul traffic will be precluded using Parking Lot B and from driving on the beach during material delivery. Excavator and bulldozer work will be mostly confined to the dry sand areas to further avoid negative species effects.

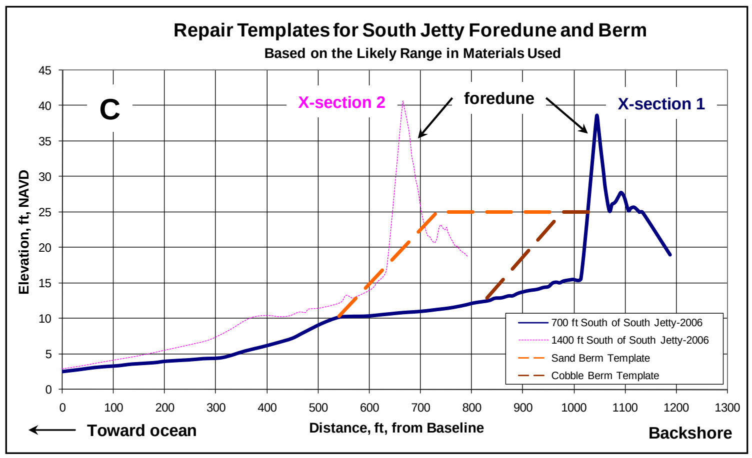
Figure 20. South Jetty Root Shoreline Area



MCR South Jetty root, south side where Clatsop Spit joins with Clatsop Plains/Beach. Panels A and B show the erosion embayment along the south jetty root for 2003 (hIgh tide) and 2007 (low tide). The embayment & adjacent shore have receded 40 ft landward during 2003-2007, reducing the protective foredune along the embayment.



Panel C shows cross-sections 1 and 2 for 2007(shown in panels A & B). Severe erosion in this area had threatened the inlet stability during early 1930s, when jetty rehabilitation and sand augmentation measures were implemented. Erosion has again become chronic since the late 1970s. The foredune protects the backshore (elevation 15-18 ft NAVD) from wave surge action during storms. If the foredune is breached, the backshore will be rapidly eroded. Without erosion abatement, it is estimated that that the Pacific Ocean will establish hydraulic connectivity with Trestle Bay in 10-15 years from 2009, and again threaten inlet stability. Panel C shows two options for protecting the foredune within the erosion embayment: A SAND berm template requires ~225,000 cy of sand placement, and a COBBLE berm template requires ~60,000 cy of cobble placement.



The dune augmentation may require maintenance every 4-10 years (assume 40% replacement volume). Consideration will be given to development of revegetation plans which incorporate native dune grasses to supplement foredune stabilization in the augmentation area. This bioengineering component could help restore habitat and take advantage of natural plant rooting functions that provide greater protection from erosive forces.

MCR Jetty A

The proposed action for Jetty A includes Immediate Rehabilitation with a small cross section, two spur groins, and head capping (Figure 21).

Jetty A Trunk and Root

The cross-section design from stations 40+00 to 91+00 will have a crest width of approximately 40 feet and will lie mostly within the existing jetty footprint based on the configuration of the original cross section, previous repair cross sections, and redistribution of jetty rock by wave action (Figure 22). About 55,000 tons (~34,375 cy) of new rock will be placed on the existing jetty cross section and relic armor stone on the estuary/channel side of the jetty and 75,000 tons (~46,875 cy) of new rock on the ocean side of the jetty. Though most of the work will occur above MLLW, there will also be some stone placement below this elevation. The small cross-section also has a higher likelihood of expanding beyond the relic base compared to repair actions.

About 63,700 cy of rock will be placed above MHHW. This represents 63% of the overall stone placement on these portions of Jetty A and a 2020% change from the existing jetty prism, as very little stone currently remains in the zone and a larger amount of stone must be placed compared to what presently remains. As described previously for North and South jetties, this same concept applies to characterizations about the rest of the zones. About 28,940 cy of rock will be placed between MHHW and MLLW. This represents 29% of the overall stone placement on these portions of Jetty A and a 280% change from the jetty prism. About 8,030 cy of rock will be placed below MLLW. This represents 8% of the overall rock on these portions of Jetty A and a 233% change from the existing jetty prism. In all zones, most of the proposed stone placement will occur on existing base relic stone that formed the original jetty cross-section. However, the footprint of the proposed prism could increase in width compared to the existing prism by up to 10 feet along the length of the jetty (though it would still be on the relic stone). This equals about 1.2 acres, but it is not expected to result in additional habitat conversion because it will be in a bottom location already comprised of jetty stone, and does not include any modification that changes the character, scope, or size of the original structure design.

Figure 21. Proposed Action for MCR Jetty A

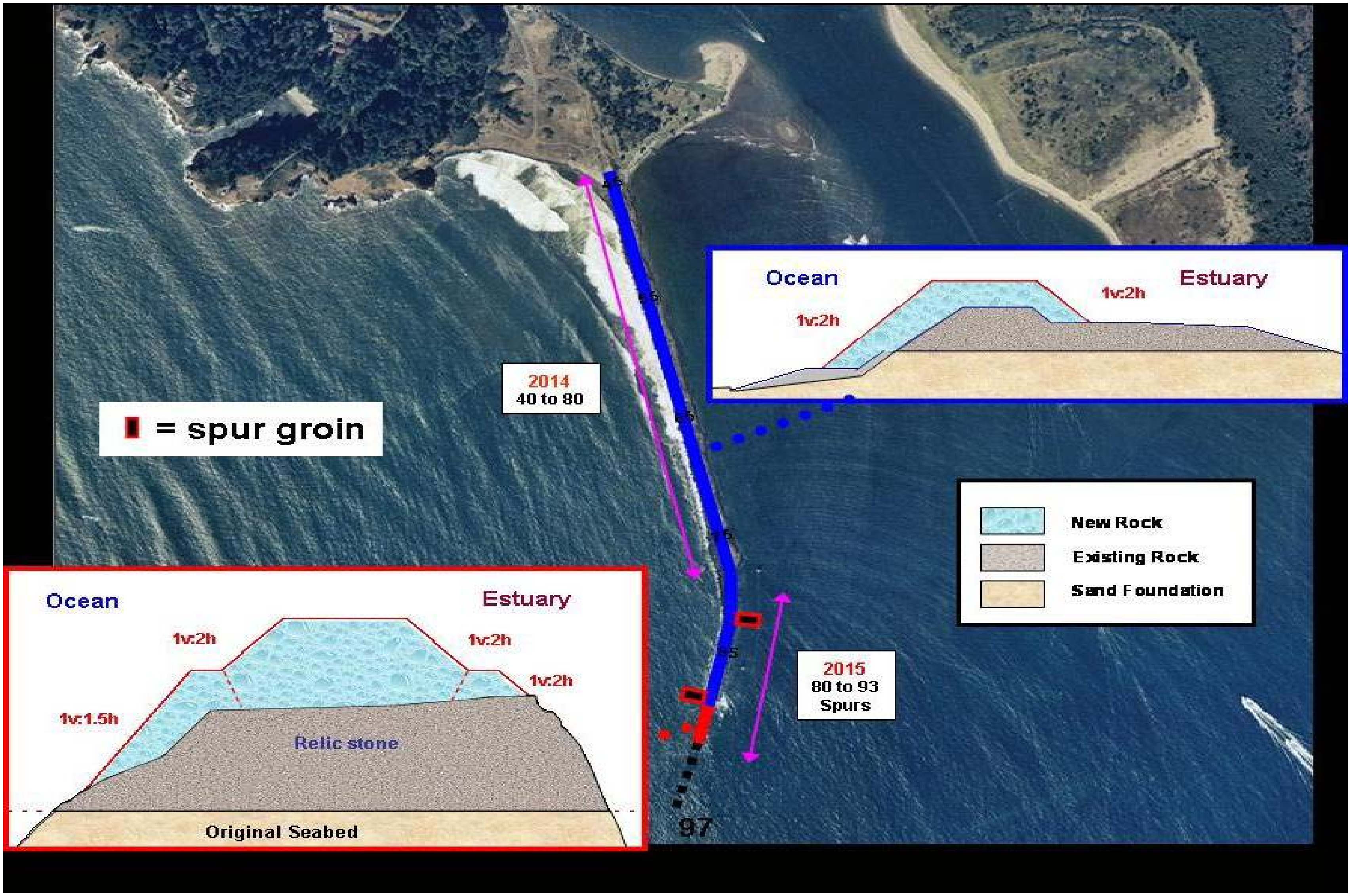
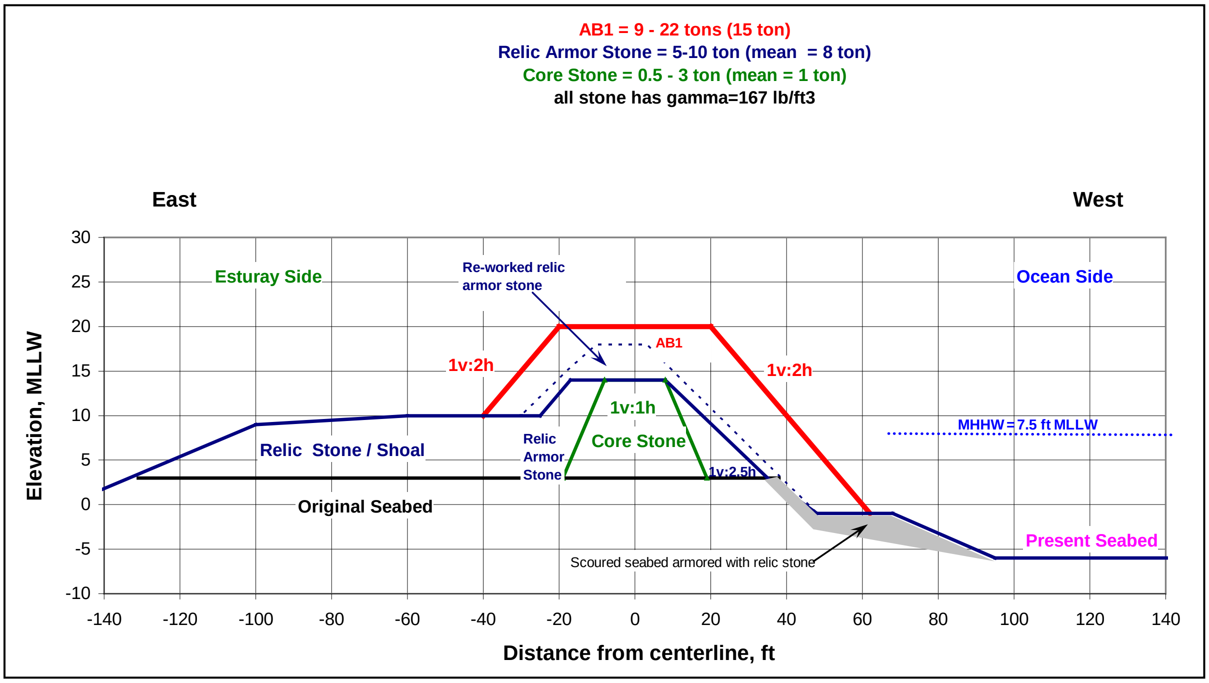


Figure 22. Jetty A Cross Section for Proposed Action



Jetty A Spur Groins

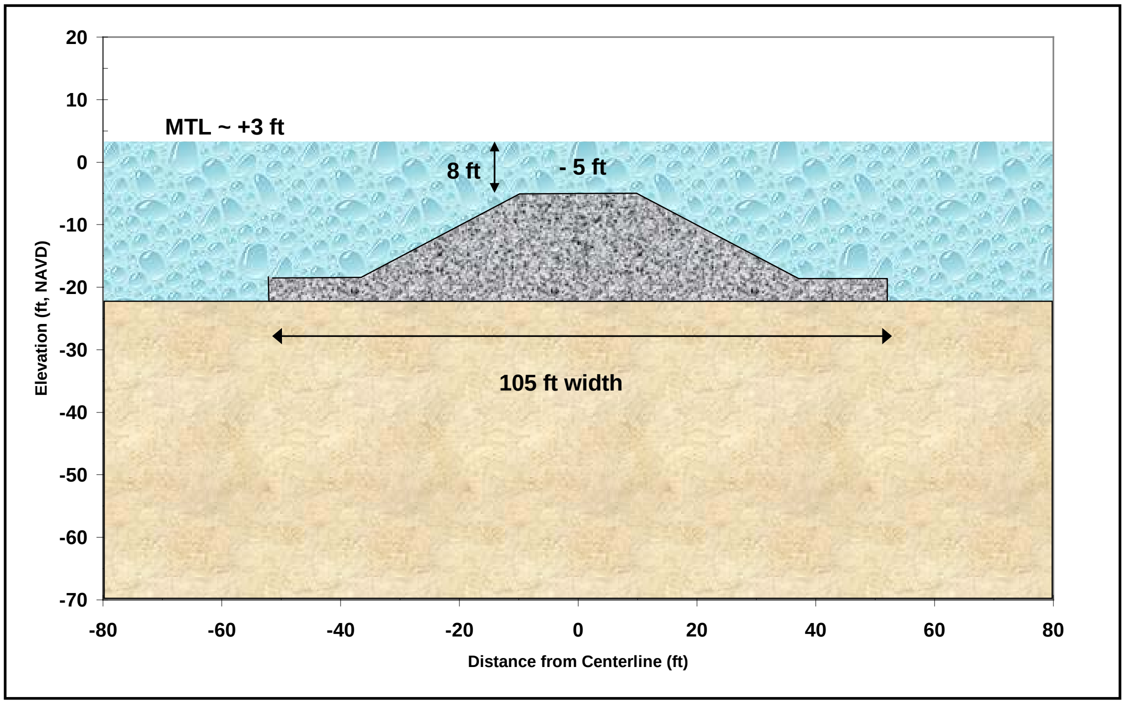
One submergent spur groin will be placed on the downstream (referred to as JA1C) side and one submergent spur groin will be placed on the upstream (referred to as JA2O) side to stabilize the jetty's foundation (Figures 23-24). The dimensions and other features of the spur groins are shown in Table 8. Representing estimated rock volume totals divided into elevation zones for all spurs on Jetty A, no stone will be placed above MLLW, and there is very little to no existing jetty stone expected to be present within either of these elevation ranges. About 10,800 cy of rock will be placed below MLLW and represents 100% of the overall stone placement on these portions of Jetty A. The footprint of the Jetty A spurs will increase from 0 acres to ~ 0.61 acres beyond existing relic stone. In the relevant figures, note that the difference in the vertical and horizontal scales causes a slight representational distortion.

Table 8. Jetty A Spur Groin Feature

Spur Groin Feature	Jetty A
Number of spurs on channel side or downstream for Jetty A	1
Number of spurs on ocean side or upstream for Jetty A	1
Approximate total rock volume per spur (+/- 20%)	JA1C: 9,650 tons (~ 6,031 cy) JA2O: 7,330 tons (~ 4,581 cy)
Approximate total rock volume (all spurs) (+/- 20%)	25,000 tons (~ 15,625 cy)
Approximate area affected by each spur	JA1C: 0.33 acres; JA2O: 0.29 acres
Approximate total area affected (all spurs)	0.61 acres
Approximate area of spurs above water	JA1C: 0%; JA2O: 0%
Approximate area of spurs below -20 MLLW	JA1C: 1%; JA2O: 0%
Approximate dimension of spurs: length x width x height (ft)	JA1C: 135 x 105 x 18 JA2O: 125 x 100 x 15

Figure 23. Jetty A Spur Groin JA1C

Note difference in scale between vertical and horizontal axes.



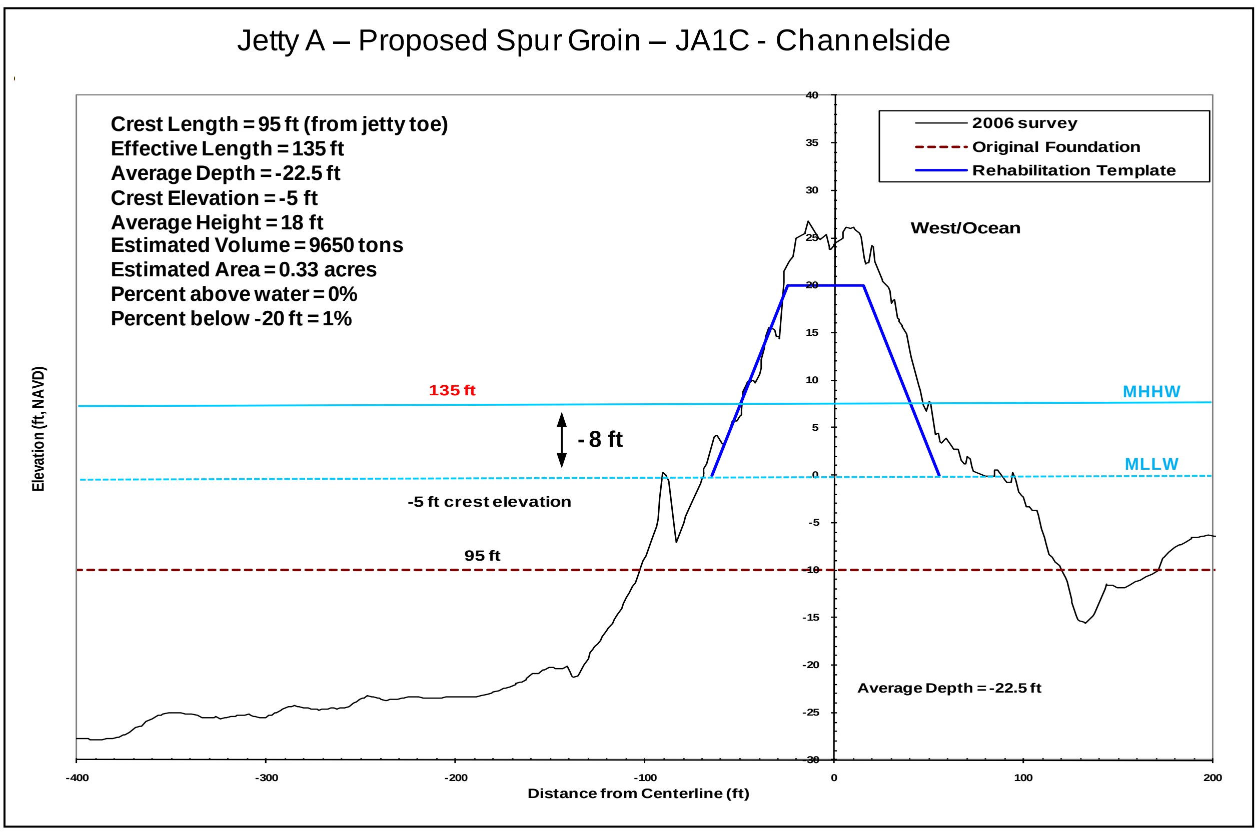
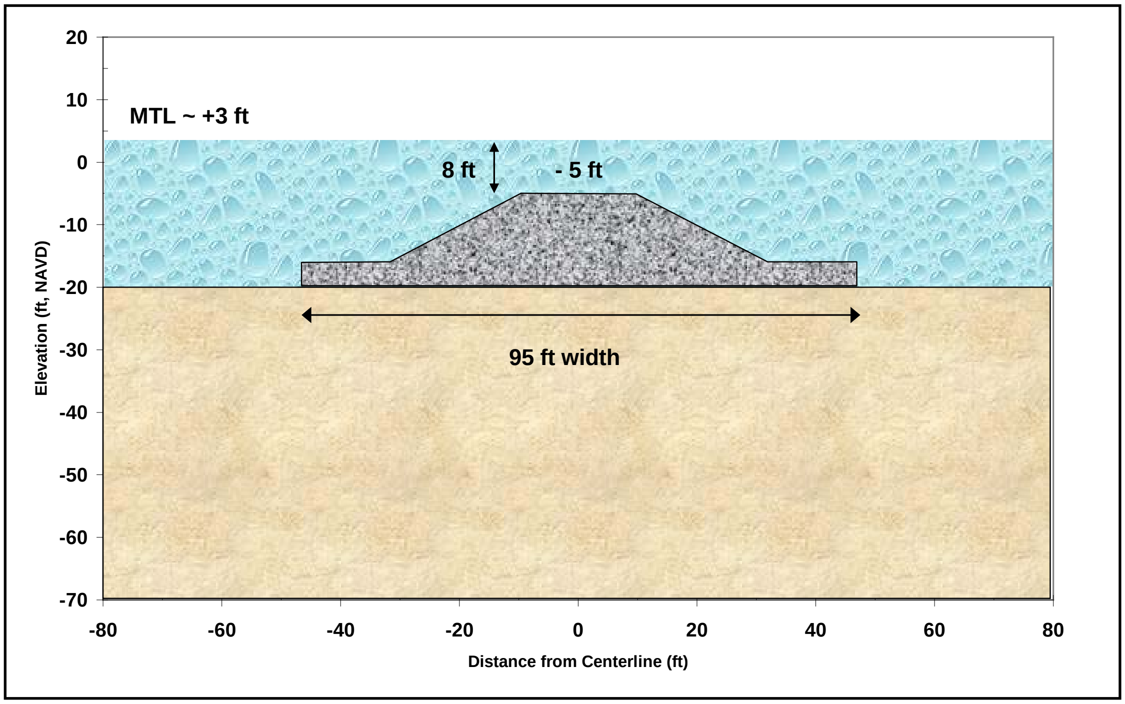
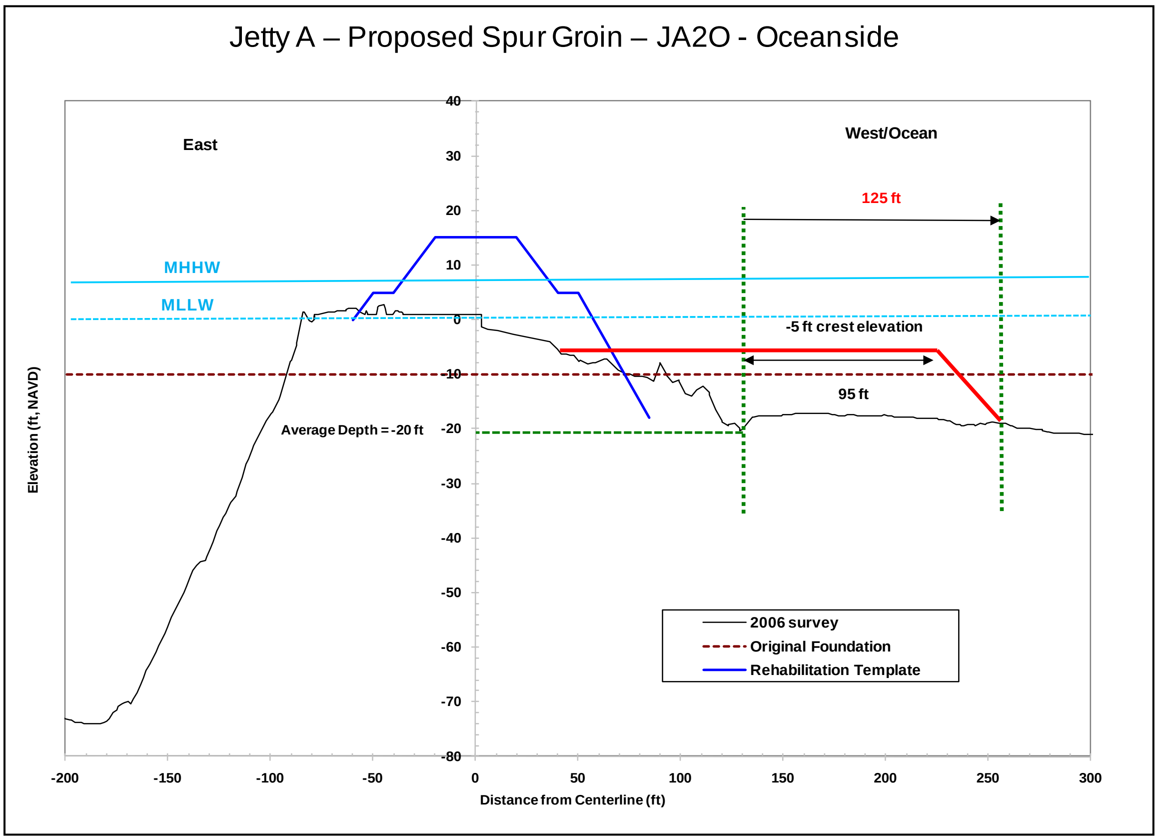


__Figure 24. Jetty A Spur Groin JA2O__

Note difference in scale between vertical and horizontal axes.





Jetty A Head Capping

An armor stone cap of approximately 24,000 tons (~ 15,000 cy) or equivalent concrete armor units will be placed on the head of the Jetty A to stop its deterioration (Figure 21). The features of this work are shown in Table 9.

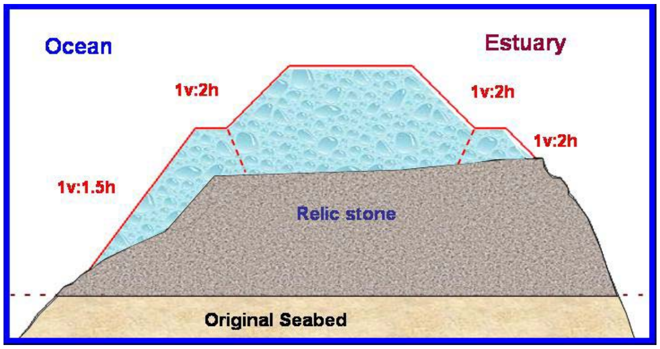
For capping of the head, divided into elevation zones about 7,920 cy of rock will be placed above MHHW. This represents 44% of the overall stone placement on this portion of Jetty A and there is very little or no existing jetty stone expected to be present within this elevation range. About 4,740 cy of rock will be placed between MHHW and MLLW. This represents a 26% of the overall stone placement on this portion of Jetty A and there is very little or no existing jetty stone expected to be present within this elevation range. About 5,420 cy of rock will be placed below MLLW. This represents 30% of the overall stone placement on this portion of Jetty A and a 1783% change from the existing jetty prism, as there is very little or no existing mounded jetty stone expected to be present within this elevation range.

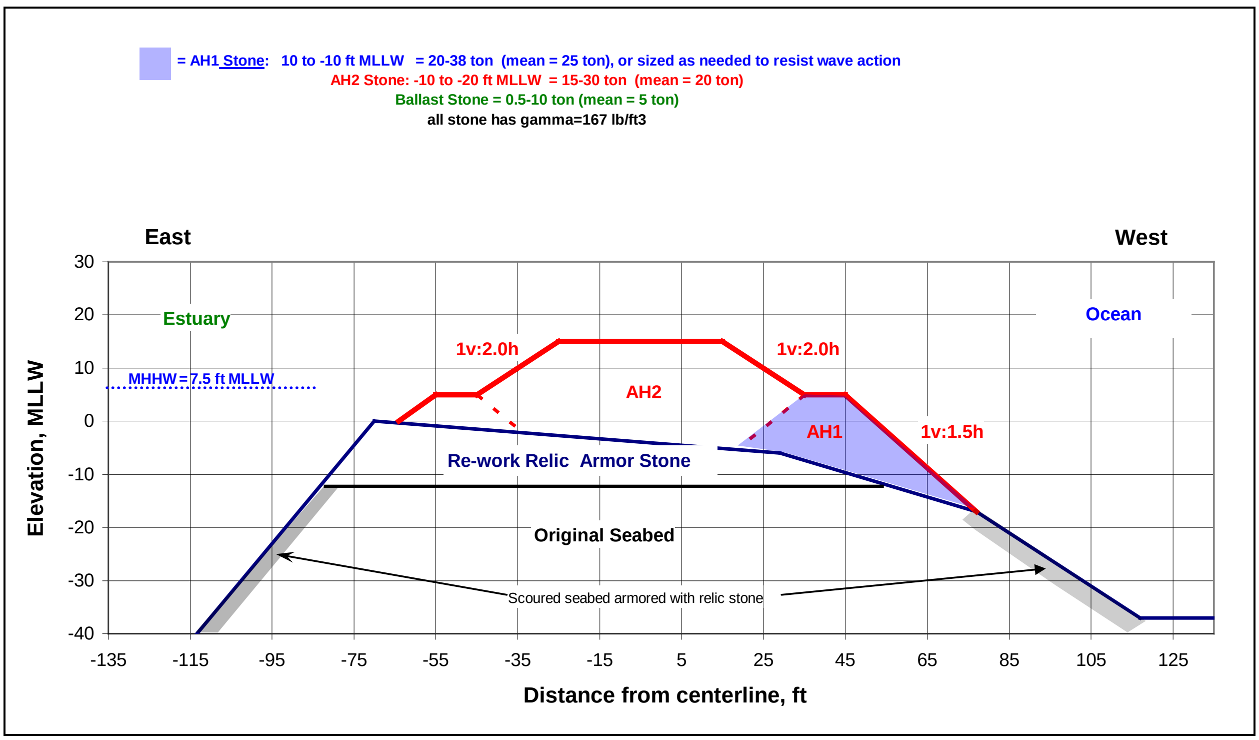
In all zones, all proposed stone placement will occur on existing base relic stone that formed the original jetty cross-section and was displaced and flattened by wave action, and does not include any modification that changes the character or increases the scope or size of the original structure design. The terminus of the head is simply closer to shore on a shorter jetty structure. . The footprint of the existing jetty mound on the flattened relic stone is approximately 0.64 acres, and the additional capping on the relic stone increases the width of the prism approximately 0.09 acres, for a total footprint of 0.73 acres on the existing relic stone.

Table 9. Jetty A Head Cap Feature

Features	Jetty A
Location of cap	stations 91 to 93
Timing of construction	2015
Dimensions of cap: length x width x height (feet)	200 x 160 x 40 (0.73 acres)
Stone size	30 to 40 tons
Area affected (outside relic stone)	None
% of cap constructed on relic stone	100%
Construction method	Land-based crane

Figure 25. Jetty A Head Cap





CONSTRUCTION MEASURES AND IMPLEMENTATION ACTIVITIES

Construction Schedule and Timing

The preferred in-water work window for the Columbia River estuary at the mouth is 1 November to 28 February. However, seasonal inclement weather and sea conditions preclude safe, in-water working conditions during this timeframe. Therefore, it is likely that most of in-water work for constructing spur groins, head capping, cross-section repairs, constructing off-loading facilities, etc. will occur outside this period during calmer seas, mostly between April and October.

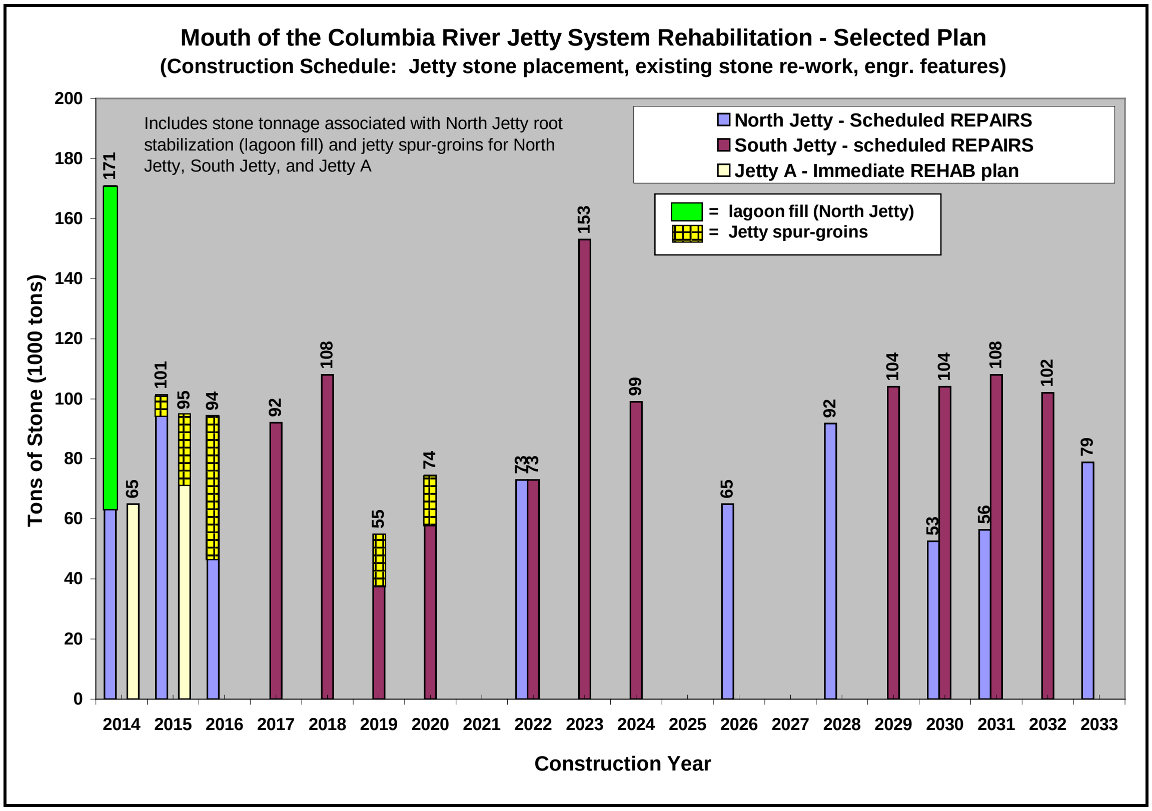
Most landward work on the jetties will be occurring from 1 April to 15 October. Work is assumed to occur 1 June to 15 October on the more exposed sections of the jetties. Placement work may extend beyond these windows if weather and wave conditions are conducive to safe construction and delivery. Stone delivery by land or water could occur year-round, depending on delivery location and weather breaks. Barge delivery would most likely occur during the months of April through October or at other times of the year depending on breaks in the weather and which jetty is being used. Quarrying of the rock may be limited to the months of April through October depending on the regulations pertinent to each quarry.

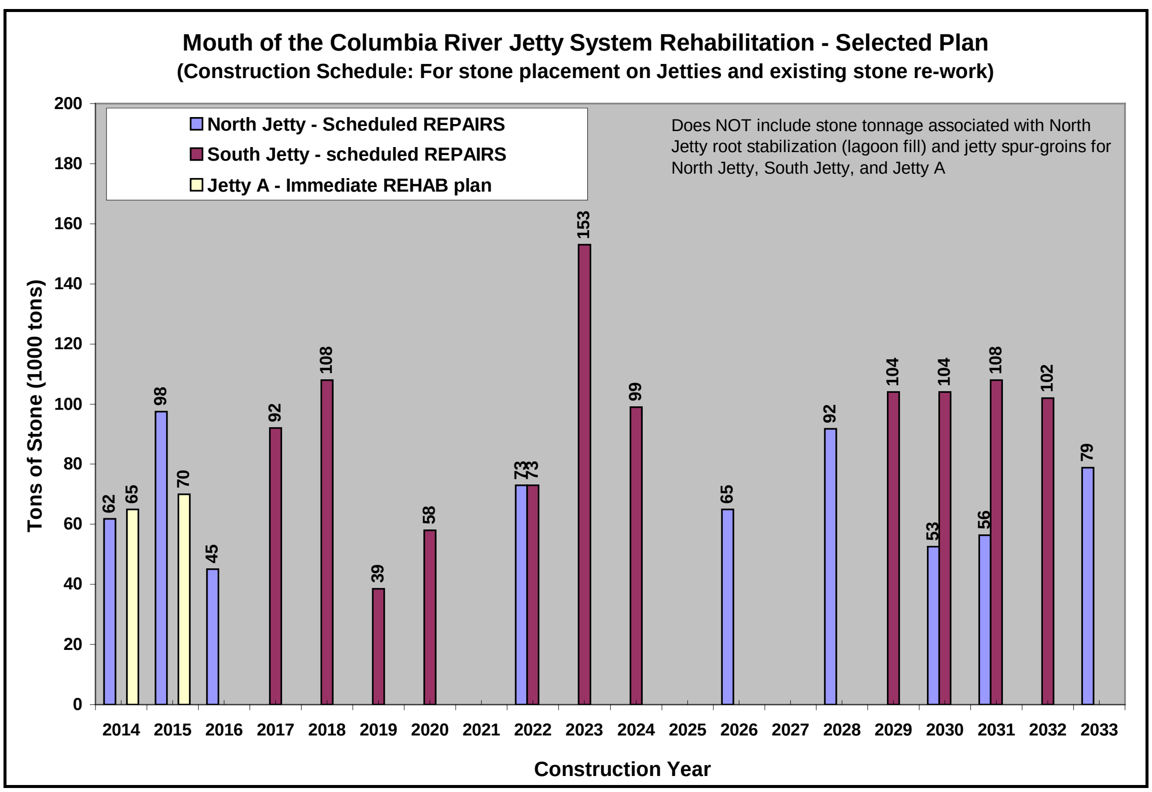
Work elements fall into four general categories for scheduling: (1) rock procurement, quarrying, and delivery transport, (2) construction site preparation, (3) lagoon fill and dune augmentations, and (4) jetty repair and rehabilitation work with construction of the design features including head capping and spur groins. Site preparation would consist of the preparation of the rock stockpile storage and staging areas, as well as the construction of any barge-offloading facilities that may be required. Approximate transport quantities by method are 30 tons per truck and 6,500 tons per barge. The majority of the jetty rehabilitation work is expected to be conducted from the top of the jetty downward using an excavator or a crane. Areas which may require marine plant work include construction at the jetty heads and some of the deeper spur groins.

For design and cost-benefit estimates, the project was modeled and designed for a 50-year operational lifespan. The schedule shown in Figure 26 illustrates construction actions related to building engineered features anticipated to occur at any one or some combination of all three of the jetties for the duration of 20 years. It also includes a predicted schedule of repair actions that the Corps' model estimates will be necessary within that same time period. Additional repairs have also been predicted to occur after the initial 20-year construction schedule and within the 50-year lifespan of the project. Additional repairs beyond the 20-year schedule will be similar in scale and nature to those described above in the standard repair template. Repair actions are generally triggered when a cross-section of the jetty falls below about 30%-40% of the standard repair template profile. The schedule described further in the narrative is a combined reflection of constructing specific engineered features and forecasting needed repairs. Real-time implementation of repair actions will likely vary based on evolving conditions at the jetties and could be shifted within and beyond this 20-year construction schedule.

In the construction schedule, rock production and stockpiling material begins in 2013. The first jetty installation is scheduled for late spring 2014 and continues through 2033. The estimate assumes the work will be accomplished with multi-year contracts.

Figure 26. Construction Schedule





Due to pinniped use at the South Jetty, the Corps proposes to conduct monitoring per conditions in the expected IHA permit. The Corps anticipates that the new IHA permit will entail requirements similar to those in the previous permit. These previous requirements included monitoring and reporting the number of sea lions and seals (by species if possible) present on the South Jetty for 1 week before (re)starting work on this jetty. During construction, the Corps provided weekly reports to the NMFS, which included a summary of the previous week's numbers of sea lions and seals that may have been disturbed as a result of the jetty repair construction activities. These reports included dates, time, tidal height, maximum number of sea lions and seals on the jetty and any observed disturbances. The Corps also included a description of construction activities at the time of observation. Post-construction monitoring occurred with one count every 4 weeks for 8 weeks, to determine recolonization of the south jetty. The Corp anticipates future monitoring and reporting requirements will be similar and will designate a biologically trained on-site marine mammal observer(s) to carry out this monitoring and reporting. The Corps will submit the required reports to the NMFS and the AMT. The Oregon Department of Fish and Wildlife, who monitors sea lion use of the South Jetty, will also be apprised of the Corps work and results of the monitoring efforts.

Conservation Measures the Corps will implement in order to minimize disturbance to Stellar sea lions includes the following; during land-based rock placement, the contractor vehicles and personnel will avoid as much as possible direct approach towards pinnipeds that are hauled out. If it is absolutely necessary for the contractor to make movements towards pinnipeds, the contractor shall approach in a slow and steady manner to reduce the behavioral harassment to the animals as much as possible. Monitoring and reporting will occur as required.

Construction Sequence and General Schedule

Rock procurement activities will be initiated for the North Jetty repair in 2013. In 2014, the on-site work will begin with filling the lagoon area behind the North Jetty root (stations 20 to 60) and installing a culvert to divert overland flow to another area that will not impact the North Jetty root stability. The lagoon area will be filled with rock, gravel, and sand. Once the lagoon is filled, the filled portion will serve as a staging and stockpile area for the rock delivered to the North Jetty site. To control further head recession of the North Jetty, in 2014 construction will focus on reconstructing the jetty head (station 88 to 99). This work will require haul road construction on top of the jetty from station 70 out to the head requiring approximately 31,000 tons of rock. The North Jetty will require installing a barge offloading facility on the channel side of the jetty at approximately station 45+00. Dredging of 30,000 cy is anticipated to provide the minimum 25-ft working clearance. Concurrently, work will begin on Jetty A beginning with constructing the off-loading facility, 60,000 cy of dredging to accommodate the rock delivery by barge, and constructing the jetty crest haul road from station 40+00 to 80+00. Total new stone consists of approximately 50,000 tons of imported rock, equivalent to 1,700 trucks or 8 barges.

In 2015 construction will continue on the North Jetty head from station 99 to 101 and installation of one spur groin at station 50 on the channel side. The haul road will need to be reworked with approximately 26,000 tons of new topping material. Work will occur concurrently with Jetty A beginning with 60,000 cy of dredging, completion of the jetty crest haul road from station 80 to 93, and installation of two spur groins. Total new stone for 2015 would consist of approximately

160,000 tons of imported rock, equivalent to 5,400 trucks or 25 barges. Work on Jetty A shall be completed this year.

In 2016, work continues on the North Jetty with placement of 36,000 tons of large armor near the head at station 80 to 88. This requires refurbishing the haul road and building vehicle turnouts. In addition, three spur groins will be installed at station 70-C, 80-O, and 90-C with a total of 50,000 tons of new stone. Total new stone would consist of approximately 86,000 tons of imported rock, equivalent to 2,900 trucks or 13 barges. Site preparation work and stockpiling stone at the South Jetty will occur to prepare staging and stockpile areas for 2017 construction.

In 2017, construction on the South Jetty is projected to begin, starting with construction work near the head from stations 173 to 176 and 180 to 195. South Jetty construction will require either a haul road be constructed on top of the jetty or constructed from a marine plant in order to get out to the head. Total work effort in 2017 is projected to consist of approximately 74,000 tons of rock; equivalent to 2,500 trucks or 12 barges.

Work continues on the South Jetty for the next 3 years working towards the head in 2018 with a total of 86,000 tons of new armor at station 290 to 311. Head construction begins in 2019 with 30,000 tons of new head armor and installation of 4 spur groins at stations 165–O, 210-C, 230-C, and 265-C for a total of 9,000 tons of spur groin rock. The South Jetty head completes in 2020 with 44,000 tons of new stone.

In 2022, construction is projected to occur concurrently on the North and South jetties: (1) continuation of North Jetty stone placement station 40 to 45 and station 65 to 73; and (2) continuation of stone placement on the South Jetty station 160 to 163, station 170 to 173, station 176 to 180, and station 195 to 200. Total rock tonnage for 2022 is estimated at 115,000 tons, equivalent to 3,850 trucks or 18 barges.

In 2023, construction continues on the South Jetty with the placement of approximately 118,000 tons of rock between stations 205 to 250. The haul road will need to be reworked with approximately 62,000 tons of quarry stone road base and topping material. Total jetty stone rock tonnage to be placed would require 4,000 trucks or 18 barge loads.

In 2024, construction continues on the South Jetty with the placement of approximately 76,000 tons of rock between stations 270 to 290. Total rock tonnage to be placed would require 2,600 trucks or 12 barge loads.

In 2026, construction resumes on the North Jetty with the placement of approximately 52,000 tons of rock between stations 20 to 30. The long time frame from the previous construction on the North Jetty will also require rebuilding the jetty haul road from station 20 to 30. Total rock tonnage to be placed would require 1,800 trucks or 8 barge loads.

In 2030, construction is projected to occur on the North and South jetties: (1) continuation of North Jetty stone placement station 30 to 40; and (2) continuation of stone placement on the South Jetty station 223 to 237, and station 250 to 253. Total rock tonnage to be placed is estimated at 129,000 tons, equivalent to 4,300 trucks or 20 barges.

In 2031, construction is projected to occur on the North and South jetties: (1) continuation of North Jetty stone placement station 88 to 99; and (2) continuation of stone placement on the South Jetty station 253 to 270. The North Jetty haul road will need to be re-built from station 65 to 99 and will require 30,000 tons of quarry waste material. Total armor stone rock tonnage to be placed is estimated at 135,000 tons, equivalent to 4,500 trucks or 21 barges.

In 2032, construction continues on the South Jetty with the placement of approximately 85,000 tons of rock between stations 295 to 311. Total rock tonnage to be placed would require 2,850 trucks or 13 barge loads. The offloading facility will be removed and scheduled construction will be complete for the South Jetty.

The final anticipated year of North Jetty rehabilitation is projected for 2033 with construction from stations 80 to 88. Total rock tonnage estimated is 63,000 tons, equivalent to 2,100 trucks or 10 barge loads. The offloading facility will be removed and scheduled construction will be complete for the North Jetty.

Because construction at the North and South jetties is spaced out from 2014 through 2033 with intermittent work, dredging at the barge offloading sites will only be required prior to a year of actual rock delivery in preparation for upcoming construction work. The Jetty A barge offloading site will only require dredging to make that site accessible for 2 years. Dredging will only be needed if the clearance depth at the barge offloading site is not found to be adequate prior to rock delivery activities.

Sources and Transportation of Rock

Rock Quarries and Transport

Currently, it is not exactly known where jetty rock will come from and how it will be transported to the jetty sites. However, one or more of the options discussed below would be employed (Figures 27 to 32 and Table 10). Stone sources located within 150 miles of a jetty are likely to be transported by truck directly to the jetty. Stone sources located at further distances, especially if they are located near waterways, are likely to be transported by truck to a barge onloading facility, then transported by tug and barge to either a Government-provided or commercial barge offloading site located nearby. Railway may also be an option for transporting stone, provided that an onloading site is convenient to the quarry. Most railroads follow main highway arterials, such as Interstate 5. The closest railroad terminal to the MCR South Jetty is at Tongue Point, east of Astoria, Oregon, which is about 15 miles from the jetty. The nearest railroad terminal to the MCR on the north side of the Columbia River is at Longview, Washington.

The Corps intends to use operating quarries rather than opening any new quarries. The Contractor and quarry owner/operator will be responsible for ensuring that quarries selected for use are appropriately permitted and in environmental compliance with all State and Federal laws.

Canadian Quarries. Quarries in British Columbia are typically located adjacent to waterways and rock produced from these quarries will likely have a limited truck haul. Due to the long distance to the MCR, plus the immediate availability to deep water, rock would likely be loaded onto barges and shipped down the Washington Coast to barge offloading sites.

Washington Quarries. Quarries located in northern Washington are typically not on the water, but are generally located within 50 miles of a potential barge on-loading site. As a result, rock would need to be hauled, at least initially, by truck. Rock would be transported by trucks most likely to a barge on-loading facility or possibly all the way to the staging site at the jetty. In the event of a combination of trucking and barging, trucks would be loaded at the quarry, and then traverse public roads to existing facilities. Once the rock is loaded on barges, it would be transported down the coast to barge offloading sites.

It also is possible that railway systems may be used to transport rock much of the way to the jetties. Burlington Northern Railroad operates a rail system that parallels Interstate 5 throughout Washington which would be the most likely route rock would be transported. Rock from the quarry would be taken by truck to a nearby railway station where they would be loaded onto railway cars and transported to an intermediate staging area. Trucks would then again take the rock the remainder of the way to the jetty staging areas.

Truck hauling of rock from northern Washington sources to the North Jetty or Jetty A most likely would be transported by public road to Interstate 5 or any of the main roads over to Highway 101. Trucks using Interstate 5 would either turn at Longview on Highway 4 to Highway 101, or cross over the Longview Bridge to Highway 30 near Rainier, Oregon. From this point they would proceed west to Astoria to Highway 101, crossing the Astoria-Megler Bridge through Ilwaco to the jetty staging areas. Delivery to the South Jetty most likely would use main roads to Interstate 5 or any of the main roads over to Highway 101.

Trucks using Highway 101 south through Washington would likely cross the Astoria-Megler Bridge, go through Warrenton using local roads into Fort Stevens State Park and the staging area. Trucks utilizing Interstate 5 would either turn at Longview on Highway 4 to Highway 101, or on Highway 30 near Rainier, proceeding through Astoria to Highway 101, going through Warrenton through local roads into Fort Stevens State Park and the jetty staging area.

Rock located within southern Washington would likely be trucked to the jetty staging areas. An exception to this would be a quarry that occurs within just a few miles of a port on the Washington Coast or a quarry that is near the Columbia River. In either of these two barge possibilities, rock would be delivered by truck to a barge on-loading facility, loaded on oceangoing or riverine barges, and delivered to one of the barge offloading facilities (see section on barge offloading facilities below). Truck hauling of rock from this area to the jetties would be as described above.

Oregon Quarries. Rock located in northern Oregon within 50 miles of the North Jetty and Jetty A would likely utilize any of the main roads over to Highway 101 or Highway 30. From this point they would cross the Astoria-Megler Bridge and proceed west through Ilwaco to the jetty staging areas. Quarries exceeding 50 miles from the jetties would likely utilize main roads at a farther distance from the jetty sites. This would involve longer haul distances on Highways 101, 30, 26, and others before crossing the Astoria-Megler Bridge and proceeding to the staging areas.

Truck hauling of rock from quarries within 50 miles of the South Jetty will most likely utilize any of the main roads over to Highway 101 or Highway 30. From this point they would proceed through Astoria and Warrenton, or Seaside and Gearhart to local roads leading to Fort Stevens State Park and the jetty staging areas. Quarries exceeding 50 miles from the jetty would likely utilize main roads at a farther distance from the jetty site. This would involve longer haul distances on Highways 101, 30, 26, and others before going through Astoria and Warrenton, or Seaside and Gearhart to local roads leading into Fort Stevens State Park and the staging areas.

The likely mode of transportation from southern Oregon quarries is trucking, or a combination of trucking and barging. Many of the quarries may be near the Oregon Coast; however, they may not be near a port facility that has barge on-loading capability. Providing that barge facilities are available, rock located south of Waldport would be loaded at the quarry onto trucks and traverse main public roads to the barge on-loading site, loaded on ocean-going barges, and shipped up the Oregon Coast to one of the barge offloading facilities (see section on barge offloading facilities below). Quarries north of Waldport would most likely be hauled by truck the entire distance.

Southern Oregon rock sources requiring trucking would be loaded onto lowboy trucks one to three at a time and would traverse main roads to more main arterials such as Highway 101 or, to a lesser degree, Interstate 5. An effort would be made to use the least distance possible to transport the rock without sacrificing transport time.

California Quarries. For northern California quarries, there would be a very long haul distance required to get rock to the jetty repair areas. Barging of rock would be the only economically feasible option. Rock would be transferred by truck from the quarries along main roads leading to Highway 101 to a barge offloading facility.

Figure 27. Potential Quarry Locations (red dots) for Repairs to MCR Jetties

See corresponding quarry information located in Table 10.

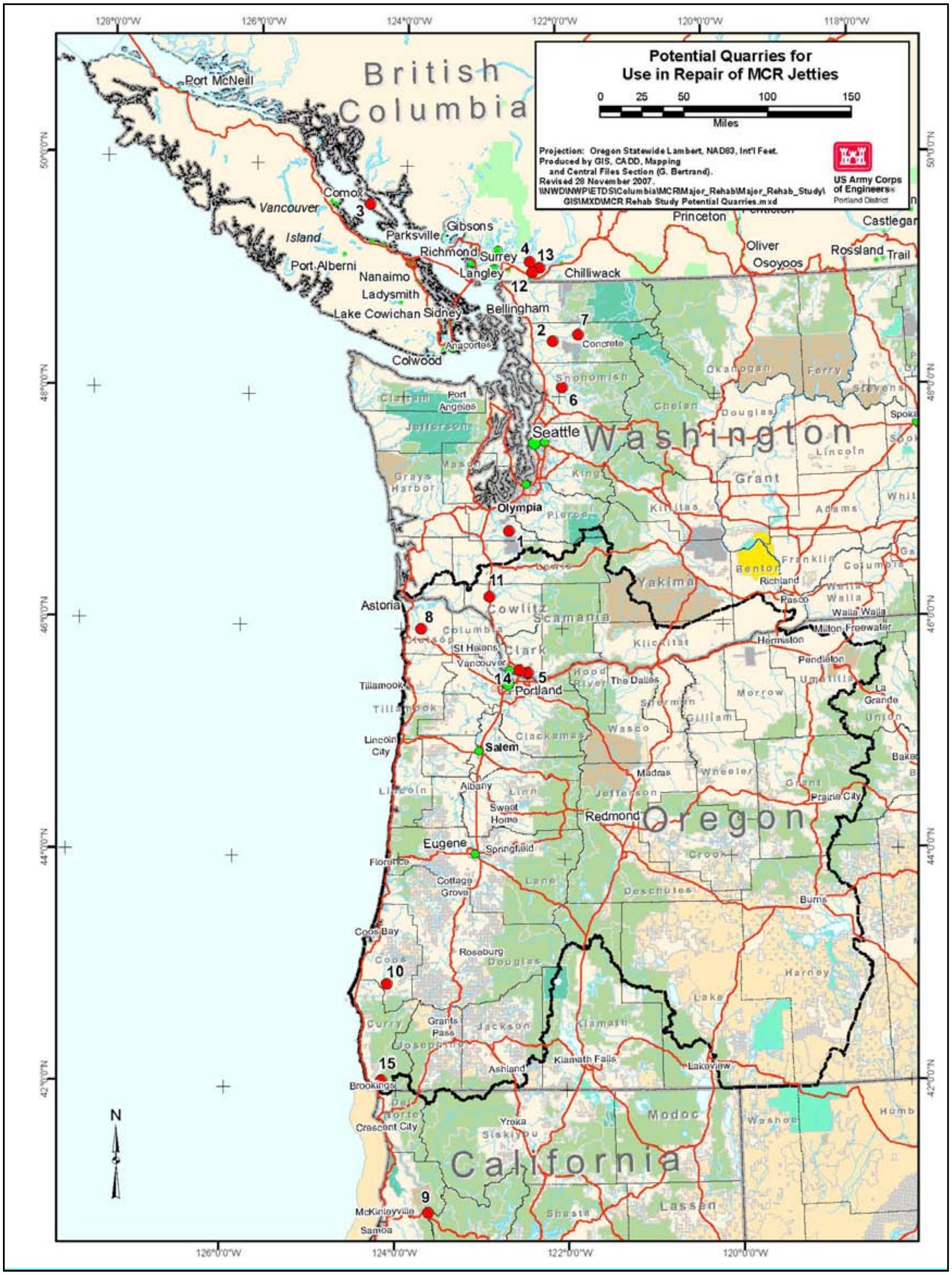


Table 10. Quarry Information

See Figure 27 for site map.

No.	Quarry	County and State	Nearest City	Road Miles from MCR	Unit Weight (pcf)	Reserves Available (tons)	Likely Transportation Method	Nearest Barge Facility
1	Columbia Granite Quarry	Thurston, WA	Vail, WA	129	168.5	28 M	Truck	N/A
2	Beaver Lake Quarry	Skagit, WA	Clear Lake, WA	251	181.1	1.86 M	Truck, then Barge	Anacortes, WA
3	Texada Quarry	BC, CANADA	Texada Island, BC	363	173.5+	275 M	Barge	Onsite
4	Stave Lake Quarry	BC, CANADA	Mission, BC	311	169.1	74 M	Truck, then Barge	Mission, BC, Canada
5	192nd Street Quarry	Clark, WA	Camas, WA	109	168.5	0.5 M	Truck/Barge	Camas, WA
6	Iron Mountain Quarry	Snohomish, WA	Granite Falls, WA	225	174	Unknown	Truck	N/A
7	Marble Mount Quarry	Skagit, WA	Concrete, WA	276	189.7	2 M	Truck, then Barge	Anacortes, WA
8	Youngs River Falls Quarry	Clatsop, OR	Astoria, OR	20	181.8	0.5 M+	Truck	N/A
9	Liscomb Hill Quarry	Humboldt, CA	Willow Creek, CA	515	179.1	0.5 M	Truck, then Barge	Eureka, CA
10	Baker Creek Quarry	Coos, OR	Powers, OR	275	200	Unknown	Truck, then Barge	Coos Bay, OR
11	Phipps Quarry	Cowlitz, WA	Castle Rock, WA	69	167.4	0.5 M	Truck	N/A
12	Cox Station Quarry	BC, CANADA	Abbotsford, BC	313	167.9	150 M	Barge	Onsite
13	Ekset Quarry	BC, CANADA	Mission, BC	309	172.2	10 M	Truck, then Barge	Mission, BC, Canada
14	Fisher Quarry	Clark, WA	Camas, WA	108	168.5	2 M	Barge	Camas, WA
15	Bankus Quarry	Curry, OR	Brookings, OR	347	183 & 195	0.7M	Truck, then Barge	Crescent City, CA

Figure 28. Potential Canadian Rock Source Transportation Routes

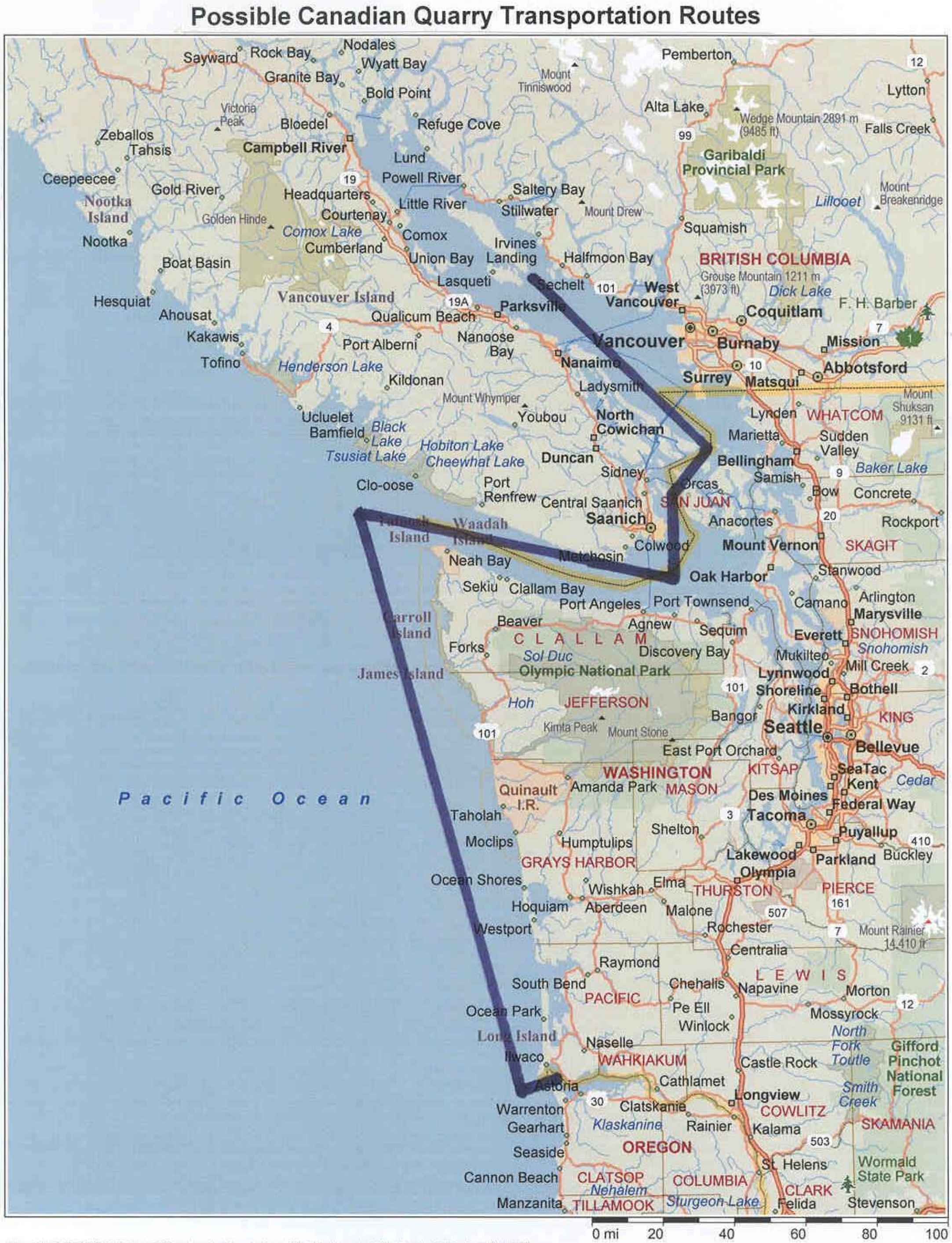


Figure 29. Potential Washington Rock Source Transportation Routes

Figure 30. Potential Oregon Rock Source Transportation Routes

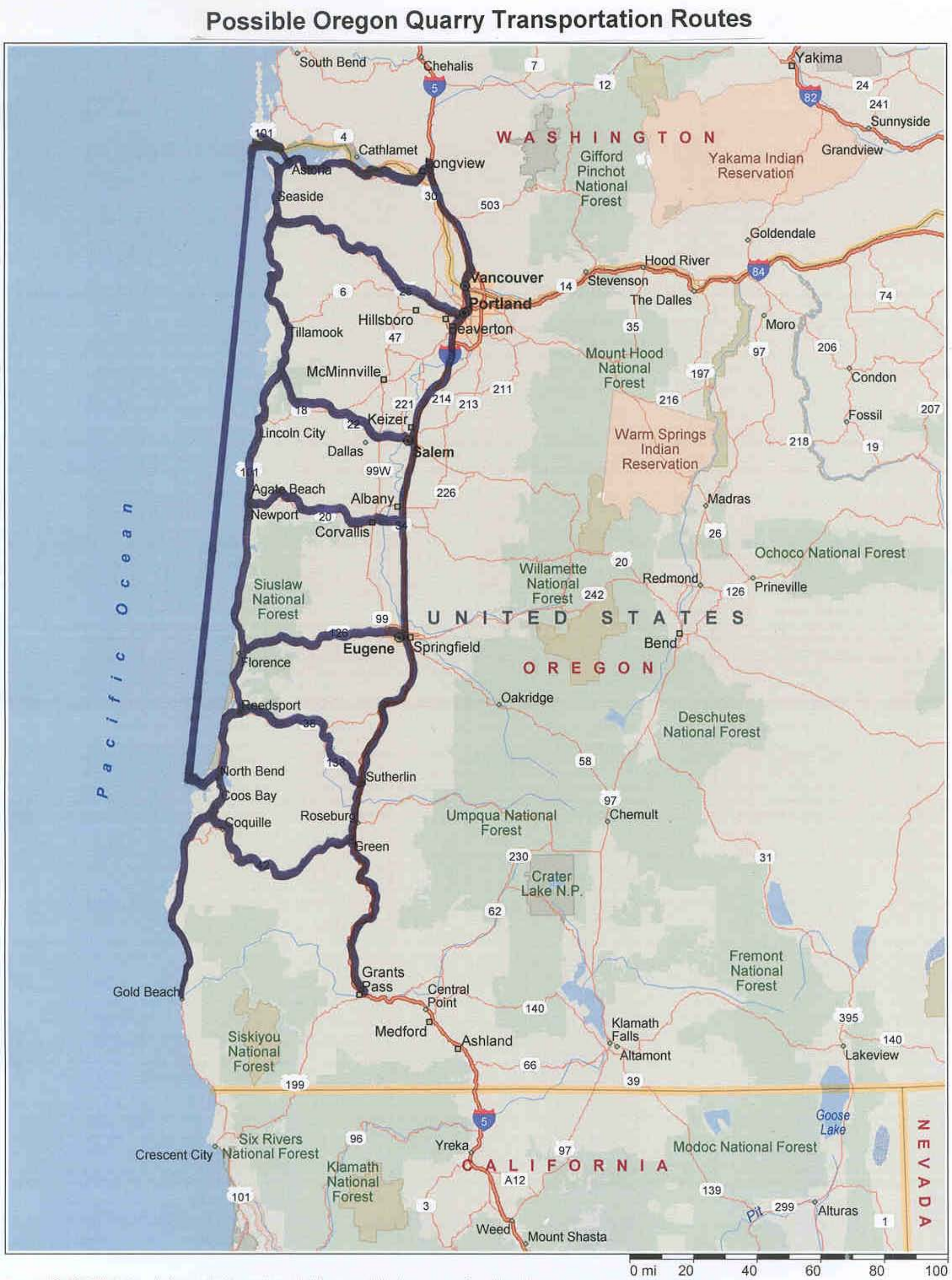


Figure 31. Potential Northern California Rock Source Transportation Routes

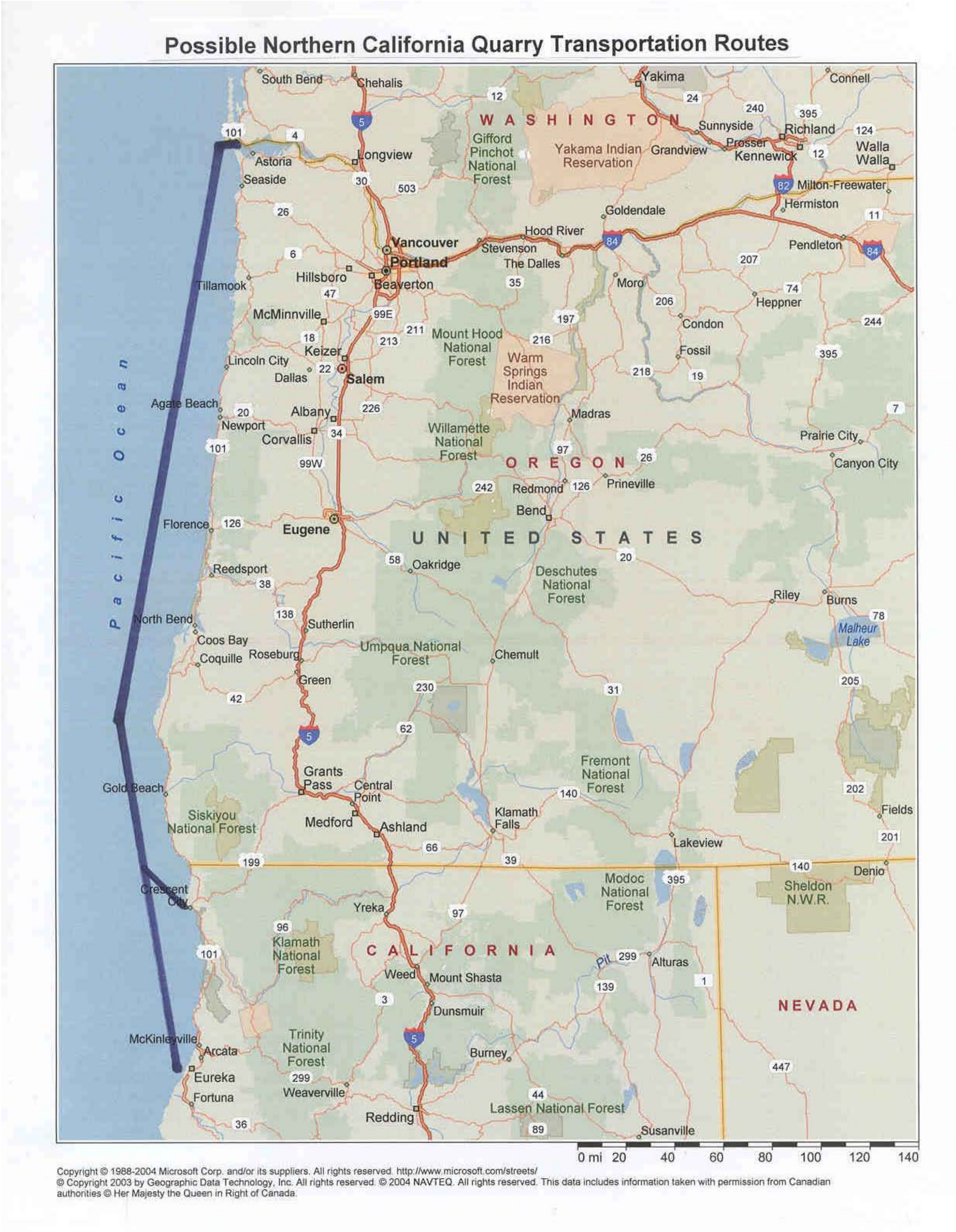


Figure 32. Potential Railway Transportation Routes

For water-based delivery of rock, a tow boat and barge would deliver the rock to the channel side of the jetties where water depth, waves, and current conditions permit. During rock offloading, the barge may be secured to approximately 4 to 8 temporary dolphins/H-piles to be constructed within 200 feet of the jetty. Rock would be off-loaded from the barge by a land- or water-based crane and either placed directly within the jetty work area or stock piled on the jetty crest for subsequent placement at a later time.

For land-based delivery of rock, jetty access for rock hauling trucks would be via an existing paved road to the Benson Beach parking lot at Cape Disappointment State Park (North Jetty) and via an existing paved road to the Parking Lots C and D at the South Jetty. An existing overland route between Jetty A and North Jetty may also be used for land-based hauling. Work areas for delivery of rock, maneuvering of equipment, and stockpiling of rock near the jetties have been identified and are shown in Figures 33-35.

Barge Offloading Facilities

Stone delivery by water could require up to four barge offloading facilities that allow ships to unload cargo onto the jetty so that it can then be placed or stockpiled for later sorting and placement. The range of locations for these facilities is shown in Figures 33-35. Depending on site-specific circumstances, offloading facilities may be converted to spur groins, may be partially removed and rebuilt, may be permanently removed, or may remain as permanent facilities upon project completion. Facility removal will depend on access needs and evolving hydraulic, wave, and jetty cross-section conditions at each offloading locations.

Facilities will range from approximately 200- to 500-ft long and 20- to 50-ft wide, which ranges from about 0.48 to 2.41 acres in total area. For initial construction of all four facilities combined, approximately up to 96 Z- or H-piles could be installed as dolphins, and up to 373 sections of Z- or H-piles to retain rock fill. Figure 36 shows a cross section diagram for stone access ramp at potential barge offloading facilities and photos illustrating typical barge offloading facilities. Facilities will have a 15-ft NGVD crest elevation and will be installed at channel depths between -20 and -30 NGVD. A vibratory hammer will be used for pile installation and only untreated wood will be used, where applicable. Removal and replacement of the facilities could occur within the duration of the construction schedule. Volume and acreage of fill for these facilities are shown in Table 11.

Table 11. Approximate Rock Volume and Area of Barge Offloading Facilities and Causeways

Location	Approximate Length (ft)	Approximate Rock Volume (cy) Below 0 MLLW	Total Approximate Rock Volume (cy)	Approximate Square Feet	Acres
North Jetty	200	7,778	29,640 cy	21,000	0.48
Jetty A – near head	200	7,778	29,640 cy	21,000	0.48
Jetty A – mid-section causeway	5000	38,888	38,888	105,000	2.41
South Jetty – Parking Area D	450	17,417	33,688 cy	47,250	1.08
South Jetty – Along Jetty Turn-out	200		18,640 cy	21,000	0.48

Figure 33. North Jetty Offloading, Staging, Storage and Causeway Facilities

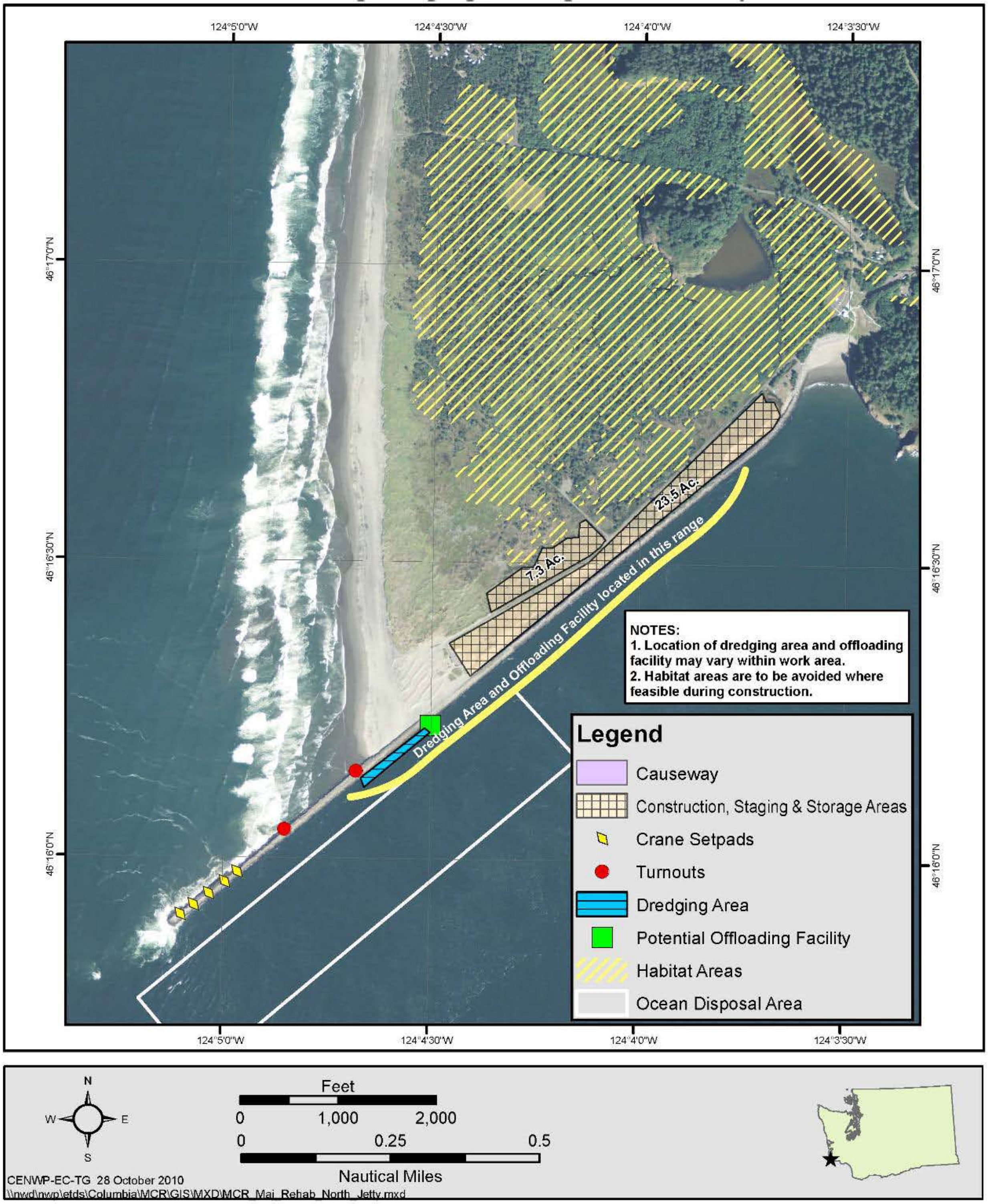


Figure 34. South Jetty Offloading, Staging, Storage and Causeway Facilities

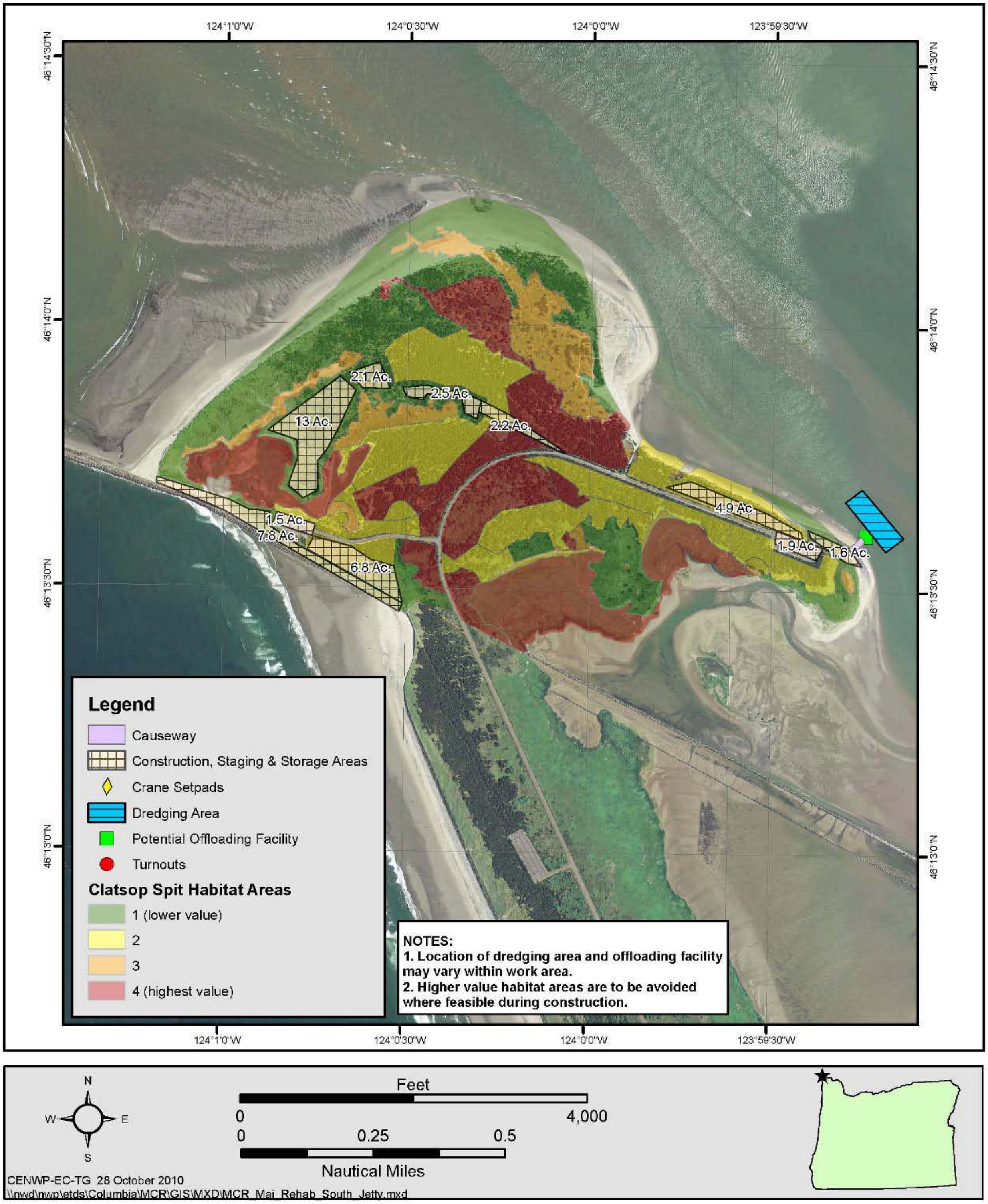


Figure 34 (continued). South Jetty Offloading, Staging, Storage and Causeway Facilities

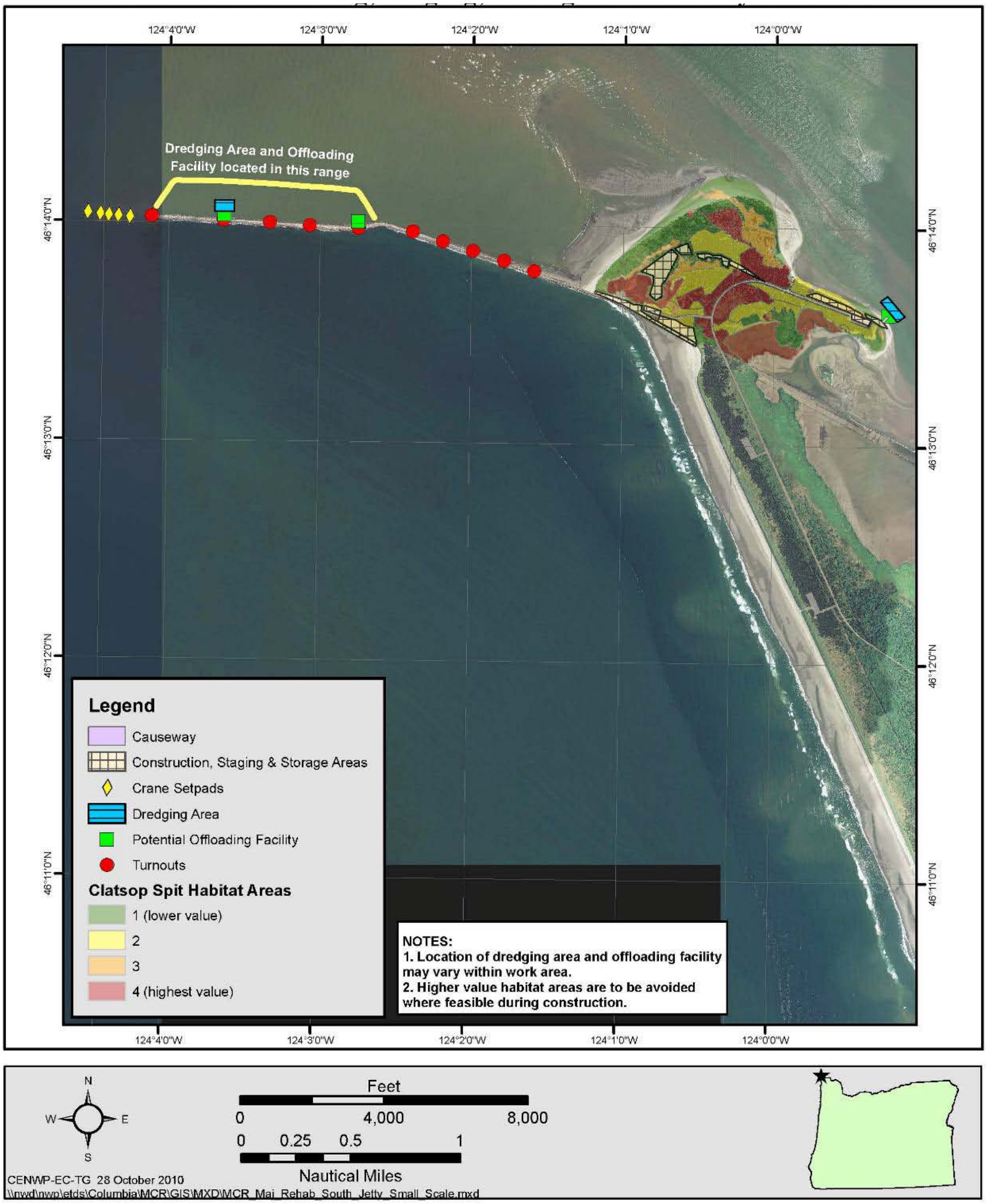


Figure 35. Jetty A Offloading, Staging, Storage and Causeway Facilities

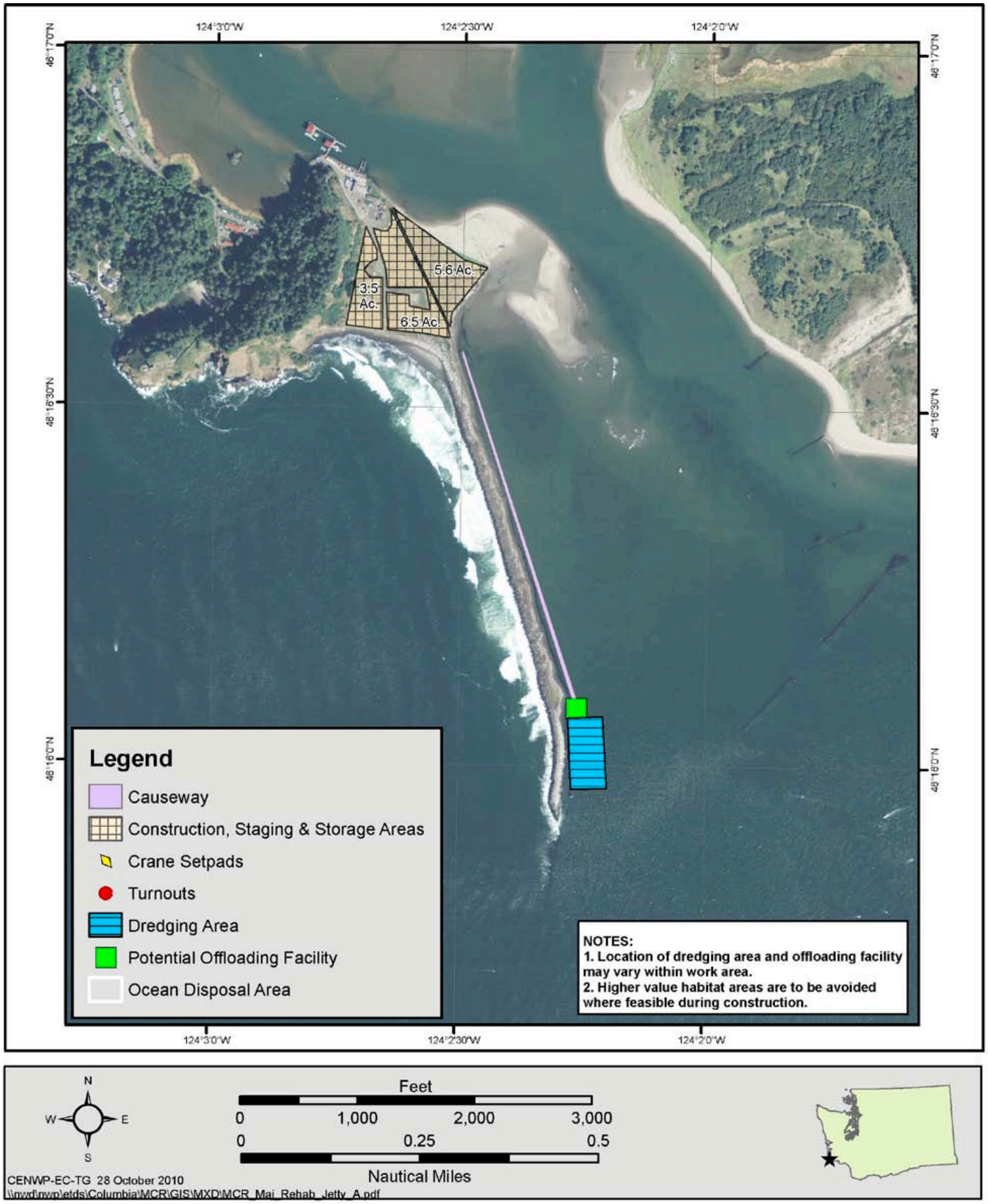


Figure 36. Cross Section of Stone Access Ramp at Barge Offloading Facilities at East End of Clatsop Spit near Parking Area D and Photos of Typical Barge Offloading Facilities

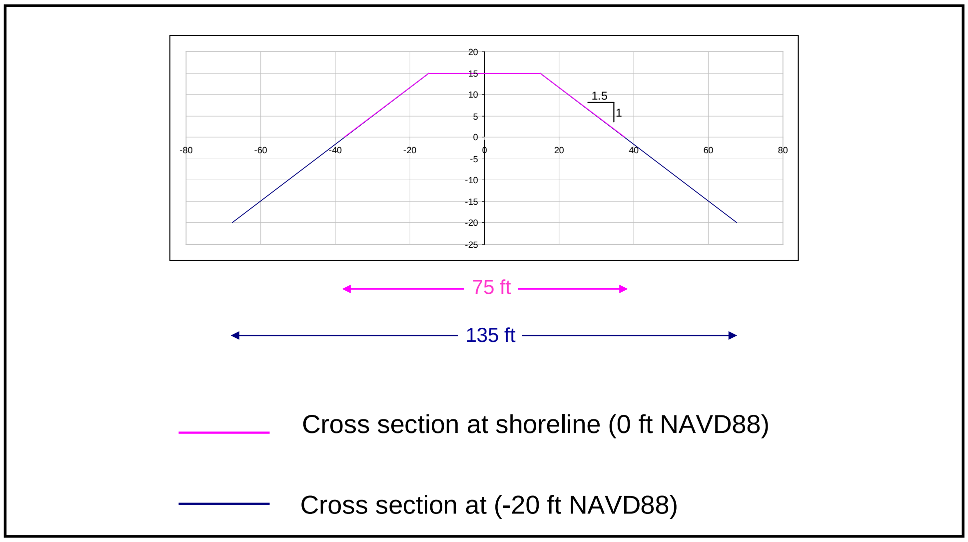


Figure 36 (continued)

The following existing private facilities may serve as potential offloading sites depending on availability for Corps' use:

- Commercial Site in Ilwaco. For the North Jetty, barges would pull up to a dock at Ilwaco where rock would be transferred by crane onto trucks that would proceed by public road to Cape Disappointment State Park. Trucks would then pass through the park grounds to the staging area adjacent to the jetty. For Jetty A, trucks would proceed through the Coast Guard facility to the staging area near the root of the jetty.

- Commercial Site in Warrenton. Nygaard Logging has a deep-water offloading site that could be used to offload rock. For the North Jetty/Jetty A, rock would be transferred to trucks that would likely use Highway 101 into Astoria, cross the Astoria-Megler Bridge, and head west through Ilwaco to Cape Disappointment State Park. Trucks would then pass through the park grounds to the staging area adjacent to the jetty. For the South Jetty, rock would be transferred to trucks which would then proceed west through Hammond to Fort Stevens State Park and use the existing park road to staging area adjacent to the jetty. This site needs no improvement to accommodate deep-draft vessels.

If existing facilities are not available or do not have adequate capacity to provide access, barge offloading facilities could be constructed at each jetty.

- North Jetty: Between or on the spur groin at/between Station 50 or 70, a barge offloading facility will be constructed. If wave conditions make it feasible, the spur groin designed for this area will first function as an offloading facility prior to conversion and stone removal to reach the spur's design depth. Otherwise, a separate facility will be installed in the reach between these two stations such that wave conditions allow safe offloading. This offloading facility will require 4-8 dolphins of 3 piles each for vessel tie-up, and sheet-pile installation will be required to shore-up and retain rock at the offloading point.

- Jetty A: An offloading facility will be sited near the location of the proposed spur groin around Station 81, at the upstream portion of the jetty near the head. The proposed spur groin could not be used for dual purposes, because it would have required additional, unnecessary rock in order to connect the offloading facility with the causeway. A 15-ft causeway will also be constructed along the entire length of the jetty on existing relic stone that runs adjacent to and abutting the upstream eastern portion of the jetty. This facility will likely remain a permanent facility, but may deteriorate due to wave and tidal action. This offloading facility will require 4-8 dolphins of 3 piles each for vessel tie-up, and sheet-pile installation will be required to shore-up and retain rock at offloading point.

- South Jetty: The South Jetty could have up to two associated offloading sites. One will be located at Parking Lot Area D near the northeastern-most corner of the Spit. The second facility will be located along the jetty and will resemble an extra-large turn-out facility. It is likely to be located somewhere on the northern, channel-side of the jetty and west of Station 270 in order to take advantage of deeper bathymetry and subsequently less need for dredging. The facility at Parking Lot Area D may be removed after 5 or more years depending on hydraulic impacts of the structure and spit. The facility along the jetty will likely be partially removed and rebuilt after each repair to avoid the potential for wave-focusing on the jetty. Otherwise, it will remain in place until around 2033. Each offloading facility will require 4-8 dolphins of 3 piles each for vessel tie-up, and sheet-pile installation will be required to shore-up and retain rock at offloading point.

Dredging for Barge Offloading Facilities

Transport of rock would most likely be done by ocean-going barges that require deeper draft (20-22 feet) and bottom clearance than river-going barges when fully loaded. Therefore, dredging will be required to develop each of the barge offloading facilities. Under-keel clearance should be no less than 2 feet. The elevation at barge offloading sites should have access to navigable waters and a dredge prism with a finish depth no higher than -25 feet MLLW, with advance maintenance and disturbance zone depths not to extend below -32 feet MLLW. These facilities should also provide for a maneuvering footprint of approximately 400 feet x 400 feet. The depth along the barge unloading sites would be maintained during the active period for which the rock barges will be unloaded.

A clamshell dredge would likely be used for all dredging, though there is a small chance that a pipeline dredge could be feasible but is unlikely to be used. The material to be dredged is medium to fine-grained sand, typical of MCR marine sands. Disposal of material would occur in-water at an existing approved disposal site. The volume of material to be dredged is shown in Table 12; these estimates are based on current bed morphology and may change. Also, maintenance dredging to a finish depth of -25 feet MLLW will be needed before offloading during each year of construction. Dredging is likely to occur on a nearly annual basis for the duration of the project construction period, but this will be intermittent per jetty, depending on which one is scheduled for construction in a particular year.

Table 12. Estimated Dredging Volumes for Barge Offloading Facilities

Location*	Estimated Dredging Volume (cy)		Approximate Acres
	Initial	Est. Maintenance**	
North Jetty	30,000	30,000	3.73
Jetty A	60,000	80,000	3.73
South Jetty	20,000	20,000	4.19
South Jetty - Parking Area D	20,000	20,000	4.19

* Some of the locations will not be used on an annual basis; it depends on the construction schedule for each jetty.
**All dredging will be based on surveys that indicate depths shallower than -25 feet MLLW.

Clamshell dredging is done using a bucket operated from a crane or derrick that is mounted on a barge or operated from shore. Sediment removed from the bucket is generally placed on a barge before disposal. This type of dredge is typically used in shallow water areas.

The following overall impact minimization practices and best management practices (BMPs) will be used for all maintenance dredging for offloading facilities.

1. To reduce the potential for entrainment of juvenile salmon or green sturgeon, the cutter-heads will remain on the bottom to the greatest extent possible and only be raised 3 feet off the bottom when necessary for dredge operations.

2. To reduce turbidity, if a clamshell bucket is used, all digging passes shall be completed without any material, once in the bucket, being returned to the wetted area. Not dumping of partial or half-full buckets of material back into the project area will be allowed. No dredging of holes or sumps below minimum depth and subsequent redistribution of sediment by dredging dragging or other means will be allowed. All turbidity monitoring will comply with Sate 401 Water Quality Certification Conditions.
3. If the Captain or crew operating the dredges observes any kind of sheen or other indication of contaminants, he/she will immediately stop dredging and notify the Corps' environmental staff to determine appropriate action.
4. If routine or other sediment sampling determines that dredged material is not acceptable for unconfined, in-water placement, then a suitable alternative disposal plan will be developed in cooperation with the NMFS, EPA, Oregon Department of Environmental Quality (ODEQ), Washington Department of Ecology (WDOE), and other agencies.

Dredged Material Disposal Sites

Two dredged material disposal sites, the Shallow Water Site (SWS) and the North Jetty site, are located near the North Jetty. These are the most likely sites to be used. Modeling has showed that the potential changes to the two disposal sites from the proposed action would not inhibit their use as disposal sites. Spur groin construction at the North Jetty would avoid the North Jetty disposal site. The northern-most cells of this site immediately adjacent to the jetty will be avoided to reduce the possibility of vessel impact with the spur groins.

Pile Installation and Removal

As mentioned earlier, inclement weather and sea conditions during the preferred in-water work window (IWWW) preclude safe working conditions during this time period. Therefore, installation of piles is most likely to occur outside the IWWW. For initial construction of all four facilities combined, approximately up to 96 Z- or H-piles could be installed as dolphins, and up to 373 sections of sheet pile to retain rock fill. They will be located within 200-ft of the jetty structure. Because the sediments in the region are soft (sand), use of a vibratory driver to install piles is feasible and will be used when necessary. The presence of relic stone may require locating the piling further from the jetty so that use of this method is not precluded by the existing stone. The dolphins/Z- and H-piles would be composed of either untreated timber or steel piles installed to a depth of approximately 15 to 25 feet below grade in order to withstand the needs of off-loading barges and heavy construction equipment. Because vibratory hammers will be implemented in areas with velocities greater than 1.6 ft/s, the need for hydroacoustic attenuation is not an anticipated issue. Piling will be fitted with pointed caps to prevent perching by piscivorous birds to minimize opportunities for avian predation on listed species. Some of the pilings and offloading facilities will be removed at the end of the construction period.

Rock Placement

Placement of armor stone and jetty rock on the MCR jetties would be accomplished by land or limited water-based equipment. Only clean stone will be used for rock placement, where appropriate and feasible. Where appropriate, there may also be some re-working and reuse of the existing relic and jetty prism stone. Fill for the jetty haul roads will not be cleaned prior to installation. Dropping armor stone from a height greater than 2 feet will be prohibited. During placement there is a very small chance of stone slippage down the slope of the jetty. However, this is unlikely to occur due to the size and cost of materials and placement.

Another approach to water-based rock placement would be via a jack-up barge. This would only be applicable at the South Jetty. For armor stone and rock placement at the head, a jack-up barge with crane could be used to serve as a stable work platform (Figure 37). Once into place, the jack-up barge would be jacked up on six legs so that the deck is at the same elevation as the jetty. The legs are designed to use high-pressure water spray from the end of the legs to agitate the sand and sink the legs under their own weight. The jacking process does not use any lubricants that contain oils, grease, and/or other hydrocarbons. The stone and rock will be barged to the jack-up barge and offloaded onto the jetty head. The jack-up barge will keep moving around the head of the jetty to complete the work. A jack-up barge would not be used on the North Jetty or Jetty A to avoid interference with navigation of fishing boats and crab and fish migrations.

Figure 37. Illustration of a Jack-up Barge

For land-based rock placement, a crane or a large track-hoe excavator could be situated on top of the jetty. The placement operation would require construction of a haul road along the jetty crest within the proposed work area limits. The crane or excavator would use the haul road to move along the top of jetty. Rock would be supplied to the land-based placement operation by land and/or marine-based rock delivery. For marine-based rock, the land-based crane or excavator would pick up rock directly from the barge or from a site on the jetty where rock was previously offloaded and stockpiled, and then place the rock within the work area. For land-based rock, the crane or excavator would supply rock via a truck that transports rock from the stockpile area. The crane or excavator would advance along the top of the jetty via the haul road as the work is completed.

In order to place stones, a haul road will be constructed on the 30-ft crest width of each jetty to allow crane and construction vehicle access. Roads will consist of an additional 3-ft of top fill material, which could also entail an additional 2-ft of width spill-over. These roads will remain in place for the duration of construction. Due to ocean conditions and the wave environment, these roads will likely need yearly repair and replacement. They will not be removed upon completion. Ramps from the beach up to the jetty road will also be constructed to provide access at each jetty.

At approximately 1000-ft intervals, turnouts to allow equipment access and passage will be constructed on the North and South jetties. These will consist of 50-ft long sections that are an additional 20-ft wide. Some of this stone for these facilities may encroach below MLLW. On the North Jetty, there will be approximately 2 turnouts. South Jetty will have approximately 8 turnouts with two additional larger-sized turnouts. These larger turnouts will be in the range of 300-ft long with an additional 20-ft width. One of these larger turnouts will function as an offloading facility on South Jetty. At Jetty A, the causeway will function as the turnout facility.

Towards the head of each jetty, additional crane set up pads will be constructed at approximately 40-ft increment to allow crane operation during the placement of the larger capping stones. Set-up pads will roughly entail the addition of 8 extra feet on each side of the crest for a length of about 50-ft. Some of this stone for these facilities may encroach below MLLW. Approximately 5 set-up pads will be required to construct each jetty head.

Construction Staging, Storage, and Rock Stock Piles

Jetty repairs and associated construction elements entail additional footprints for activities involving equipment and supply staging and storage, parking areas, access roads, scales, general yard requirements, and rock stock pile areas. It was determined that for most efficient work flow and placement, a 2-year rock supply would be maintained on site and would be continuously replenished as placement occurred on each jetty. In order to estimate the area needed, a surrogate area was determined for a reference volume of 8,000 cy, which was then used to extrapolate the area needed at each jetty. These results are shown in Table 13.

Table 13. Acreages Needed for Construction Staging, Storage, and Rock Stock Piles

Location	Approximate Acres
North Jetty	31
Jetty A	23
South Jetty	44

Several actions will be taken to avoid and minimize impacts from these activities. Staging and stockpiles will remain above MHHW and where feasible have also been sited to avoid impacts to wetlands and habitats identified as having higher ecological value. In order to maintain erosive resilience along the shoreline, a vegetative buffer will be preserved. When available and possible, partial use will be made of existing parking lots. Additional measures specific to each jetty have also been considered. Besides access roads in the areas identified in Figures 33-35, no additional roadways or significant roadway improvements are anticipated. Some roadway repair and maintenance will likely be required on existing roads experiencing heavy use by the Corps.

At the North Jetty, the lagoon and wetland fill necessary for root stabilization will also serve a dual purpose as for the bulk of staging and storage activities.

At the South Jetty, a small spur road will be required to connect the existing road with the proposed staging area and is indicated in Figures 33-35. The existing road along the neck of the South Jetty that will be used for dune augmentation work may require minor repair/improvements for equipment access. Construction access to the area receiving dune augmentation will be limited to an existing access road along the relic jetty structures at the neck of the spit. Equipment will be precluded from delivery using the access point from Parking Lot B in order to avoid impacts to water quality and razor clam beds in the vicinity of the proposed dune fill area. Grading equipment may have to access the area by driving along the shore, but this route will be used as a last resort and equipment will be limited to dry sand where feasible. Additionally, the proposed actions will avoid the more sensitive habitat areas south of Parking Lot D.

If possible, the project will avoid and minimize impacts to the adjacent marshland by allowing crossing between the construction area and jetty via a Bailey bridge, which may require small removable abutments on either end of the marsh crossing. Otherwise a series of culverts and associated fill will be installed, or equipment will be required to enter and exit from the same access road on the northeast end of the main staging area indicated in Figures 33-35.

Additionally, at the outlet of the marsh complex a culvert will be installed under the construction access road, which will allow continuous hydrologic connectivity between affected portions of the marsh and ocean exchange through the jetty. This will also avoid equipment passage through marsh waters. To connect the staging area to the jetty haul road, a temporary gravel access road would be constructed from the staging area nearest the jetty to the jetty crest. The access road would measure approximately 400 ft in length by 25 ft in width, would be above MHHW, would require approximately 4,000 cy of sand, gravel and rip rap, and would require the installation and removal of a temporary culvert near station 178+00 to maintain tidal exchange into and out of the intertidal wetland and through the jetty. The staging areas and haul roads, except for the jetty haul road, would be removed and restored to pre-construction conditions once repairs to the jetty are completed.

Prior to in-water work for installing the construction access road and culverts across the southern portion of the marsh wetland outlet at the South Jetty, the Corps will conduct fish salvage and implement fish exclusion to and from the wetland complex upstream of the proposed culvert. Also, post-installation of the culvert, the Corps will develop and implement fish monitoring as necessary to ensure that no listed fish species are stranded. If listed fish species are found, NMFS will be contacted immediately to determine the appropriate course of action.

At Jetty A, adequate area may not be available for the estimated storage and staging needs. Therefore, construction sequencing will accommodate the supply that can be fit into the acreage available. Land-based delivery options may be precluded due to road access constraints, though some existing access may prove available and feasible depending on load and truck sizes.

The following measures will also be required at each location to further avoid and minimize impacts to species. Before significant alteration of the project area, the project boundaries will be flagged. Sensitive resource areas, including areas below ordinary high water, wetlands and trees to be protected will be flagged. Chain link fencing or something functionally equivalent will likely encircle much of the construction areas.

Temporary Erosion Controls

Temporary erosion controls will be in place before any significant alteration of the site. If necessary, all disturbed areas will be seeded and / or covered with coir fabric at completion of ground disturbance to provide immediate erosion control. Erosion control materials (and spill response kits) will remain on-site at all times during active construction and disturbance activities (e.g., silt fence, straw bales). If needed these measures will be maintained on the site until permanent ground cover or site landscaping is established and reasonable likelihood of erosion has passed. When permanent ground cover and landscaping is established, temporary erosion prevention and sediment control measures, pollution control measures and turbidity monitoring will be removed from the site, unless otherwise directed.

An Erosion Sediment and Pollution Control Plan (ESPCP) or Stormwater Pollution Prevention Plan (SWPPP), as applicable to each State, will outline facilities and Best Management Practices (BMPs) that will be implemented and installed prior to any ground disturbing activities on the project site, including mobilization. These erosion controls will prevent pollution caused by surveying or construction operations and ensure sediment-laden water or hazardous or toxic materials do not leave the project site, enter the Columbia River, or impact aquatic and terrestrial wildlife. The Corps retains a general 1200-CA permit from Oregon Department of Environmental Quality (DEQ), and will also work with EPA to obtain use of the NPDES General Permit for Stormwater Discharge from Construction Activities. At a minimum, these ESCP and SWPPP plans will include the following elements and considerations. Construction discharge water generated on-site (debris, nutrients, sediment and other pollutants) will be treated using the best available technology. Water quality treatments will be designed, installed, and maintained in accordance with manufacturer's recommendation and localized conditions. In addition, the straw wattles, sediment fences, graveled access points, and concrete washouts may be used to control sedimentation and construction discharge water. Construction waste material used or stored on-site will be confined, removed, and disposed of properly. No green concrete, cement grout silt, or sandblasting abrasive will be generated at the site.

Emergency Response

To avoid the need for emergency response a Corps' Government Quality Assurance Representative (GQAR) will be on-site or available by phone at all times throughout construction. Emergency erosion/pollution control equipment and best management practices will be on site at all times; Corps' staff will conduct inspections and ensure that a supply of sediment control materials (e.g., silt fence, straw bales), hazardous material containment booms and spill containment booms are available and accessible to facilitate the cleanup of hazardous material spills, if necessary.

Hazardous Materials

A description of any regulated or hazardous products or materials to be used for the project, including procedures for inventory, storage, handling and monitoring, will be kept on-site. Fuels or toxic materials associated with equipment will not be stored or transferred near the water, except in a confined barge. Equipment will be fueled and lubricated only in designated refueling areas at least 150 feet away from the MHHW, except in a confined barge.

Spill Containment and Control

A description of spill containment and control procedures will be on-site, including: notification to proper authorities, specific cleanup and disposal instructions for different products, quick response containment and cleanup measures that will be available on the site including a supply of sediment control materials, proposed methods for disposal of spilled materials, and employee training for spill containment. Generators, cranes, and any other stationary power equipment operated within 150-feet MHHW will be maintained as necessary to prevent leaks and spills from entering the water. Vehicles / equipment will be inspected daily for fluid leaks and cleaned as needed before leaving staging and storage area for operation within 150 feet of MHHW. Any leaks discovered will be repaired before the vehicle / equipment resumes service. Equipment used below MHHW will be cleaned before leaving the staging area, as often as necessary to remain grease-free. Additionally, the Corps proposes to use a Wiggins fast fuel system or equivalent to reduce leaks during fueling of cranes and other equipment in-place on the jetties (Figure 38). Also, spill pans will be mounted under the crane and monitored daily for leaks.

Water Quality Monitoring

In-water work will require turbidity monitoring that will be conducted in accordance with 401 Water Quality Certifications Conditions to ensure the project maintains compliance with State water quality standards. Turbidity exceedences are expected to be minimal due to the large size of stone being placed. Dynamic conditions at the jetties in the immediate action area preclude the effective use of floating turbidity curtains (or approved equal). Sedimentation and migration of turbid water into the Columbia is not expected to be a significant issue. Best management practices will be used to minimize turbidity during in-water work. Turbidity monitoring will be conducted and recorded each day during daylight hours when in-water work is conducted. Representative background samples will be taken according to the schedule set by the resource agencies at an undisturbed area up-current from in-water work. Compliance samples will be taken on the same schedule, coincident with timing of background sampling, down-current from in-water work. Compliance sample will be compared to background levels during each monitoring interval. Additional 401 Water Quality Certification conditions and protocols may be required.

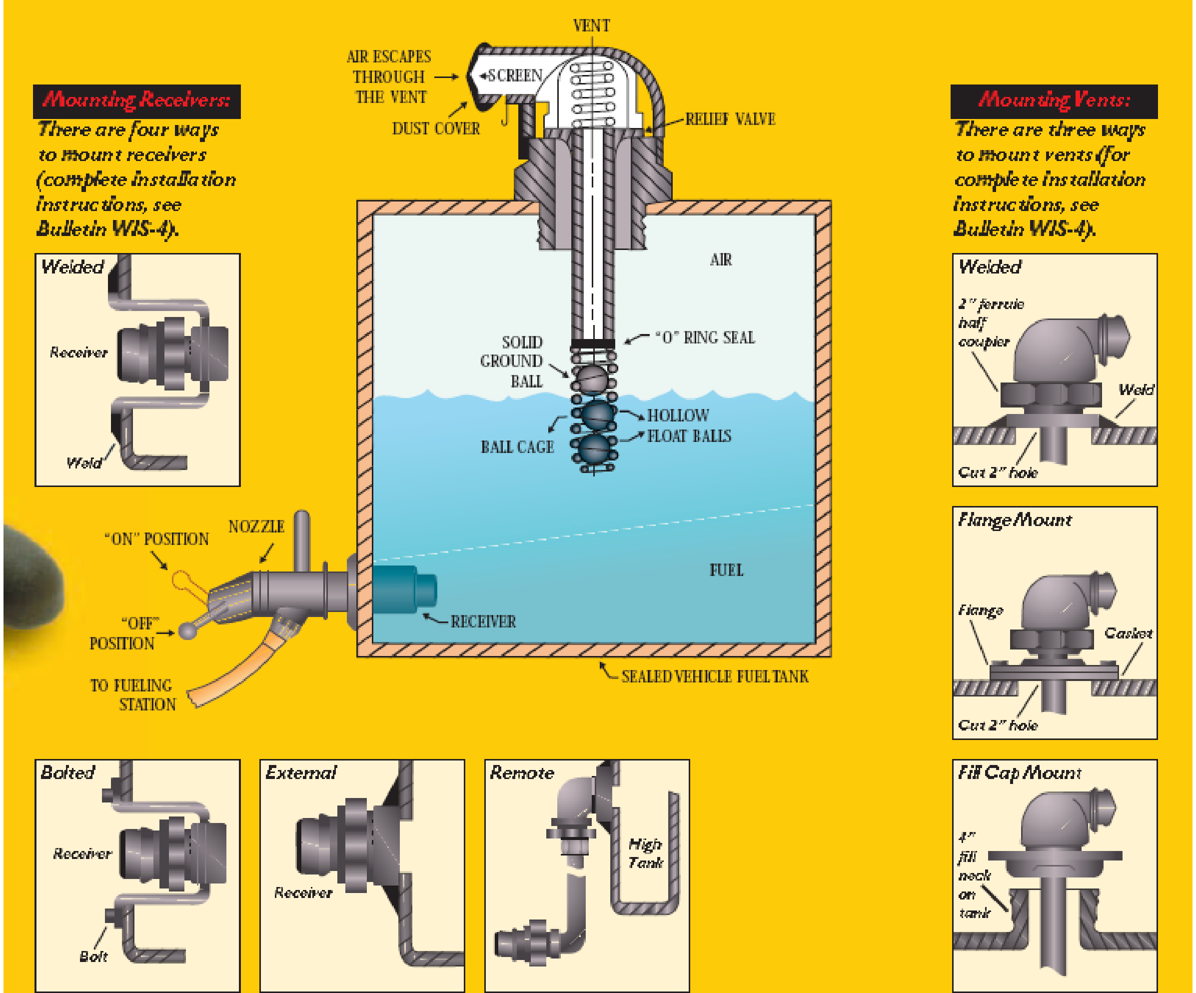
Figure 38. Fast Fuel System

Wiggins Service Systems

How It Works

The Wiggins "fast fuel" System is based on the simple concept of using a sealed vehicle tank to allow a small amount of back pressure to build up and automatically shut off the nozzle. A receiver is mounted on the tank, located near the bottom. Bottom filling helps eliminate foaming which can occur during top fueling "splash fill".

The Wiggins ZZ9A1 nozzle is attached to the receiver, the handle is turned to the "ON" position, and fuel begins to fill the fuel tank at a rate up to 150 gallons per minute. As fuel enters the tank, it forces the air inside the tank to exit through the Wiggins vent. When the fuel level nears the top of the tank, the "hollow floating balls" force the third "solid ball" to seal against the vent "stem", sealing the tank and stopping the air flow out of the tank. As fuel continues to flow, pressure inside the tank builds until it reaches 8 to 10 PSIG. At 8 to 10 PSIG, the nozzle automatically shuts off. The nozzle shut off is gradual, preventing a hammer effect which could damage the fuel line. The nozzle can then be removed, and is ready to fuel the next vehicle!



WETLAND MITIGATION AND HABITAT IMPROVEMENTS

The selected plan design and construction methods for repair and rehabilitation of the MCR jetties have been developed and refined to take advantage of opportunities to avoid and minimize the project's ecological impacts to habitats and species. As required under the Clean Water Act, the Corps will mitigate for impacts to wetlands which could not be otherwise avoided or minimized. The Corps has also incorporated habitat improvements into the proposed action to assist with the recovery of ESA-listed salmonid habitats and ecosystem functions and processes. These actions are not proposed to directly mitigate or compensate for any Project-related impacts to ESA-listed salmonids. The habitat improvement components of the overall ecosystem restoration action are proposed as Conservation Measures under Section 7(a) (1) of the ESA and have been included into the proposed action by the Corps. These actions are the Corps' affirmative commitment to fulfill responsibility to assist with conservation and recovery of ESA-listed salmonids.

Habitat improvement features will be designed to create or improve salmonid habitat, specifically tidal marsh, swamp, and shallow water and flats habitat, and to improve fish access to these habitat features. In addition, one of the features would create habitat for snowy plover. Habitat improvement and wetland mitigation plans currently address three general categories: actions that create, improve, and restore wetlands, actions that improve in-water habitats, and actions that restore upland habitats. From the list of possible wetland mitigation and habitat improvement features shown in Table 14, one or a combination of projects will be selected for further development and implementation. Selection will occur with input from the AMT and work is anticipated to be completed concurrent with jetty repair actions.

Table 14. Possible Wetland Mitigation and Habitat Improvement Features

Feature/Site	Area Affected	Type and Function
Trestle Bay	5-8 acres with potential of additional acres	Estuarine Saltwater Marsh Wetland and Intertidal Mudflat Creation and Restoration • Create and expand estuarine intertidal brackish saltwater marsh wetland habitat. • Expand and restore Lyngby sedge plant community. • Expand/increase intertidal shallow water habitat, including dendritic mud flats and off-channel habitat. • Remove and control invasive species and improve/restore diversity and density of native plant assemblages. • Increase habitat complexity for fisheries benefit. • Potentially expand floodplain terrace and improve riparian function. • (Re)introduce natural tidal disturbance regime to area currently upland dunes.
Walooskee to Youngs Bay	~151 acres	Levee Breach for Estuarine Emergent Wetland and Brackish Intertidal Shallow-water Habitat Restoration • Restore connection between Walooskee and Youngs River via levee breach. • Restore and expand estuarine intertidal brackish marsh wetland habitat. • Expand and restore Lyngby sedge and native estuarine vegetation community to improve trophic foodweb functions. • Restore and expand brackish intertidal shallow water habitat including dendritic mud flats and off-channel edge habitat. • Remove and control invasive species and improve/restore diversity and density of native plant assemblages. • Increase habitat access and complexity for fisheries benefit including expanded foraging, rearing, and refugia habitat types. • Improve riparian function. • Potentially restore floodplain terrace and increase flood storage capacity. • (Re)introduce natural tidal disturbance regime to area currently diked pasture land. • Restore hydrologic regime and restore/improve water quality function. • Improve capacity for additional carbon sequestration via native root masses. • Increase and restore hyporheic functions for improved water quality and potential creation of cold water refugia.
Walooskee to Youngs Bay	~39 acres	Levee Breach and/or Tide Gate Retrofits for Emergent Wetland and Intertidal Shallow-water Habitat Restoration • Restore connection with Walooskee River via levee breach and/or tide gate retrofits. • Restore and expand intertidal marsh wetland habitat. • Expand and restore native vegetation community to improve trophic foodweb functions. • Restore and expand intertidal shallow water habitat including dendritic and off-channel edge habitat. • Remove and control invasive species and improve/restore diversity and density of native plant assemblages. • Increase habitat access and complexity for fisheries benefit including expanded foraging, rearing, and refugia habitat types. • Improve riparian function. • Potentially restore floodplain terrace and increase flood storage capacity. • Restore hydrologic and natural tidal disturbance regime and restore/improve water quality function to area currently functioning as diked pasture land. • Improve capacity for additional carbon sequestration via native root masses. • Increase and restore hyporheic functions for improved water quality and potential creation of cold water refugia.
Slough to Youngs River	~250-500 acres	Levee Breach for Estuarine Wetland and Intertidal Restoration • Restore connection between Slough and Youngs River via levee breach. • Restore and expand estuarine intertidal brackish marsh wetland habitat. • Expand and restore Lyngby sedge and native estuarine vegetation community to improve trophic foodweb functions. • Restore and expand brackish intertidal shallow water habitat including dendritic mud flats and off-channel edge habitat.

Feature/Site	Area Affected	Type and Function
		• Remove and control invasive species and improve/restore diversity and density of native plant assemblages. • Increase habitat access and complexity for fisheries benefit including expanded foraging, rearing, and refugia habitat types. • Improve riparian function. • Potentially restore floodplain terrace and increase flood storage capacity. • Restore hydrologic and natural tidal disturbance regimes to an area currently functioning as diked pasture land. • Improve capacity for additional carbon sequestration via native root masses. • Increase and restore hyporheic functions for improved water quality and potential creation of cold water refugia.
Youngs River - Diked Farmland, Freshwater Intertidal Restoration	45-50 acres With potential up to 80 acres	Levee Breach for Wetland and Intertidal Restoration • Restore connection with Youngs River via levee breach. • Restore and expand freshwater intertidal wetland habitat. • Expand and restore native vegetation community to improve trophic foodweb functions. • Restore and expand intertidal shallow water habitat including dendritic mud flats and off-channel edge habitat. • Remove and control invasive species and improve/restore diversity and density of native plant assemblages. • Increase habitat access and complexity for fisheries benefit including expanded foraging, rearing, and refugia habitat types. • Improve riparian function. • Potentially restore floodplain terrace and increase flood storage capacity. • (Re)introduce natural tidal disturbance regime to area currently diked pasture land. • Restore hydrologic regime and restore/improve water quality function. • Increase and restore hyporheic functions for improved water quality and potential creation of cold water refugia.
Tributary Cr. to Youngs River	~5 or more acres	Estuarine Wetland and Intertidal Restoration; Tributary Reconnection to Youngs Bay • Convert diked pasture land to brackish estuarine wetland and shallow water intertidal habitat. • Improve and restore hydrologic regime and increase regular hydrologic connectivity between Crosel Cr. And Youngs Bay estuary. • Improve and restore fish passage and provide access throughout greater range of flows to off-channel juvenile rearing, refuge and foraging habitats. • Remove and control invasive species and improve/restore diversity and density of native plant assemblages. • Increase habitat complexity for fisheries benefit. • Improve adult salmonid access to headwaters and potential spawning habitat. • Potentially expand floodplain terrace and improve riparian function. • (Re)introduce natural flow regime and tidal disturbance regime to area currently functioning as pasture land.
Tributary Cr. and Slough to the Columbia River - near Clatskanie	Up to ~43 acres	Levee Breach and/or Tide Gate Retrofits for Emergent Wetland and Intertidal Shallow-water Habitat Restoration and Tributary Reconnection • Restore connection between Tandy and Graham creeks and Westport Slough and Columbia River via levee breach and/or tide gate retrofits. • Restore and expand intertidal wetland habitat. • Expand and restore native vegetation community to improve trophic foodweb functions. • Restore and expand intertidal shallow water habitat including dendritic and off-channel edge habitat. • Remove and control invasive species and improve/restore diversity and density of native plant assemblages. • Increase habitat access and complexity for fisheries benefit including expanded foraging, rearing, and refugia habitat types. • Improve riparian function. • Potentially restore floodplain terrace and increase flood storage capacity. • Restore hydrologic and natural tidal disturbance regime and restore/improve water quality function to area currently functioning as diked pasture hayfields.

Feature/Site	Area Affected	Type and Function
		• Improve capacity for additional carbon sequestration via native root masses. • Increase and restore hyporheic functions for improved water quality and potential creation of cold water refugia. • Improve adult salmonid access to headwaters and potential spawning habitat.
Knappa - Warren Slough	~100 or more acres	Preservation and Expansion of Estuarine Intertidal Restoration; Improve Tributary Reconnection for Fish Passage • Maintain and enhance evolving restoration that has occurred since inundation of previously diked pasture land to estuarine wetland and shallow intertidal habitat. Maintain restored ecosystem function and intertidal shallow water habitat established post-breach. • Maintain and enhance restored hydrologic regime and increase regular hydrologic connectivity between Hall Cr. and Warren Slough. • Maintain and improve existing fish passage and provide access throughout greater range of flows to off-channel juvenile rearing, refuge and foraging habitat types. • Maintain and increase habitat complexity for fisheries benefit. • Improve adult salmonid access to headwaters and potential spawning habitat. • Remove and control invasive species and improve/restore diversity and density of native plant assemblages; Improve riparian function as appropriate. • Potentially expand floodplain terrace. • Maintain restored natural tidal disturbance regime, dendritic channels, and connection between Hall Cr. and Warren Slough.
Snowy Plover Work on Clatsop Spit	Up to ~22 acres	Forego Revegetation and Convert Upland Areas to Snowy Plover Habitat • Convert upland scrub-shrub habitat with invasive species to snowy plover habitat via periodic tilling and application of shell hash.
Wetland Creation at Cape Disappointment	Up to ~10 acres	Creation and Expansion of Interdunal Wetland Complex • Excavation of new interdunal wetlands adjacent to existing wetlands. • Establishment of native wetland plant communities and removal of invasive species around a buffer zone. • Restoration or provision of hydrology to newly excavated wetlands via appropriate elevation design. • Restoration of wetland connectivity between existing fragmented wetlands via culvert retrofits, if feasible.
Tide Gate Retrofits for Salmonid Passage	Variable	Select Tributaries from ODFW Priority Culvert Repair List - Tributary Reconnection • Restore and improve existing fish passage and provide access throughout greater range of flows to off-channel juvenile rearing, refuge and foraging habitat types. • Restore and increase habitat complexity for fisheries benefit. • Restore and improve adult salmonid access to headwaters and potential spawning habitat.

Wetlands and shallow-water habitat will be filled and converted as a result of the project. Official wetland delineations have not yet been completed for all three of the jetties. However, available preliminary information has allowed the Project Delivery Team (PDT) to site construction activities and features to reduce anticipated impact to wetlands. This information has also been used to calculate initial estimates regarding the possible acreage of impacts. The approximated acreages identified as potentially impacted are North Jetty ~4.78, South Jetty up to ~22 and Jetty A up to ~11. This comes to an estimated total of ~38.28 acres of potential wetlands impacts. To reiterate, official delineations must be completed, and these numbers will be revised accordingly after report results and project design details are further developed and available. These estimates are on the conservatively high end of what final wetland impacts will likely be.

In-water habitats, both shallow intertidal and deeper subtidal areas will also be affected by the project. Habitat conversions will occur from maintenance dredging and placement of the spur groins, jetty cross-sections, turnouts, barge offloading facilities, and causeways. There will also be permanent lagoon fill at the North Jetty root. Without drawing a distinction between depths, initial acreage estimates for all in-water impacts include North Jetty ~11.75, South Jetty ~21.2, and Jetty A ~7.23. This comes to an approximated total of ~40.18 acres of potential in-water conversions. Shallow-water habitat is especially important to several species in the estuary; therefore, specific initial estimates were also calculated regarding shallow-water habitat (shallow here defined as -20-ft or -23-ft below MLLW). About 30 acres (out of the ~40 mentioned above) of area at these depths will be affected by groins, maintenance dredging, and construction of the causeways and barge offloading facilities. However, this estimate does NOT including any expansion of the jetty's existing footprint or overwater structures from barge offloading facilities. The approximate acreage breakdowns entail: spur groin fill = 1.56 (shallow defined as -20-ft or less below MLLW; ~3.26 total area including all depths); dredge for barges ~20, likely all shallow (less than -23-ft deep below MLLW); and causeway fill~ 7, likely all shallow (less than -23 ft deep below MLLW). For this analysis, there was no distinction drawn between periodically exposed intertidal habitat and shallow-water sandflat habitat. As with wetland estimates, these approximations will be updated as project designs are refined and as additional analyses and surveys are completed to quantify changes in jetty and dune cross sections.

Ultimately the project seeks to achieve no net loss in wetland habitat, to protect, improve and restore overall ecosystem functions, and to provide actions that are anticipated to benefit listed species in the vicinity of the project. Towards that end, specific project footprints and activities described above have been identified, categorized, and quantified with conservative estimates where appropriate. The calculated extents were strictly based on the area of habitat that was converted. They did not include value or functional assignments regarding the significance of the conversion, whether it was a beneficial, neutral, or detrimental effect, nor if conversions created unforeseen, indirect far-field effects. For example, acreage of conversion for shallow sandy sub-tidal habitat to rocky sub-tidal habitat was calculated in the same manner as conversion from shallow intertidal habitat to shallow sub-tidal habitat. Per initial consultation with resource agencies, a preliminary suggested ratio of 2:1 for wetland mitigation will likely be required. This is described in Table 15. These estimated footprints will likely change slightly during final design and after updated wetland delineations are completed.

Table 15. Maximum Estimated Acreages for Habitat Improvement and Wetland Mitigation

Jetty	Wetland	In-water	Upland Replanting
North Jetty Total	9.56	--	--
South Jetty Total	44.00	--	--
Jetty A Total	23.00	--	--
TOTAL Wetland and Habitat Improvements	76.56	60.00	55.00

Specific opportunities have been identified in the Columbia River estuary and Youngs Bay (see Table 14) and are under consideration to improve and restore functions affected in each of the generalized habitat categories (wetland, in-water, and upland). Depending on further development of wetland mitigation and habitat improvement alternatives, a specific project or combination of projects will be designed and constructed concurrently as the proposed repair and rehabilitation options are completed over time. Mitigation actions and extents will be commensurate with wetland impacts and ratios identified. Proposed projects are subject to further analysis, and unforeseen circumstances may preclude further development of any specific project. In all cases, final selection, design, and completion of specific improvement features is contingent on evolving factors and further analyses including hydraulic and hydrologic conditions, real estate actions, cultural resource issues, etc. For this reason a suite of potential proposals has been identified, and subsequent selection of one or some combination of projects and designs will occur during continued discussion with resource agencies participating on the Adaptive Management Team. These wetland mitigation and habitat improvement measures will therefore require additional Consultations, and it is anticipated that the AMT will facilitate in this process. It is also anticipated that a programmatic Opinion similar to SLOPES or Limit 8 may be useful to fulfill clearance requirements.

Actions adjacent to or onsite in the vicinity of the North and South Jetties that could potentially mitigate wetland impacts include: excavation of low and high saltwater marsh wetlands and new interdunal wetlands adjacent to existing wetlands; establishment of native wetland plant communities and removal of invasive species around a buffer zone for wetlands; restoration or provision of hydrology to newly excavated wetlands via appropriate elevation design; and/or restoration of wetland connectivity between existing fragmented wetlands. Offsite opportunities for wetland mitigation in the estuary that warrant further investigation are associated with: levee breaches, inlet improvements, or tide gate retrofits, as appropriate. Purchasing mitigation bank credits may be a possibility, though this is currently constrained by limitations of service area and availability of appropriate wetland types. However, private farmlands behind existing levees may provide wetland mitigation opportunities to pursue further. Hydrology and vegetative communities are heavily influenced by elevation; therefore providing improved hydrology combined with strategic excavation and appropriate plantings should result in a simple and self-sustaining design and outcome.

Actions to provide benefits and improvements to in-water habitat include the following opportunities: levee breaches, inlet improvements, or tide gate retrofits, as appropriate. Additional associated actions include: excavation in sand dunes and uplands to specified design elevations in order to create additional intertidal shallow water habitat with dendritic channels and mud flats, and excavation for potential expansion of the floodplain terraces. Though conceptually considered, specific opportunities for additional projects such as the following were not identified but could warrant further investigation if none of the projects in the list is determined to be feasible: removal of overwater structures and fill in the estuary; removal of relic pile-dike fields; removal of fill from Trestle Bay or elsewhere; removal of shoreline erosion control structures and replacement with bioengineering features; beneficial use of dredge material to create ecosystem restoration features (Lois Island Embayment is an example from Columbia River Channel Improvement that may be applicable here); and restoration of eelgrass beds. Certain pile fields and engineering features may be providing current habitat benefits that could be lost with removal, and such actions would require appropriate hydraulic analysis coordination with engineers and resource agencies.

For potential habitat improvement projects located in Trestle Bay, there is additional monitoring and assessment opportunity. A separate hydraulic/engineering study should investigate whether or not an expansion of low-energy, intertidal habitat near Swash Lake could effectively provide additional storage capacity and affect circulation in the Bay such that erosive pressure at neck of Clatsop Spit could be reduced. The previous 1135 action which breached a section of the relic jetty structure is speculated to have been the cause of increased circulation and erosion. It would be worth evaluating whether or not projects that expand floodplain and intertidal areas in the Bay provide significant energy dissipation and additional low-energy storage capacity to offset or redirect erosive pressures. Alternatively, if other habitat improvement concepts are pursued that include removal of additional piles or creation of additional inlets; it would be worth investigating whether these actions could have indirect positive impacts that further reduce concern with erosion at the neck. Evaluating actions in this light would provide valuable information and insight regarding possible solutions and concerns for erosion and breaching at the neck area of Clatsop Spit on Trestle Bay.

Post-construction upland restoration would include the following actions: re-establishing native grasses, shrubs, and trees where appropriate; controlling and removing invasive species like scotch broom and European beach grass in the project vicinity; and re-grading/tilling the area to restore natural contours. Oregon Parks and Recreation Department has requested that the Corps utilize the State Forester as one resource for determining optimal revegetation plans.

On the Clatsop Spit there is also a unique opportunity to partner with U.S. Fish and Wildlife and Oregon Parks and Recreation Department (OPRD) regarding creation and management of snowy plover habitat on the Spit. This would be an alternative to re-vegetative restoration of the uplands. The OPRD is currently developing a Habitat Conservation Plan in the area to address snowy plover habitat management prior to an anticipated designation of Critical Habitat by US Fish and Wildlife. There may be locations in the vicinity and away from projected construction and staging areas to convert upland habitat to snowy plover habitat via invasive species removal, tilling, and application of shell hash. Ongoing operation and maintenance during the project via regular tilling and shell hash distribution could possibly be coordinated between the agencies through a vehicle such as a Memorandum of Agreement or similar avenue.

Refinement and implementation of this wetland mitigation and habitat improvement plan will help protect species and habitats while restoring wetland functions affected by the MCR project.

Monitoring and maintenance of wetland mitigation and habitat improvement actions will likely be required to ensure successful establishment of goals and satisfactory return on investment. Regular coordination with the AMT will further facilitate selection and implementation of wetland mitigation and habitat improvement actions that appropriately meet the framework for successful restoration, protection, and preservation of ESA listed species and high-value habitat.

ADDITIONAL CONSERVATION MEASURES

In addition to standard environmental protection measures to be included in the contract specifications, measures 1, 2, and 3 will be employed during the marbled murrelet nesting season (April 1 – September 15) to reduce impacts from noise to nesting marbled murrelets on the Washington side, and measure 4 will be considered to create western snowy plover nesting habitat:

1. Trucks will only be allowed to use the roads through Cape Disappointment State Park during daylight hours.

2. Trucks will not unnecessarily stop along the roads through Cape Disappointment State Park.

3. Trucks will be prohibited from using compression brakes (also known as jake brakes) on the roads through Cape Disappointment State Park.

4. The Corps is currently investigating opportunities to create western snowy plover nesting habitat on Clatsop Spit, Oregon within Fort Stevens State Park. Since rock could be stored on Clatsop Spit for years, the Corps will consider creation of habitat after use of the spit for rock storage is complete to avoid potential limitations to rock storage and transport on the spit if plovers begin to nest. The Corps will also consider options to create plover habitat concurrently with rock storage if it is certain that plover use of the created habitats and beaches would not interfere with the Corps' ability to use Clatsop Spit throughout the life of the project. Habitat maintenance each year after creation would be required to provide functional habitat, but maintenance would not be the responsibility of the Corps. Habitat creation work would be conducted under 7(a) (1) authority of the ESA. The Corps has had initial discussions with the Oregon Department of Parks and Recreation regarding plover habitat creation.

ACTION AREA

"Action area" means all areas to be affected directly or indirectly by the federal action and not merely the immediate area involved in the action (50 CFR 402.02). For this consultation, the action area includes (see Figure 1): (1) an area extending 10 miles offshore from Columbia River mile -1; (2) extending 5 miles north and 5 miles south of river mile -1, including all terrestrial habitats; (3) extending upstream as far as the Astoria-Megler Bridge, river mile 13.5; and (4) all areas where quarried stone will be transported, including offshore and inland navigation channels, existing roadways and/or rail routes in the Pacific ocean or along inland transportation routes extending as far north as Vancouver B.C. in the Puget Sound, and as far south as Eureka, and Humbolt Bay, California. See Figures 28-32 for possible route illustrations.

The sixth field HUCs in the vicinity of the MCR include: Baker Bay-Columbia River – 1708000605; Necanicum River-Frontal Pacific Ocean – 1710020101; Youngs River-Frontal Columbia River – 1708000602; Long Beach-Frontal Pacific Ocean – 1710010607 and Wallacut River-Frontal Columbia River – 1708000604.

Federally listed fish, bird, plant, invertebrate, mammal, and turtle species and their critical habitat may be present in the action area (Table 16).

Transportation of rock from Canada, California, the Puget Sound and in-between sources will occur in navigation channels and along existing truck or rail routes through or adjacent to areas where additional listed inland terrestrial species and their critical habitat may occur. However, barge traffic is not expected to encounter these species and therefore will not affect their behaviors or habitats. Truck traffic in the vicinity of the MCR jetties, rather than along existing haul routes, has a higher likelihood of encountering such species and possible effects are discussed further. Therefore, it is anticipated that the rock transport outside the vicinity of the MCR jetty system as described above will have no effect on listed species or their critical habitat; therefore, only the species described below have been included further in this effects analysis.

Table 16. Federal Register Notices for Final Rules that List Threatened and Endangered Species, Designate Critical Habitats, or Apply Protective Regulations to Species under Consideration

Listing status: 'T' means listed as threatened under the ESA; 'E' means listed as endangered; 'P' means proposed.

Species	Listing Status	Critical Habitat
Birds		
Marbled Murrelet *(Brachyramphus marmoratus)* **T**		
Oregon, Washington, and California Populations	10/01/92; 57:FR 45328; 2/11/09 74 FR 6852	05/24/96; 61 FR 26255; 02/11/09; 74 FR 6852
Western Snowy Plover *(Charadrius alexandrinus nivosus)* **T**	3/05/93; 58 FR 12864	09/29/05; 70 FR 56969
Short-tailed Albatross *(Phoebastria albatrus)* **E**	7/31/00; 65 FR 46643	Not applicable
Northern Spotted Owl *(Strix occidentalis caurina)* **T**	6/26/90; 55 FR 26114	1/15/92; 57 FR 1796; 08/13/08 73 FR 47325
Mammals		
Columbian White-tailed Deer *(Odocoileus virginianus leucurus)* **E**		
Columbia River Population	03/11/67; 68 FR 43647	Not applicable
Fish		
Bull Trout *(Salvelinus confluentus)* **T**		
Columbia DPS	06/10/98; 63 FR 31647	10/18/10 75 FR 63897
Invertebrates		
Oregon Silverspot Butterfly *(Speyeria zerene hippolyta)* **T**	07/02/80; 45 FR 44935	07/02/80; 45 FR 44935
Plants		
Nelson's Checker-mallow *(Sidalcea nelsoniana)* **T**	02/12/93; 58 FR 8235	Not applicable
Reptiles and Amphibians		
Green turtle (*Chelonia mydas*) **E, T**		
Excludes Pacific Coast of Mexico & FL	7/28/78; 43 FR 32800	9/02/98; 63 FR 46693
Leatherback turtle (*Dermochelys coriacea*) **E**	6/02/70 ; 39 FR 19320	1/5/10; 75FR319;
Loggerhead turtle (*Caretta caretta*) **T**	7/28/78; 43 FR 32800	Not applicable
Olive ridley turtle (*Lepidochelys olivacea*) **E, T**	7/28/78; 43 FR 32800	Not applicable

ENDANGERED SPECIES ACT ENVIRONMENTAL ASSESSMENT

INTRODUCTION

The summaries that follow describe the status of the ESA-listed species, and their designated critical habitats, that occur within the geographic area of this proposed action and are considered in this Assessment. More detailed information on the status and trends of these listed resources, and their biology and ecology can be found in the listing regulations and critical habitat designations published in the Federal Register (see Table 16) and in many publications available from the USFW Washington and Oregon Offices and the NMFS Northwest Region, Protected Resources Division in Portland, Oregon.

It is likely that climate change will play an increasingly important role in determining the abundance of ESA-listed species, and the conservation value of designated critical habitats, in the Pacific Northwest. During the last century, average regional air temperatures increased by 1.5°F, and increased up to 4°F in some areas (USGCRP 2009). Warming is likely to continue during the next century as average temperatures increase another 3° to 10°F (USGCRP 2009). Overall, about one-third of the current cold-water fish habitat in the Pacific Northwest is likely to exceed key water temperature thresholds by the end of this century (USGCRP 2009).

Precipitation trends during the next century are less certain than for temperature, but more precipitation is likely to occur during October through March, and less during the summer; and more of the winter precipitation is likely to fall as rain rather than snow (ISAB 2007, USGCRP 2009). Where snow occurs, a warmer climate will cause earlier runoff so stream flows in late spring, summer, and fall will be lower and water temperatures warmer (ISAB 2007, USGCRP 2009).

The earth’s oceans are also warming, with considerable inter-annual and inter-decadal variability superimposed on the longer-term trend (Bindoff et al. 2007). Historically, warm periods in the coastal Pacific Ocean have coincided with relatively low abundances of salmon and steelhead, while cooler ocean periods have coincided with relatively high abundances (Scheuerell and Williams 2005, Zabel et al. 2006, USGCRP 2009). Ocean conditions adverse to salmon and steelhead may be more likely under a warming climate (Zabel et al. 2006).

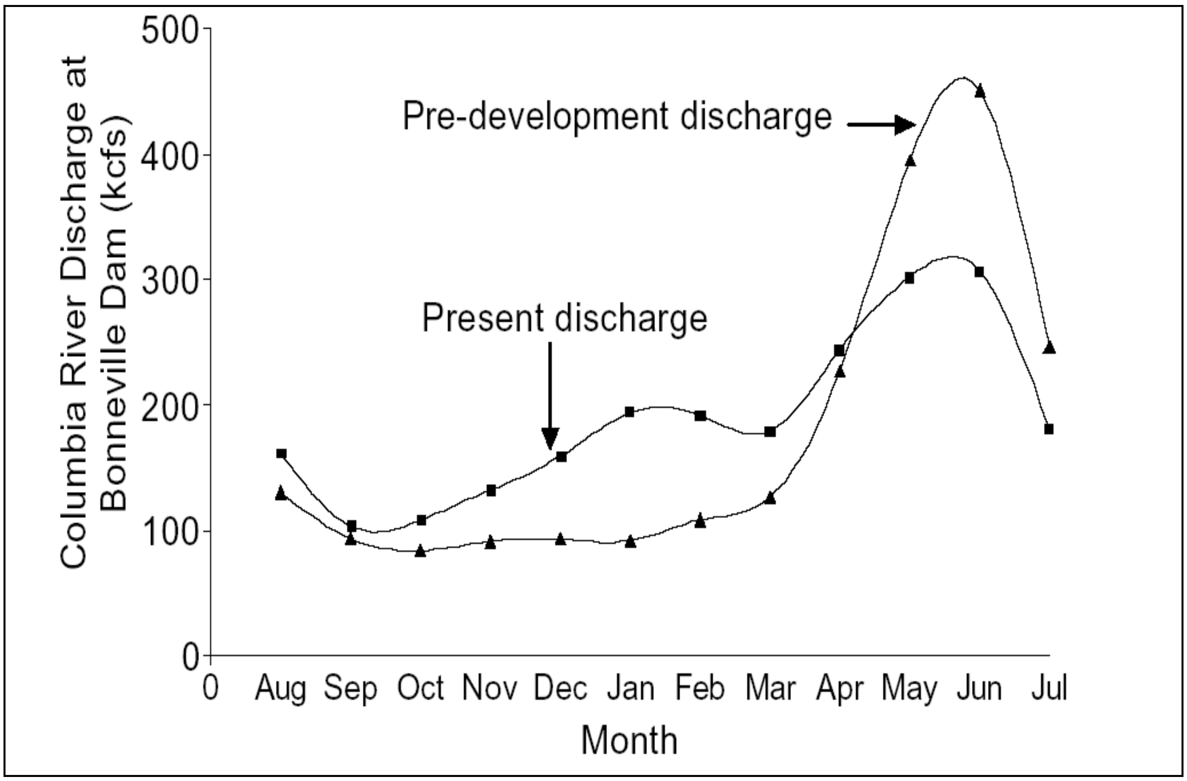
ENVIRONMENTAL BASELINE

The environmental baseline includes the past and present impacts of all Federal, State, or private actions and other human activities in the action area, the anticipated impacts of all proposed Federal projects in the action area that have already undergone formal or early section 7 consultation, and the impact of State or private actions which are contemporaneous with the consultation in process (50 CFR 402.02).

Overview

The Columbia River drains an area of 259,000 square miles and flows 1,243 miles from its headwaters in the Canadian Rockies of British Columbia, across the state of Washington, and along the border of Washington and Oregon to its mouth on the Pacific Ocean near Astoria, Oregon. The lower Columbia River extends from Bonneville Dam (RM 146) to the mouth of the Columbia River. Historically, unregulated discharges at the mouth ranged from 79,000 cubic feet per second (cfs) to over 1 million cfs, with average discharges of 273,000 cfs (Figure 39). Currently, discharge at the mouth of the river ranges from 100,000 to 500,000 cfs, with an average of about 260,000 cfs.

Figure 39. Annual Monthly River Discharge at Bonneville Dam under Current Operations as Compared to Historical River Discharge with No Mainstem Dams



Source: Corps Portland District

Highest discharges occur between December and March. Stream discharge in the lower Columbia River is influenced by snowmelt, winter rainstorms, and dam regulation. Stream discharge peaks generally occur during April through June. Local flooding in the lower Columbia River now begins when stream discharge reaches about 450,000 cfs, while the unregulated peak discharge would have been 602,000 cfs. Low stream flow generally occurs between August and October.

Discharge and sediment load have been altered by construction of 31 irrigation and hydropower dams, and 162 smaller dams, in the basin since 1890. Before 1890, the Columbia River estuary had extensive sand beds and variable river discharges. However, the construction of upriver hydroelectric dams has dramatically changed the nature of the estuary, as these dams have translated into different discharge rates and sediment discharges. Moreover, channel deepening, use of jetties and dredging to stabilize channels, development of perennial wetland areas, and isolation of remaining wetlands from the mainstem river have altered the physical character of the estuary; these changes have affected the biological systems supported by the estuary.

Physical Characteristics

The Columbia River estuarine environment extends from the mouth to approximately RM 38. The river varies from 2 to 5 miles wide throughout the estuary and is about 1 mile wide at RM 30. Tidal effect extends almost 150 miles upstream (Corps 1983), but the saltwater wedge is limited to approximately RM 20 (Corps 1999). The North and South jetties and Jetty A were constructed at the mouth to help stabilize the channel, reduce the need for dredging, and provide protection for ships. A series of pile dikes were also historically constructed for similar reasons. The navigation channel is currently maintained at authorized depths of 48-55 feet deep below MLLW and 0.5-mile wide from RM -3 to RM 3. River flows are controlled by upstream storage dams. A dredged material disposal site near the North Jetty was established in 1999 to protect the North Jetty from erosion. About 100,000 to 500,000 cubic yards of sand are placed there annually. The MCR Shallow Water Site (SWS), Deep Water Site (DWS), and Chinook Channel Area D Sites are also active disposal locations within the action area but offshore and upstream of MCR, respectively. Historic disposal sites no longer active within vicinity of the jetties include Site E located within the expanded SWS and sites A, B, and F, which are in deeper water but still shoreward of the active DWS.

The Corps regularly conducts operations and maintenance activities to maintain the jetty system and the authorized navigation channels and facilities. In the action area, there are several turning and mooring basins and federally authorized periodically dredged channels extending to various ports from the navigation channel. The Columbia River Channel Improvements Project was recently completed and deepened the navigation channel 3 feet from approximately RM 3-104.

Waves, Currents, and Morphology

The MCR is a high energy environment. The ocean entrance at the MCR is characterized by large waves and strong currents interacting with spatially variable bathymetry. The MCR is considered one of the world's most dangerous coastal inlets for navigation. Approximately 70% of all waves approaching the MCR are from the west-northwest. During winter storm conditions, the ocean offshore of the jettied river entrance is characterized by high swells approaching from the northwest to southwest combined with locally generated wind waves from the south to southwest. From October to April, average offshore wave height and period is 9 feet and 12 seconds, respectively. From May to September, average offshore wave height and period is 5 feet and 9 seconds, respectively, and waves approach mostly from the west-northwest. Occasional summer storms produce waves approaching MCR from the south-southwest with wave heights of 6.5 to 13 feet and wave periods of 7 to 12 seconds. Astronomical tides at MCR are mixed semi-diurnal with a diurnal range of 7.5 feet. The instantaneous flow rate of estuarine water through the MCR inlet during ebb tide can reach 1.8 million cfs. Tidally dominated currents within the MCR can exceed 8.2 feet per second. A large, clockwise-rotating eddy current has been observed to form between the North Jetty, the navigation channel, and Jetty A during ebb tide. A less pronounced counter-clockwise eddy forms in response to flood tide. Horizontal circulation in the estuary is generally clockwise (when viewed from above), with incoming ocean waters moving upstream in the northern portion of the estuary and river waters moving downstream in the southern portion. Vertical circulation is variable, reflecting the complex interaction of tides with river flows and bottom topography and roughness (Corps 1983). The North Jetty eddy has varying strength and direction (based on location and timing of tide) ranging from 0.3 to 3.3 feet per second.

As waves propagate shoreward toward the mouth of the Columbia River, the waves are modified (waves begin to shoal and refract) by the asymmetry of the mouth of the Columbia River underwater morphology. Nearshore currents and tidal currents are also modified by the jetties and the mouth of the Columbia River morphology. These modified currents interact with the shoaling waves to produce a complex and agitated wave environment within the mouth of the Columbia River. The asymmetric configuration of the mouth of the Columbia River and its morphology is characterized by the significant offshore extent of Peacock Spit on the north side of the North Jetty, southwesterly alignment of the North/South jetties and channel, and the absence of a large shoal on the south side of the mouth of the Columbia River. The asymmetry of the mouth of the Columbia River causes incoming waves to be focused onto areas which would not otherwise be exposed to direct wave action. An example of this wave-focusing effect is the area along the south side of the North Jetty. Upon initial inspection, it would appear that this area is most susceptible to wave action approaching the mouth of the Columbia River from the southwest. However, this is not the case; the opposite is what occurs. The area located between the North Jetty, the navigation channel, and Jetty A is affected by wave action during conditions when the offshore wave direction is from the west-northwest, because of the refractive nature of Peacock Spit. Waves passing over Peacock Spit (approaching from the northwest) are focused to enter the mouth of the Columbia River along the south side of the North Jetty. Conversely, large waves approaching the mouth of the Columbia River from the southwest are refracted/diffracted around the South Jetty and over Clatsop Spit, protecting the south side of the North Jetty from large southerly waves.

Channel stability at the mouth of the Columbia River is related to the jetties and the morphology of Peacock and Clatsop spits (Moritz et al. 2003). Because of phased jetty construction from 1885 to 1939 and the associated response of morphology, mouth of the Columbia River project features and the resultant morphology are now mutually dependent both in terms of structural integrity and project feature functional performance.

The Columbia River plume is the zone of freshwater/saltwater interface where the freshwater exiting the Columbia River meets and rises above the denser saltwater of the Pacific Ocean, just seaward of the MCR. The plume is formed as thin, buoyant lenses of fresher water flowing over denser, oceanic water and is more pronounced when flow from the river is large in comparison to tidal volume. The Columbia River plume is ephemeral and may persist for several hours and is controlled by fluctuating tide. A frontal boundary (front) is formed between the river plume and adjacent marine waters. The front is richer in zooplankton than adjacent marine waters and plume waters, being attributed to increased abundance of surface-oriented organisms (Morgan et al. 2005). The plume front is easily identified by well defined horizontal gradients in salinity and water clarity and by the accumulations of foam and flotsam (De Robertis et al., 2005).

Nutrients were not found to be more abundant in the fronts than adjacent plume and ocean waters and, therefore, it is unlikely that plume fronts are regions of greater production. Greater zooplankton biomass in the plume front was largely due to the concentration of surface-oriented species along the front, particularly Dungeness crab (*Cancer magister*) megalopae and the concentration of the eggs of northern anchovy (*Engraulis mordax*) and sanddab (*Citharichthys* spp.). This increased concentration of surface-oriented zooplankton is caused by convergent water flows at the frontal boundary. Although biomass was greater, density of all zooplankton combined (including non-surface-oriented zooplankton) was not found to be greater at the plume compared to adjacent plume and ocean waters. More bird feeding activity was noted at the front compared to the adjacent plume and ocean waters (Morgan et al. 2005). Increased bird foraging could contribute to limiting salmon use of fronts.

In the study by Morgan and others (2005), there was no significant difference in the mean temperature among the three habitats in 2001 but the plume was significantly warmer than the ocean and front habitats in 2002. The mean salinity of the front was more similar to that of the plume in 2001 and to the ocean habitat in 2002.

This multi-layered mixing zone plays an important role as habitat for juvenile salmonids and other fish species. The first few weeks of their ocean life, some of which is spent in the plume, are critical for recruitment success of salmonids (Pearcy 1992). The Columbia River plume provides a high turbidity refuge from predation, provides fronts and eddies where prey become concentrated, and provides a stable habitat for northern anchovy spawning (Richardson 1981, Bakun 1996). A strong, quickly moving plume also helps juvenile salmonids and other species move rapidly offshore.

<u>Foundation Conditions</u>

The project has two main shoaling areas. The outer shoal extends from approximately RM -1.6 to RM -1.0. The inner shoal, Clatsop Shoal, extends from approximately RM 0.0 to RM 2.6, beginning on the south side and crossing the channel near RM 1.0. To maintain the channel's depth, dredging is conducted and materials dredged from the project are placed in one of two EPA Section 102 of the Marine Protection, Research, and Sanctuaries Act (MPRSA) Ocean Dredged Material Disposal Sites (ODMDS) -- the Deep Water Site (DWS) or the Shallow Water Site (SWS), or alternately in a Clean Water Act Section 404 North Jetty site (Corps 2008).

The MCR jetties were constructed on these underwater sand shoals which are considered to be crucial project elements. These shoals are currently receding, which could affect the sediment budget supplying the adjacent littoral zones north and south of the MCR. As morphology near the jetties experiences significant erosion, the jetties will be undermined by waves and currents.

<u>Landforms</u>

Near the Oregon shore of the estuary, Clatsop Spit is a coastal plain. On the Washington shore, Cape Disappointment is a narrow, rocky headland. Extensive accretion of land has occurred north of the North Jetty since its construction. This accreted land, however, is now in the process of recession as is evident by erosion at Benson Beach. The Corps is in the process of placing Columbia River sand back into the littoral drift cell north of the North Jetty at Benson Beach. Behind the headland is beach dune and swale. Wetlands occur on accreted land north of the North Jetty and on Clatsop Spit.

Wetlands near the North Jetty

Scouring has occurred on the north side of the North Jetty resulting in the formation of wetlands and a backwater lagoon within the approximately 16-acre wedge of land between the North Jetty and Jetty Road. Lagoons are characterized by shallow water and intermittent ocean connectivity and are often oriented parallel to the shoreline. Because of their interface location between land and sea, their exposure to rapidly changing physical and chemical influences, their short and varied water residence time, and their wind and weather dependent vertical and horizontal stratification, these lagoon features can be very dynamic and productive based on these natural constraints (Troussellier 2007). A recently repaired sand berm separates the western entrance of the North Jetty lagoon from tidal flows along the south end of Benson Beach. Thus, the North Jetty lagoon and wetlands are separated from direct ocean connectivity by the berm and the jetty itself. Fish access to and use of the lagoon is not likely. However, the lagoon is often inundated both by tidal waters that come through the jetty and by freshwater from wetlands that have formed in accreted lands north of Jetty Road and which drain through a culvert into the lagoon and its adjacent wetlands. The lagoon area and three wetland areas were delineated in this wedge of land and total approximately 6.5 acres of wetlands and waters of the United States.

Wetlands within and fringing the lagoon that are proposed to be filled are located between the North Jetty and the beach access road to the north and comprise a total of 1.78 acres. These wetlands were delineated by Tetra Tech (2007a, b) in accordance with the Corps' Wetlands Delineation Manual (Corps 1987). Three distinct wetlands were identified.

Wetland 1 (0.61 acre). These disjunct wetlands are classified as estuarine emergent, persistently regularly flooded. These patches of wetlands fringe the scoured-out tidal channel and are characterized by bighead sedge, American dune grass, Baltic rush, and tufted hairgrass. These fringe wetlands are ephemeral in nature in that they can be affected by moving sand. This was evident during a field visit in fall 2007 when a storm during the previous winter washed sand eastward covering nearly all of a patch of wetland that occurred near Benson Beach.

Wetland 2 (0.97 acre). This wetland is classified as palustrine emergent, persistently seasonally flooded and as palustrine scrub-shrub broad-leaved deciduous seasonally flooded. It occurs adjacent to the beach access road in drainage ditches. Three plant communities characterize this wetland: baltic rush-velvet grass emergent, slough sedge emergent, and willow shrub.

Wetland 3 (0.20 acre). This wetland is classified as palustrine scrub-shrub, broad-leaved deciduous, seasonally flooded. This bowl-shaped wetland occurs toward the west end of the area projected for filling and is characterized by a thick understory of slough sedge and an overstory mainly of alder. Pacific crabapple and Sitka spruce are also present.

Two of the three wetlands described above were rated by the Washington Department of Ecology and the Corps on November 16, 2007 in accordance with the Washington State Wetland Rating System (Hruby 2004). Wetland 1, the tidal fringe wetlands, was not rated by this system because they are considered estuarine wetlands. Because of lack of hydrologic connection, Wetland 2 (consisting of two ditches) was broken out into discrete wetlands for rating purposes (referred to here as Wetland 2a and Wetland 2b). Wetland 2a is between the east parking lot and beach access road and Wetland 2b is just west of Wetland 2a. Categories assigned by the rating system are: Category I (score ≥ 70), Category II (score 51-69), Category III (score 30-50), and Category IV (score < 30). All three wetlands rated are considered depressional wetlands and qualify as Category III wetlands. Scores for the wetlands are shown in Table 34.

Table 17. North Jetty Wetland Scores

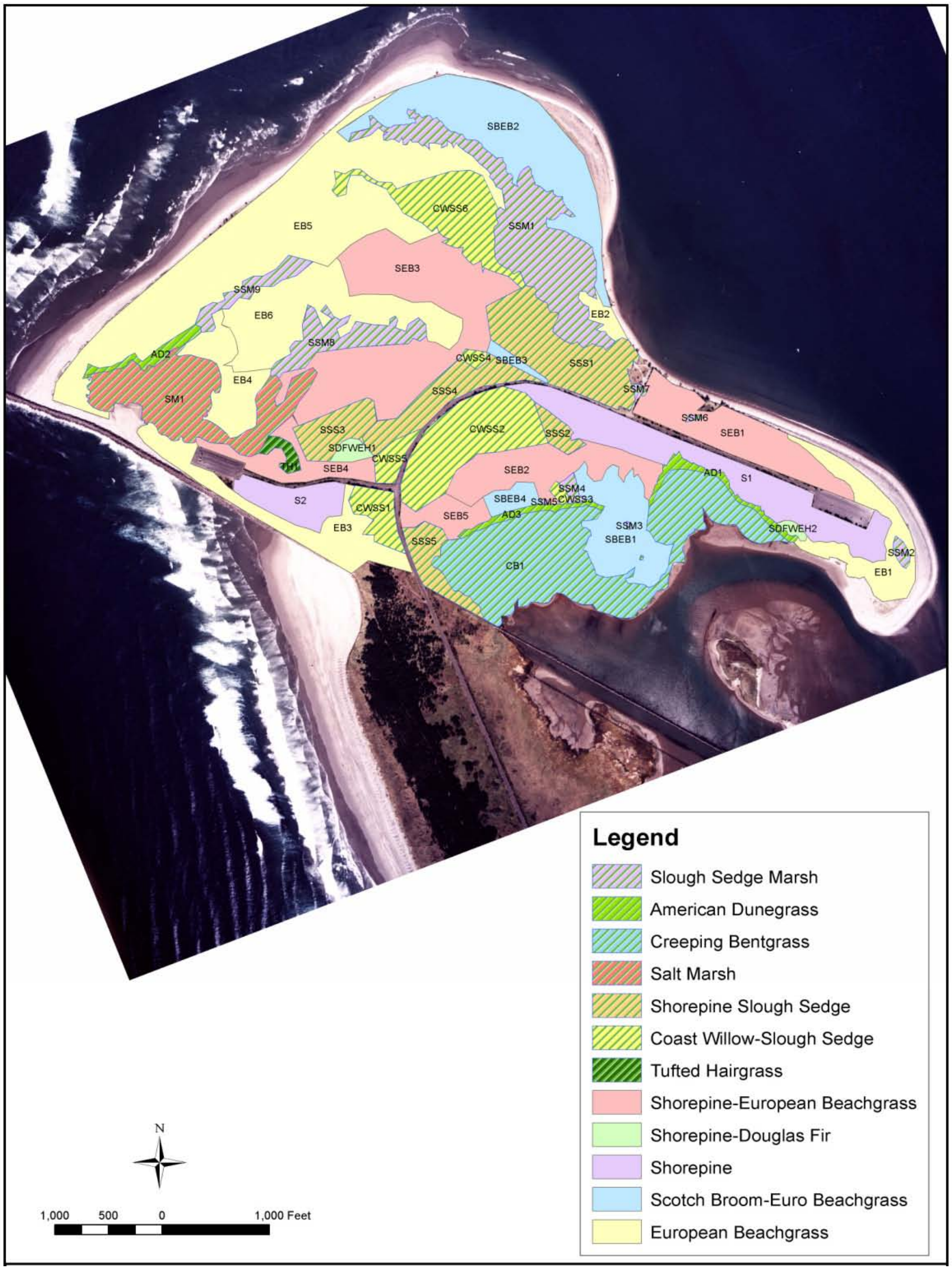
Function	Wetland		
	2a	2b	3
Water Quality Functions	12	20	12
Hydrologic Functions	5	10	12
Habitat Functions	13	13	15
Total Score	30	43	39

Note: Rating by Washington State Wetland Rating System.

Wetlands near the South Jetty (on Clatsop Spit)

Though official delineations have not yet been completed near the South Jetty, habitat surveys (Tetra Tech, 2007b) suggest that of the 600-acres of Clatsop Spit surveyed, there are likely 193-acres of wetlands. The topography of the area is complex with dunes and intertidal swales forming a mosaic of various vegetation communities, including: shorepine-slough sedge, slough sedge marsh, American dune grass, creeping bent grass, salt marsh, coast willow-slough sedge, tufted hair grass, shorepine-European beach grass, shorepine-Douglas fir, shorepine, Scotch broom-European beach grass, and European beach grass (Figure 40). At least three of these communities (shorepine-slough sedge, shorepine-Douglas fir, and coast willow-slough sedge) have been ranked globally and by the state for their rarity and vulnerability to extinction.

Figure 40. Clatsop Spit Vegetative Communities (Tetra Tech 2007b)



It is anticipated that the proposed actions will avoid most impacts to wetlands and waters of the United States in this area to the maximum degree feasible. The marsh wetlands at the South Jetty are also mostly isolated and separated from active direct ocean access by an existing dune that precludes regular connectivity, therefore regular anadromous fish use is not expected. However, fish monitoring surveys from the 2007 repairs did observe some stranding of threespine stickleback (*Gasterosteus aculeatus*), which was reported to NMFS. As mentioned, at the South Jetty fish salvage and exclusion have been proposed to avoid stranding listed species.

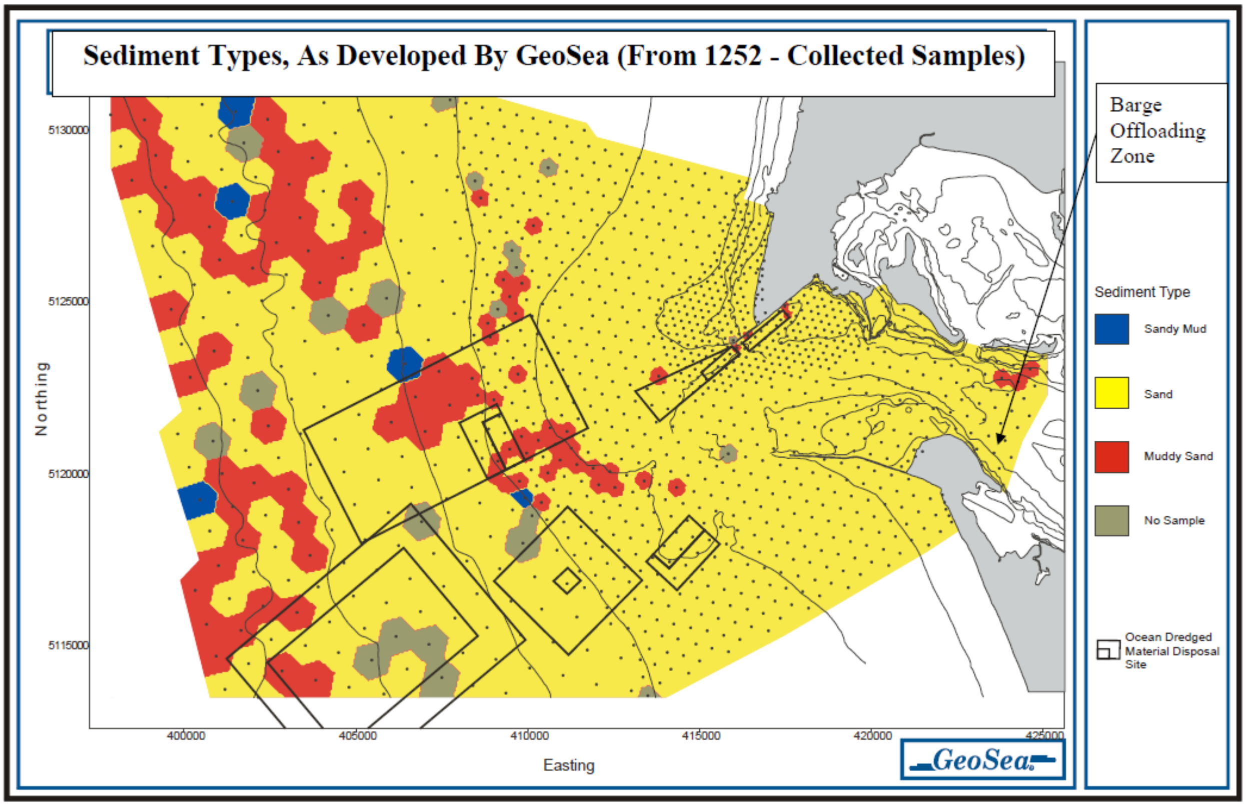
Wetlands near Jetty A

Land around the base of Jetty A received a cursory inspection on January 22, 2007 and on September 13, 2010. It is possible that sparse, perched wetlands composed of sedge and grassy fringe estuarine wetlands were present; no official wetland delineation was completed.

Sediment Quality

In 2000 a Sediment Trend Analysis (STA) was conducted by GeoSea Consulting, under contract to the Corps. Over twelve hundred (1,252) samples were collected in the MCR and surrounding off-shore locations (Figure 41). Physical analyses, of the samples surrounding the study area (6 samples selected), indicate the project area consists of >99 % sand. Select samples (10) from the GeoSea study in the MCR project were analyzed for physical and chemical contamination. These samples indicated no contaminates were detected at or near the DMEF screening levels. See http://www.nwp.usace.army.mil/ec/h/hr/Reports/Mcr/mouth00.pdf for the complete report on chemical results (Corps 2008).

Figure 41. Sediment Trend Analysis in MCR Area



In 2005 a Tier I evaluation was conducted near the proposed the South Jetty barge offloading site following procedures set forth in the Inland Testing Manual (ITM) and the Upland Testing

Manual (UTM). The methodologies used were those adopted for use in the Dredge Material Evaluation Framework (DMEF) for the Lower Columbia River Management Area, November 1998, and its updated draft 2005 version, the Sediment Evaluation Framework (SEF). This Tier I evaluation of the proposed dredge material indicated that the material was acceptable for both unconfined in-water and upland placement. No significant, adverse ecological impacts in terms of sediment toxicity were expected from disposal (Corps 2005a).

In 2008 using USEPA's OSV Bold, ten Van Veen surface grab samples were collected from sites previously sampled during the September 2000 sediment evaluation study. Percent sand averaged 98.45% with a range of 99.3% to 97.0%. Percent silt and clay averaged 1.59% ranging from 3.0% to 0.7%. Per the Project Review Group approved SAP, no chemical analyses were conducted. Physical results for the 2000 and 2008 sampling events were compared. The mean percent sand for all samples in September 2000 was 98.11% for June 2008 it was 98.45%. Within both data sets, sediment towards the outer portion of the mouth is finer than sediments towards the center of the mouth (Corps 2008).

Other Activities and Conditions

Commercial and recreational fishing activities also have some influence on listed species and their prey items in the action area. The major fisheries are for bottom fish, salmon, crab, and other species of shellfish. Crab fishing occurs from December to September with the majority of the catch occurring early in the season. Most crab fishing occurs north of the Columbia River mouth at depths ranging from 25 to 250 feet mean sea level (MSL). Dungeness crab population numbers are subject to large cyclic fluctuations in abundance. Catch records for fishery are generally believed to represent actual population fluctuations. Modeling studies by Higgins and others (1997) show that small scale environmental changes, such as a short delay in the onshore currents in spring, can dramatically impact survival of young-of-the-year crab but have no effect on adults and older juveniles inshore. Bottom fishing by trawl for flatfish, rockfish, and pink shrimp occurs year-round throughout the entire offshore area, primarily at depths offshore from the jetties. Many of these species interact with listed species in a predator-prey relationship that, in some cases, can change over the course of each species' life history. Fisheries could have some effect on prey availability and species numbers in the action area.

EFFECTS OF THE ACTION

Effects of the action refers to the direct and indirect effects of an action on the species or critical habitat, together with the effects of other activities that are interrelated or interdependent with that action, that will be added to the environmental baseline (50 CFR 402.02). Indirect effects are those that are caused by the proposed action and are later in time, but still are reasonably certain to occur. Interrelated actions are those that are part of a larger action and depend on the larger action for their justification. Interdependent actions are those that have no independent utility apart from the action under consideration. The Corps has determined that the effects of the proposed action could occur from:

- Rock Transport
- Construction Access, Staging, Storage, And Rock Stockpiling
- Rock Placement
- Dredging
- Disposal
- Barge Offloading Facilities
- Pile Installation and Removal
- Lagoon And Wetland Fill And Culvert Replacement
- Dune Augmentation
- Water Quality
  - Suspended sediment
    - Dredging
    - Disposal
    - Pile Installation and Removal
  - Spills Leaks
  - Contamination
- Hydraulic and Hydrological Processes
  - Water Velocity
  - Salinity and Plume Dynamics
  - Bed Morphology
- Wetland Mitigation and Habitat Improvements

Rock Transport

As discussed, barge transport of stone from quarry sites is likely and would occur mostly during daylight hours along major navigation routes in existing harbors and navigation channels. The number of additional barge trips per year attributable to the proposed action is expected to be somewhere between 8 and 22 ships. This is small annual percentage increase relative to the current number of other commercial and recreational vessels already using any of these potential routes. MCR is the gateway to the Columbia-Snake River system, accommodating commercial traffic with an approximate annual value of $16 billion dollars a year. Loaded water-borne container traffic identified as foreign in- and outbound to/from Portland that would likely have crossed the MCR in 2008 totaled approximately 195,489 ships (Corps 2010). Traffic from the proposed action will also be limited mostly to summer months when fair weather allows safe passage. Though transport will occur on an annual basis, stone may or may not be delivered to one or more jetties seasonally. Due to the infrequency of these vessel trips, their geographic limitations to existing navigation channels, and their minimal duration in any particular area, the disturbance effects are expected to be discountable. The proposed action will not cause any meaningful increase (less than 1%) in annual vessel traffic along the routes or around the MCR jetty system. Any increase in acoustic levels from barge traffic during delivery will be transient. Sound levels are expected to return to background near the source, and are not expected reach harmful levels. Therefore, these effects are negligible and discountable.

Construction Access, Staging, Storage, and Rock Stockpiling

Construction activities will occur on an annual basis, could happen through-out the year, and may occur at one or more jetties simultaneously. Upland effects could include: repetitive disturbance; de-vegetation; residual rock side-cast; and soil compaction. Changes in soil structure and composition could also result in localized habitat conversion of the vegetative and biological communities. Invasive species are located in the vicinity of all three jetties, and chronic disturbance can increase the spread and establishment of such species. Changes in the plant communities can also cause trophic effects on the faunal communities that rely on these ecosystems for forage and habitat. However, the Corps expects effects to listed species from associated construction activities for staging, roadways, and stockpiles to be localized at all jetties, as the majority of these construction features have been sited in upland areas above mean high tide elevation in locations that were identified as of lower habitat value, and were in some cases previously used as staging areas. Avoidance and minimization measures have reduced the construction footprint where possible, and higher value habits like marsh wetlands and slough sedge communities have been preserved such that activities are limited to areas where previous disturbance and development have already occurred. Wetland fill effects from these activities are discussed in the wetland fill section.

Whenever feasible, stabilizing dune vegetation is being preserved and little if any riparian or vegetative cover will be removed or disturbed. Furthermore, protective fencing, set-backs, and an Erosion and Sediment Control Plan or Stormwater Protection Plan will be implemented so that best management practices (BMPs) avoid stormwater erosion and run-off from disturbed areas. The topography in this area is flat, and proposed impact minimization measures for construction will reduce the likelihood for sediment to enter the Columbia River. When construction activities are suspended for the season, appropriate demobilization and site stabilization plans will limit the distribution and duration of any effects. No pollutants are expected to enter waterways.

Any increase in acoustic levels from truck traffic during delivery will be transient and intermittent. Conservation measures limit the hours for stone delivery as well as the use of compression brakes, which will reduce species exposure to acoustic effects. Trucks will only be allowed to use the roads through Cape Disappointment State Park during daylight hours. Sound levels are expected to return to background near the source, and are not expected reach harmful levels. Therefore, these effects are negligible and discountable. There may be some disturbance from equipment sounds and human presence, but these will be indirect and of low intensity, mostly during daylight hours and summer months. The geographic area will be limited, and species will be able to avoid work areas. Therefore, disturbance effects from these activities are expected to be minimal and discountable.

Rock Placement

Rock placement will occur on an annual basis starting in the late spring through the late to early fall seasons. Placement may occur at more than one jetty per season and will occur regularly throughout the duration of the construction schedule. Some permanent habitat conversion and modification will occur as a result of stone placement for repair and rehabilitation of jetty features. Along specific portions of North and South jetties and along the entire length of Jetty A, substrate will be converted to rocky sub and intertidal habitat, and associated benthic communities will be covered. In addition, crane set-up pads and turnouts will require placement of rock that could extend slightly off the current centerline of the jetty trunk. However, this total area is a relatively small percentage of the existing jetty structures, and conversion is mostly limited to the spur groin locations. Generally, effects to in-water habitat could include the following sub-tidal and intertidal habitat conversion from sandy to rocky substrate and potential unforeseen indirect far-field effects from hydraulic influence (slight, localized changes to accretion, currents, velocities, etc). However, relatively little habitat conversion and footprint expansion will occur because a majority of the stone placement for construction of the jetty head, trunk, and root features will occur on existing relic jetty stone and within the existing structural prism. Moreover, aquatic species will experience limited exposure, since stone placement for cross-section repair and rehabilitation actions occurs mostly above the MHHW elevation. This is summarized below.

North Jetty

- About 58% of the overall stone placement on these portions of the jetty will be placed above mean higher high water (MHHW); about 25% of the volume will be placed between MHHW and MLLW; and about 18% of the volume placed will be below MLLW. Therefore, approximately 83% of the volume placed for trunk and root cross section repairs is above MLLW. There is no expected expansion of the footprint beyond the relic jetty stone or structure.
- A small percentage (about 0.1%) of the overall stone placement for spur groins will be above MHHW; about 4% will be placed between MHHW and MLLW; and about 95.9% will be placed below MLLW. Therefore, approximately 96% of the spur groin construction will be below MLLW, and this will cause 1.55 acres of habitat conversion from sandy to rocky substrate. Bottom topography and shallow water habitat will be altered in a limited geographical area, and benthic organisms will be covered. This is a small percentage relative to the existing acreage of the jetty structure and the available adjacent remaining shallow-water sand habitat in the vicinity of the action area. These structures are also relatively short, remaining close to the jetty trunk and root. Channel-side groins are submerged a minimum of 5 to 35 ft below MLLW.
- About 49% of the overall stone placement on the capping portions of the jetty will be placed above MHHW; about 24% of the volume will be placed between MHHW and

MLLW; and about 27% of the volume placed will be below MLLW. Therefore, approximately 73% of the volume placed for head capping will remain above MLLW. This feature is not expected to expand beyond the footprint of the relic jetty stone.

- Stone placement for barge offloading facilities (additional effects discussed further elsewhere), turn-outs, and set-up pad facilities will cover and convert about 0.63 acres and will be confined within the same location as the stone placed for repairs. This is a small percentage relative to the existing acreage of the jetty structure and the available adjacent remaining shallow-water sand habitat in the vicinity of the action.

South Jetty

- About 68% of the overall stone placement on these portions of the jetty will be placed above mean higher high water (MHHW); about 19% of the volume will be placed between MHHW and MLLW; and about 13% of the volume placed will be below MLLW. Therefore, approximately 87% of the volume placed for trunk and root cross section repairs is above MLLW. There is no expected expansion of the footprint beyond the relic jetty stone or structure.
- A small percentage (about 0.1%) of the overall stone placement for spur groins will be above MHHW; about 12.3% will be placed between MHHW and MLLW; and about 87.6% will be placed below MLLW. Therefore, approximately 88% of the spur groin construction will be below MLLW, and this will cause 1.10 acres of habitat conversion from sandy to rocky substrate. This is a small percentage relative to the existing acreage of the jetty structure and the available adjacent remaining shallow-water sand habitat in the vicinity of the action area. These structures are also relatively short, remaining close to the jetty trunk and root.
- About 52% of the overall stone placement on the capping portions of the jetty will be placed above MHHW; about 25% of the volume will be placed between MHHW and MLLW; and about 23% of the volume placed will be below MLLW. Therefore, approximately 77% of the volume placed for head capping will remain above MLLW. This feature is not expected to expand beyond the footprint of the relic jetty stone or structure.
- Stone placement for barge offloading facilities, causeways, turn-out, and set-up pad facilities will cover and convert about 1.96 acres. This is a small percentage relative to the existing acreage of the jetty structure and the available adjacent remaining shallow-water sand habitat in the vicinity of the action.

Jetty A

- About 63% of the overall stone placement on these portions of the jetty will be placed above mean higher high water (MHHW); about 29% of the volume will be placed between MHHW and MLLW; and about 8% of the volume placed will be below MLLW. Therefore, approximately 92% of the volume placed for trunk and root cross section rehabilitation will remain above MLLW. There may be some expansion of the footprint beyond the relic jetty stone or structure. This is not expected to extend beyond 10-ft off the existing prism, which is a possible conversion of 1.2 acres from sandy to rocky substrate. This is a small percentage relative to the existing acreage of the jetty structure and the available adjacent remaining shallow-water sand habitat in the vicinity of the action.

- 100% of the spur groin construction will be below MLLW, and this will cause 0.61 acres of habitat conversion from sandy to rocky substrate. This is a small percentage relative to the existing acreage of the jetty structure and the available adjacent remaining shallow-water sand habitat in the vicinity of the action area. These structures are also relatively short, remaining close to the jetty trunk and root. Both groins are submerged a minimum of 5 below MLLW.
- About 44% of the overall stone placement on the capping portions of the jetty will be placed above MHHW; about 26% of the volume will be placed between MHHW and MLLW; and about 30% of the volume placed will be below MLLW. Therefore, approximately 70% of the volume placed for head capping will remain above MLLW. This feature is not expected to expand beyond the footprint of the relic jetty stone or structure.
- Stone placement for barge offloading facilities, causeways, turn-out, and set-up pad facilities will cover and convert about 2.89 acres. This is a small percentage relative to the existing acreage of the jetty structure and the available adjacent remaining shallow-water sand habitat in the vicinity of the action.

Indirect disturbance effects due to placement activities will be localized and occur mostly during daylight hours in the summer months. Disturbance effects are expected to be of limited duration and minimal, since a majority of the placement is above MHHW and on existing relic stone. Acoustic effects of construction on the jetties similar to those mentioned in the Construction and Staging section are less likely to reach the land at levels much above background. There may be temporary disturbance to species using the jetty structure in the vicinity of placement activities. However, the Corps does not expect long-term negative effects from these actions.

Dredging

As previously described, dredging will for construction and maintenance of barge offloading facilities and is likely during early summer prior to rock delivery, but may not occur at all facilities annually. If all facilities were dredged, this would total about 16 acres near the jetties. However, it is likely only one or two facilities would be used seasonally for short durations and would be dredged on a periodic basis as needed.

The effects of dredging on physical habitat features include modification of bottom topography, which in the vicinity of the jetties is by nature extremely dynamic. Dredging may convert intertidal habitats to subtidal, or shallow subtidal habitats to deeper subtidal. Such conversions may affect plant and animal assemblages uniquely adapted to the particular site conditions these habitats offer. However, the dredged prisms are very small as a relative percentage of the ~19,575 acres of shallow-water habitat available within a 3-mile proximity to the MCR. The proposed dredging of the offloading facilities will affect bottom topography, but is unlikely to cause large-scale or long-term effects to habitat features. Dredging activities will also have some contribution to increased acoustic disturbance that could occur for a limited duration while dredging is underway. These effects are expected to attenuate rapidly such that they return to background levels within a short distance from the source.

The effects on water quality and suspended sediment are discussed further under the Water Quality section.

Disposal

Disposal is likely to occur on an annual basis originating from one or more of the offloading facilities. The duration of disposal will be limited and will likely occur earlier in the construction season prior to use of offloading facilities. As mentioned previously, all disposal of dredged material will be placed at previously evaluated and EPA-approved in-water ODMDS or Clean Water Act disposal sites. No new or different impacts to species or habitats than those previously evaluated by EPA for disposal approval are expected from these actions. Per EPA guidelines, all ocean dumping sites are required to have a site management and monitoring plan (SMMP) which is aimed at assuring that disposal activities will not unreasonably degrade or endanger the marine environment. This involves regulating the times, the quantity, and the physical/chemical characteristics of dredged material that is dumped at the site, establishing disposal controls, and monitoring the site environs to verify that unanticipated or significant adverse effects are not occurring from past or continued use of the disposal site and that permit terms are met. The relative quantities, characteristics, and effects of the proposed action area not expected to have different or significant negative impacts to these sites.

The effects of disposal on physical habitat features include modification of bottom topography. In some cases, disposal may result in the mounding of sediments on the bed of the disposal site. Such conversions may affect plant and animal assemblages uniquely adapted to the particular site conditions these habitats offer. However, the area impacted by disposal is relatively small and will likely occur in deeper habitat offshore, in the littoral cell or near the North Jetty vicinity. The proposed disposal is unlikely to cause large-scale or long-term effects to habitat features. The effects on suspended sediment are discussed further under the Water Quality section.

Barge Offloading Facilities

Installation of offloading facilities is likely to occur once, likely in the late spring or early summer prior to or during the first season of construction on the associated jetty. Subsequently, periodic maintenance may be required as facilities weather wave and current conditions at the MCR. Facilities may also occasionally be partially removed and reconstructed, which could slightly increase the frequency of disturbance. Depending on the specific facility and contemporary conditions at the time, removal would then occur at the end of the scheduled construction duration. Temporally, this limits the repetition of disturbance activities associated with the construction of these facilities. Use of the facilities may be annual with periodic breaks in between, depending on the construction schedule and conditions at the jetties. Annual use is likely on at least one of the facilities and will be seasonally concentrated in the spring, summer, and fall. Though unlikely, occasional breaks in weather could allow offloading at other times of the year.

Stone placement for barge offloading facilities could have the same minimal effects and were described previously under rock placement. However, - with the exception of the facility at Parking Lot D on the Clatsop Spit - construction and maintenance of the facility and associated and piles would be equivalent to actions already occurring from jetty repair and stone placement, and would not cause a separate or cumulative increase in disturbance. Also as mentioned previously, chemically treated wood will not be used for decking material, as treated decking could leach toxic substances into the water. Therefore water quality is not expected to be negatively impacted by these facilities. Possible effects of the action to water quality are discussed under Water Quality. Offloading facilities will be areas of slightly increased activity and vessel traffic, but the intensity of use is expected to be low and seasonal in nature. Additional noise from vessel activities may increase disturbance, but acoustic effects are not expected to reach harmful levels and will be geographically and temporally limited. A return to background noise levels is likely near the source.

The effects from dredging and pile installation and removal for these facilities are discussed under their respective sections.

Pile Installation and Removal

Pile Installation and subsequent removal is likely to occur once, likely in the late spring or early summer prior to or during the first season of construction on the associated jetty. Subsequently, periodic maintenance may be required as piles weather barge use and wave and current conditions at the MCR. Pile may also occasionally be partially removed and installed, which could slightly increase the frequency of disturbance. Depending on the specific associated offloading facility and contemporary conditions at the time, removal would then occur at the end of the scheduled construction duration. Temporally, this limits the repetition of disturbance activities associated with the installation and removal of these structures.

As mentioned previously, for initial construction of all four facilities combined, up to approximately up to 96 Z- or H-piles could be installed as dolphins, and up to approximately 373 sections of sheet piles installed to retain rock fill. However, it is unlikely that all facilities would be installed at the same time. Installation is likely to happen early in the construction season sometime between April and June, and is weather dependent. Piles will be located within 200-ft of the jetty and offloading structures. Vibratory drivers will be used and will dampen any acoustic effects to fish and other species. Because of the soft substrates in the lower Columbia River, vibratory drivers can be used effectively to install and remove piles. Sound wave form and intensity is not expected to reach harmful levels and are expected to return to background levels within a short distance from the source. Any acoustic impacts would be short duration and intermittent in frequency. Therefore, this action is not expected to have any significant direct effects, though it may cause temporary displacement during installation.

The presence of piles at the offloading facilities could increase perching opportunities for piscivorous birds, especially cormorants and brown pelicans. However, piling caps will avoid any significant increase in new perch sites so that the effects are expected to be minimal and discountable. Furthermore, perching opportunities for these birds are abundant in the lower Columbia River and are not expected to increase cormorant and pelican use of this area.

Wetland and Lagoon Fill and Culvert Replacement

Wetland fills and culvert installations at all jetties will occur once, and could happen during anytime in the construction season depending on weather. Sequentially, these actions will be required prior to several of the other proposed action. Subsequent removal of construction related culverts is likely to occur once, and could also happen during anytime in the construction season depending on weather and construction need. Periodic culvert maintenance may be required during construction. Temporally, this limits the repetition of disturbance activities to single event and season on separate jetties.

Where possible, the Corps has planned the construction, access, and staging areas at all jetties so that the footprint minimizes impacts to wetlands and higher value habitat features. Protections will be implemented for the identified rare and ranked vegetative communities within this area. Strategic use of uplands and lower quality wetlands for rock storage will be done to the most practical extent in order to avoid and minimize these impacts. However, permanent and temporary wetland fill will occur as a result of construction staging, storage, and rock stockpiles at all three jetties. Fill to protect the North Jetty root will also affect wetlands. Long-term direct and indirect impacts to wetlands could include: permanent wetland fill; potential fragmentation of and between existing wetlands; soil compaction; loss of vegetation; altered hydrology; conversion to upland; and loss of ecosystem functions (water quality, flood storage, nitrogen cycling, habitat, etc.). However, the Corps further expects effects from wetland impacts and lagoon fill to be insignificant on river functions, as the wetlands are not within the channel prism of the Columbia River. Although these wetlands are connected hydrologically to the Columbia River, wetland fill impacts are not likely to negatively alter groundwater-stream exchange or hyporheic flow because wetlands are on accreted land that has formed on stabilized sand shoals behind the jetties. Wetland hydrology is mostly elevation and rainfall dependent, and fill impacts will be relatively insignificant to the Columbia channel. Culverts will be installed to maintain wetland hydrology and connectivity with permanent replacement at the North Jetty and when temporary construction roadways cross wetlands. See the Wetland Mitigation and Habitat Improvements sections for further information about actions that will offset any habitat and functional losses from wetland fill.

Dune Augmentation

Dune augmentation will occur once during a single season, and could happen likely in the late spring or early summer depending on weather. Sequentially, this action will be required prior to several of the other proposed action. Periodic maintenance may be required, likely on a decadal scale. This is only proposed at the South Jetty. Therefore, temporally and geographically this limits the repetition of disturbance activities to single event and season on a single jetty.

Dune augmentation at the South Jetty will occur above mean high tide; therefore, actions will cause limited exposure to aquatic species. Though substrate modification will occur along the shoreline, the Corps does not expect any measurable changes from in-water habitat conversion below MHHW. This action is likely to be completed in a single season, and cobble replenishment would likely be on a decadal scale. Clean cobble material will be placed from an existing roadway, and delivery via beach access will be prohibited. Some equipment will be required to move materials around on the dry sand. There is little likelihood of having any direct or indirect negative impacts to water quality or intertidal species, and the amount of dry sand conversion is relatively small compared to the amount of similar adjacent habitat that is available. The effects of this conversion are discountable and species exposure is unlikely.

Water Quality

Effects of the proposed action to water quality could occur by: increasing suspended sediments; increasing the potential occurrence of spills and leaks, and; increasing the potential for contamination. However, the Corps does not expect these effects to be significant.

Placement of rock by heavy equipment, jetty access road construction, dredging, disposal, and pile installation and removal could all cause temporary and local increases in suspended sediment. This is expected to have minimal and limited effects on the environment. Previous tests have confirmed that material to be dredged will be primarily sand with little or no fines, which does not stay suspended in the water column for a significant length of time. During infrequent and limited duration dredging and disposal, suspended sediments may increase locally for a short time. However, light attenuation and water quality effects from increased suspended sediments are expected to be minimal and fleeting. Pile driving is also expected to occur in sand and therefore have similar transient and minimal effects to water quality. Jetty roads could also contribute suspended sediments that would create turbidity, but since they are above MHHW this will likely be an infrequent occurrence. Increases in turbidity from construction activities on the jetties will likely occur on a nearly daily basis but will be of limited extent and duration, as rock placement will involve clean fill. Wave and current conditions in the action area naturally contribute to higher background turbidity levels; and such conditions also preclude the effective use of isolating measures to minimize turbidity. However, other BMPs described in the proposed action will further reduce effects of turbidity from the proposed action. Effects from potential stormwater runoff were addressed in the Construction Staging and Stockpile section. Therefore, impact from suspended sediments should be insignificant.

The Corps will require the contractor to provide a spill prevention and management plan that will include measures to avoid and minimize the potential for spills and leaks and to respond quickly to minimize damages should spills occur. Good construction practices, proper equipment maintenance, appropriate staging set-backs, and use of a Wiggins fueling system would further reduce the likelihood of leak and spill potential and exposure extent and its associated effects.

Test results on dredge material described earlier further indicated that materials in the area are approved for unconfined in-water disposal and do not contain contaminants in concentrations harmful to organisms occupying the action area. The prohibition of treated wood will also avoid contamination from the migration of creosote and its components [e.g., copper and polynuclear aromatic hydrocarbons (PAHs)] from treated wood in the lotic environments.

Temporally, effects to water quality from suspended sediment and turbidity could occur on a daily basis, but are not expected to be continuous throughout the day. Turbidity levels and durations will be limited to conditions required in the State Water Quality Certifications which include exceedence windows that are protective of beneficial uses like salmonids and other aquatic life. Contamination, spill, or leaks are expected to be infrequent and unlikely. Though, temporally the repetition of disturbance could be greater, this is still expected to remain within safe ranges that do not have long-term or significant effects. Furthermore, effects are expected to be geographically limited, short term and minor.

Hydraulic and Hydrological Processes

As mentioned previously, over the years of project development, USGS and ERDC have conducted numerical modeling to evaluate changes in circulation and velocity, salinity, and sediment transport at the MCR for various rehabilitation design scenarios of the MCR jetty system. The purpose of the 2007 USGS evaluation was to assess the functional performance of the extended jetty system and to aid in the assessment of potential impacts to fish from the rebuilt lengths and spur groins. Except for the spur groins, modeling components including rebuilding jetty lengths is not proposed in this action. However, results under the larger build-out scenario are still relevant for comparing and evaluating previously estimated potential changes to the MCR system as a whole. Previous modeling work also remains somewhat valid for consideration because the current proposed action caps the jetties at their present location, which is essentially the same length as the original base conditions used for the previous models.

In 2007, modeling by USGS was done for two time periods, August-September and October-November. The model period of August-September was in existence from the 2005 Mega-Transect experiment (see below). The October-November run was established for engineering purposes as this time period represents extreme conditions at the MCR. A series of plots was produced to show existing and post-rehabilitation conditions for the following parameters: residual (average for all tides) velocity and current direction for bed and near surface, residual bed load transport, residual total load transport (bed load + suspended load), and mean salinity for bed and near surface. Rehabilitation components for USGS modeling included restoring the lengths of the North Jetty and Jetty A, and installing spur groins (Moritz and Moritz 2010; USGS 2007).

Existing conditions were established using August-September 2005 data collected from the Mega-Transect, a data collection system at the MCR. The Mega-Transect experiment was a 6-week field data collection effort to observe currents, suspended sediment, and salinity-temperature across the MCR. Data was collected concurrently at five fixed locations spanning 2 miles across the MCR during August-September of 2005. Instrumented tripods were placed at these five critical hydraulic-morphologic locations. Acquisition of prototype data describing the three-dimensional circulation within the MCR was intended to improve the hydrodynamic understanding and improve the ability to manage the sediment resources within the inlet/estuary (Moritz et al., undated).

The ERDC analyzed the impacts of the presence of spur groins at the MCR. This analysis was done independently of the modeling conducted by USGS and was conducted with the coastal modeling system (CMS) and other models that operate within the surface water modeling system (SMS). A regional circulation model (ADCIRC) provided the tidal and wind forcing for the boundaries of project-and local-scale wave, current, sediment transport, and morphology change calculated by the CMS. The half-plane version of the wave transformation model, STWAVE, was coupled with two-dimensional and three-dimensional versions of the CMS, which calculates current, sediment transport, and morphology change. These models were coupled to provide wave forcing and update calculated bathymetry used in both models at regular intervals (Connell and Rosati 2007).

Water Circulation and Velocity

The Columbia River estuary has a greater range between high and low tides and receives a larger river discharge than most other estuaries in the U.S. resulting in rapid and turbulent currents. The primary factors controlling circulation in the Columbia River estuary are river flow, tides, and currents resulting from the pressure gradient force. The variability in the above mentioned parameters result in large variability in velocity (see charts presented in Fox et al. 1984). Quinn (2005) notes that there is great spatial variation in estuaries and that and that physiochemical attributes of the water such as depth, salinity, temperature, turbidity, and velocity vary over complex temporal scales including seasonal, lunar, and tidal periods. The USGS modeling results, for example, showed that in near surface waters near the landward portions of the North Jetty, velocity naturally varies with tides to over 1 meter/second during August-September. Under the rebuild scenario, changes to bed and surface velocities and current directions predicted by the models were negligible, particularly with respect to fluctuations that already occur. Though spur groins remain a component, no length rebuild is proposed under the current action. Therefore, any previously predicted effects to water circulation and velocity are even less likely under the current proposed action.

To further illustrate for the sake of comparison, previous model results quantified changes for the length rebuilds, which were negligible despite the larger scale action than what is currently proposed. When viewing the figures below, it is important to keep in mind they represent a previous action of a larger scope and scale. The representative original condition along with the spur groins is now more reflective of what the likely post-project conditions could entail.

For the August-September timeframe, an increase to residual bed layer velocity was predicted on the west side of the south portion of Jetty A to currents oriented in a south-southeast direction (Figure 42) but mean differences (existing to predicted) were less than 0.1 meter/second in this area. Smaller changes in residual velocities were predicted for near surface waters in the vicinity of Jetty A (Figure 43) (Moritz 2010, USGS 2007). These changes are small (10% or less) relative to the natural variation in this high energy environment. In these velocity charts, length of arrows indicates magnitude of velocity; red arrows indicate existing conditions and black arrows indicate predicted conditions resulting from implementation of the proposed project.

Under the length rebuild scenario, surface current direction for the August-September timeframe was predicted to change slightly toward the north as water flowed around Jetty A forming a more pronounced clockwise eddying effect west of Jetty A and tending to force water more directly toward the North Jetty. Residual velocities toward the North Jetty were predicted to decrease, however, and this effect would have protected the North Jetty. Predicted changes to current direction in the bed layer are less pronounced than in the surface layer (Figures 44 and 45). Changes to current direction and velocities are negligible in the vicinity of the South Jetty (Figure 45) (Moritz 2010, USGS 2007).

Figure 42. Residual Velocity Bed Layer for August/September Time Window

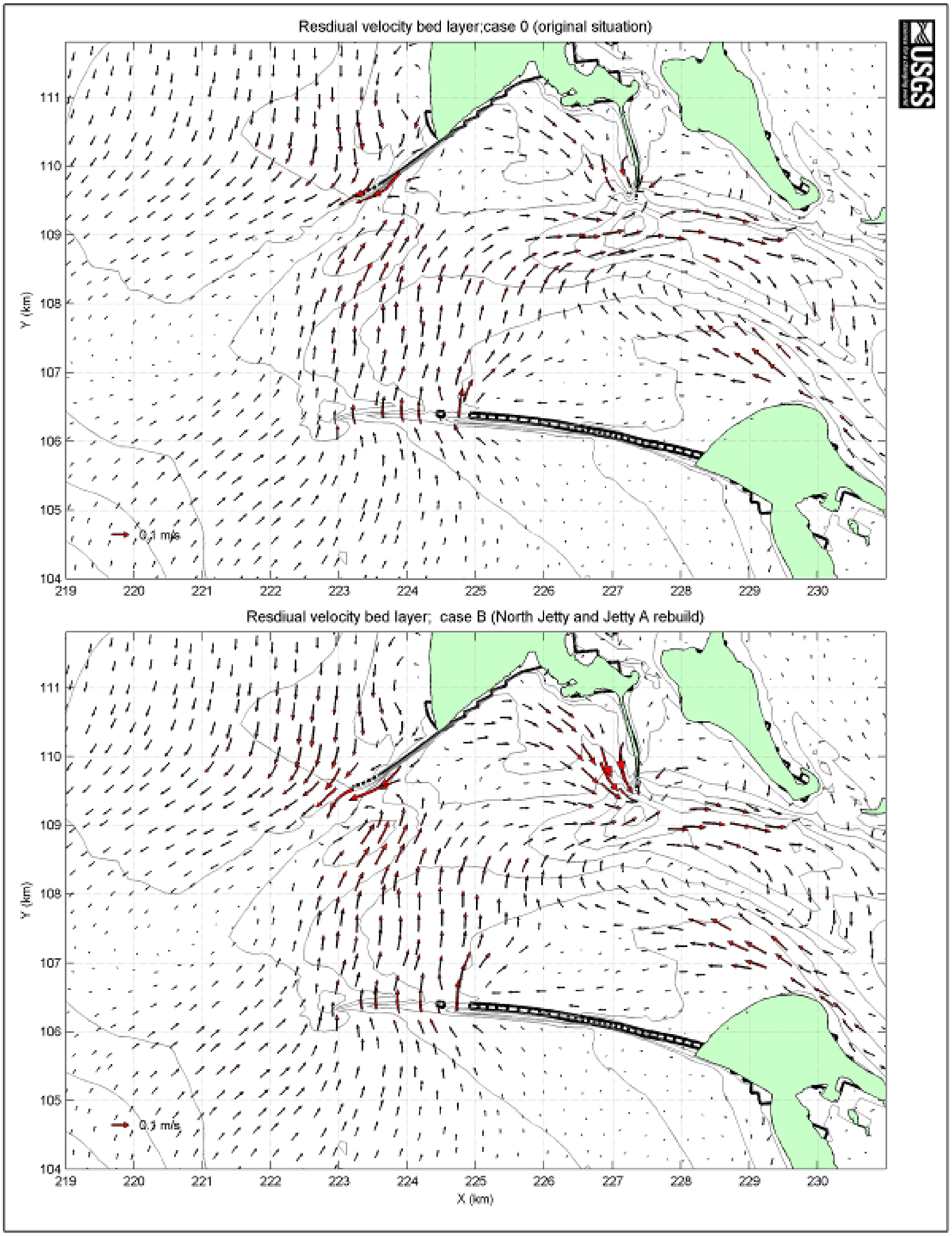


Figure 43. Residual Velocity Surface Layer for August/September Time Window

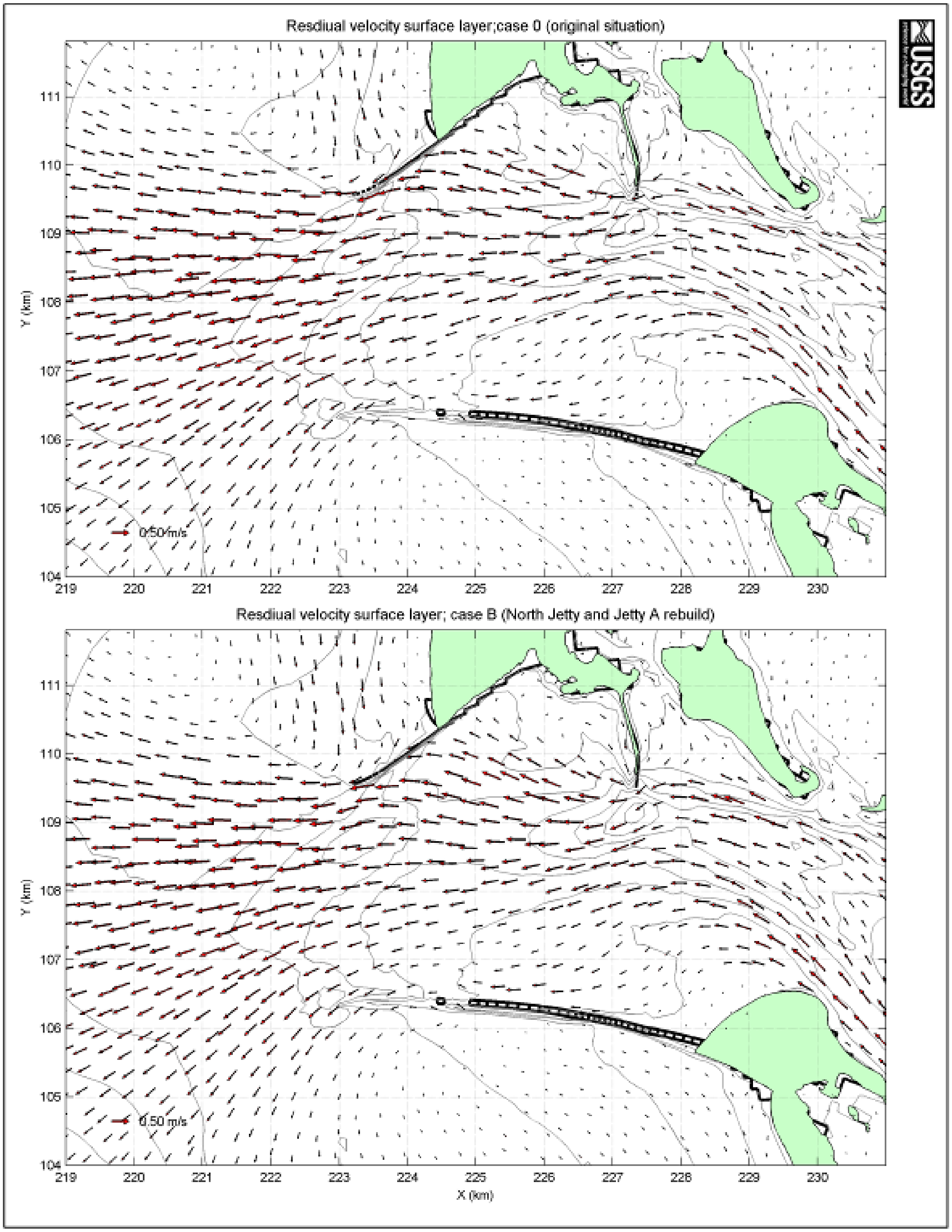


Figure 44. Residual Velocity near North Jetty and Jetty A for August/September Time Window

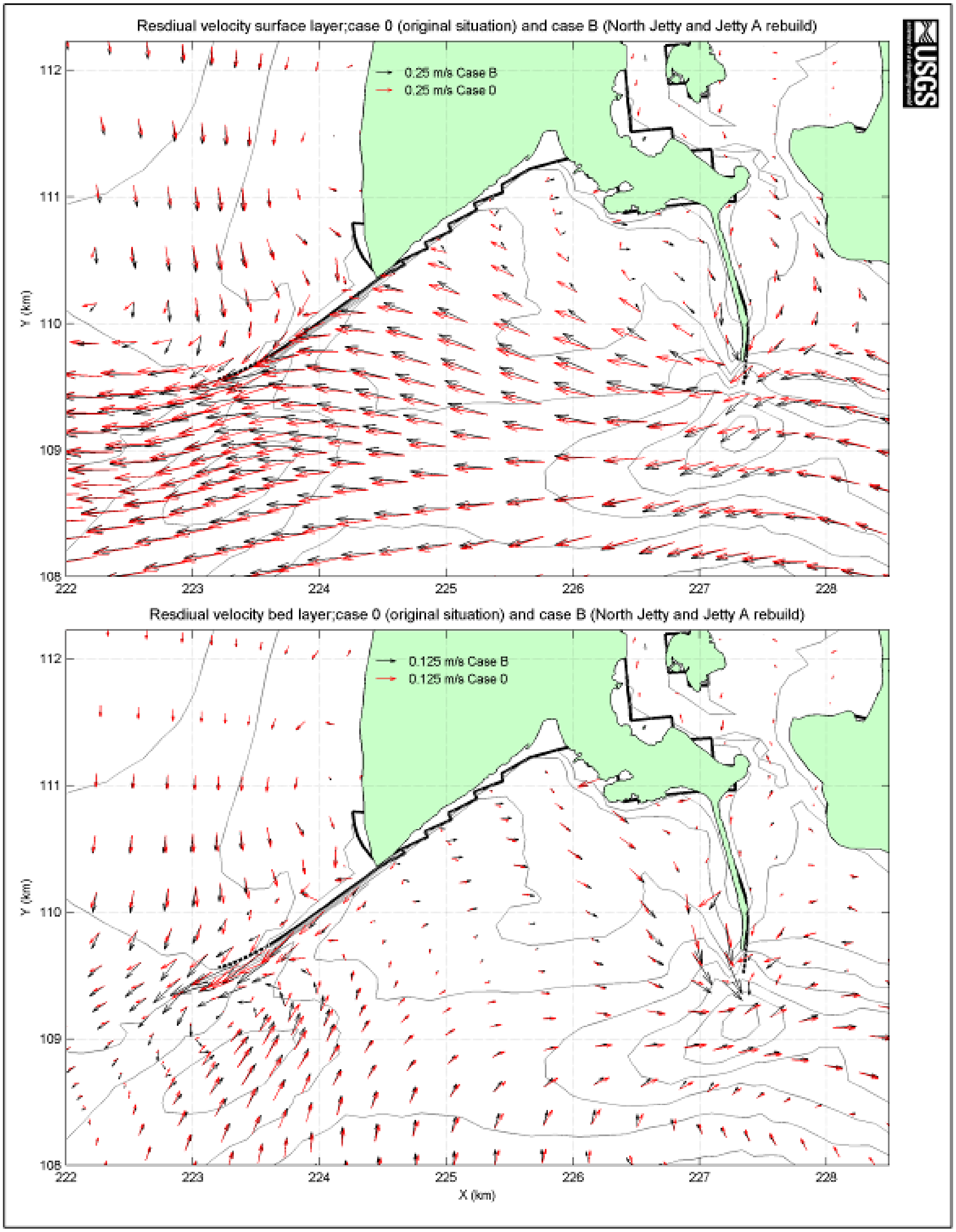
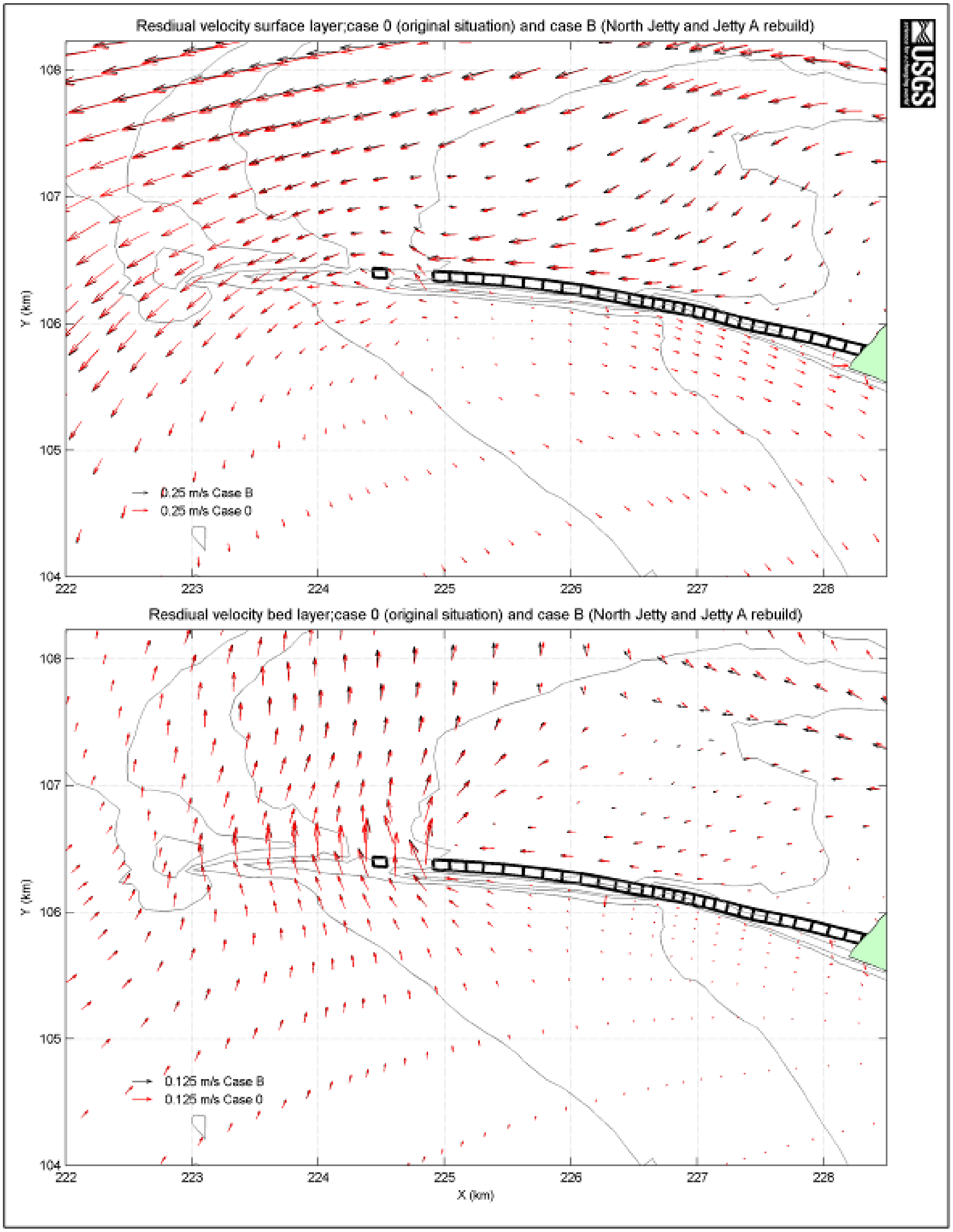


Figure 45. Residual Velocity near South Jetty for August/September Time Window



For the October-November timeframe, the situation was similar to the August-September timeframe in that a relatively large increase to residual bed layer velocity, compared to other areas in the MCR, was predicted on the west side of the south portion of Jetty A to currents oriented in a south-southeast direction (Figure 46) (Moritz 2010, USGS 2007). These changes, however, as with the August-September timeframe, were small as compared to natural variability.

For the October-November timeframe, current direction was predicted to change slightly toward the north as water flows around Jetty A forming a more pronounced clockwise eddying effect west of Jetty A and tending to force water more directly toward the North Jetty (Figure 47). Residual velocities toward the North Jetty are predicted to decrease, however, and this effect would act to protect the North Jetty, as is the case with the August-September timeframe (Moritz 2010, and USGS 2007). Such changes to velocities and currents are even less likely now since the current proposed action does not involve a length rebuild.

For the October-November timeframe, there also were predicted increases in bed layer velocity near the terminus of the North Jetty (Figure 47). Only small changes in residual velocities were predicted for near surface waters near the North Jetty terminus. Changes in surface current direction are similar to those described above for the August-September timeframe. Changes to velocities and current directions were predicted to be minimal for areas near the South Jetty (Figure 48), because these parameters at the South Jetty are essentially unaffected by alterations on the north side of the river (Moritz 2010, USGS 2007). As mentioned above, such changes are unlikely now since the current proposed action does not involve any length rebuild.

Figure 46. Residual Velocity Bed Layer for October/November Time Window

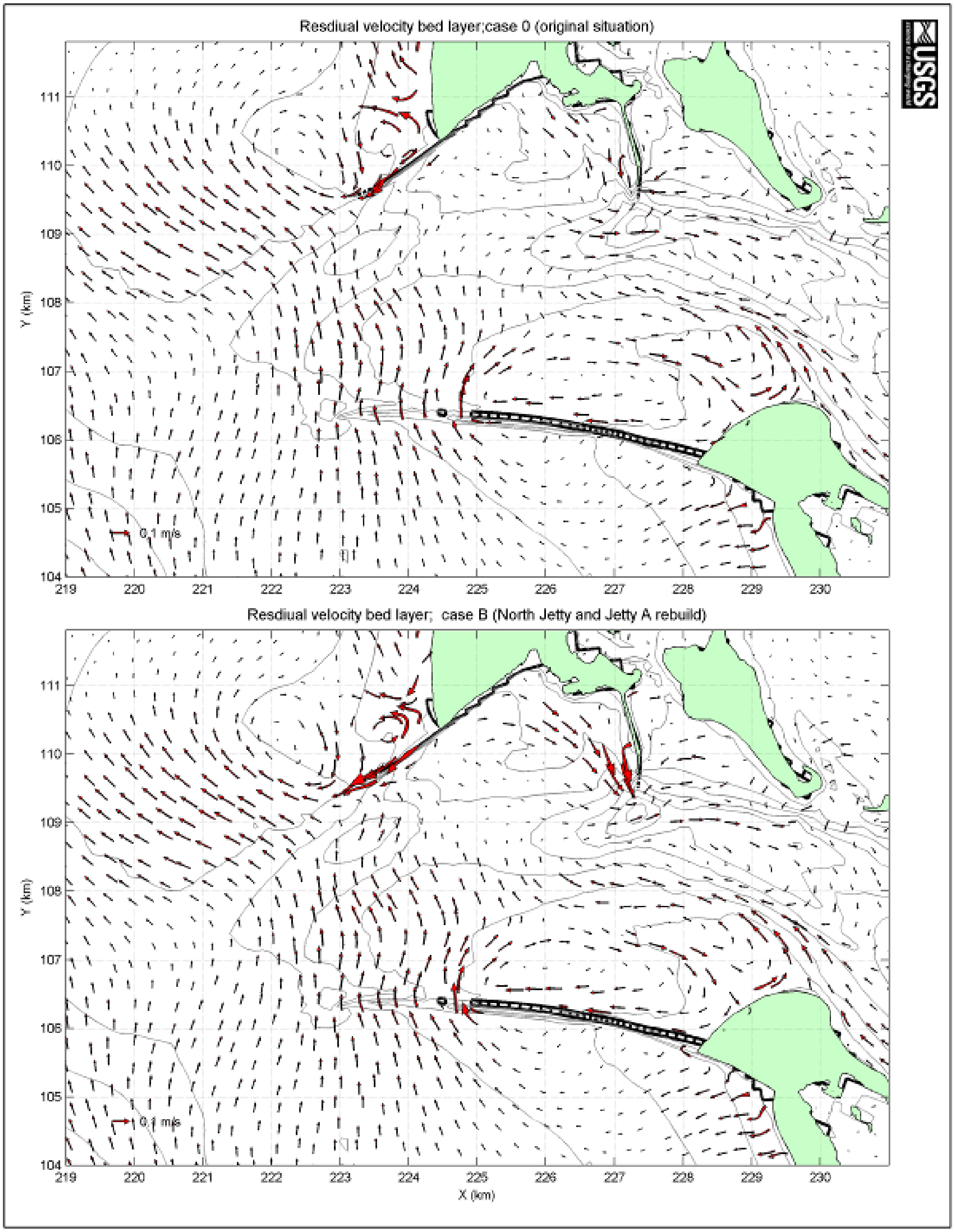


Figure 47. Residual Velocity near North Jetty and Jetty A for October/November Time Window

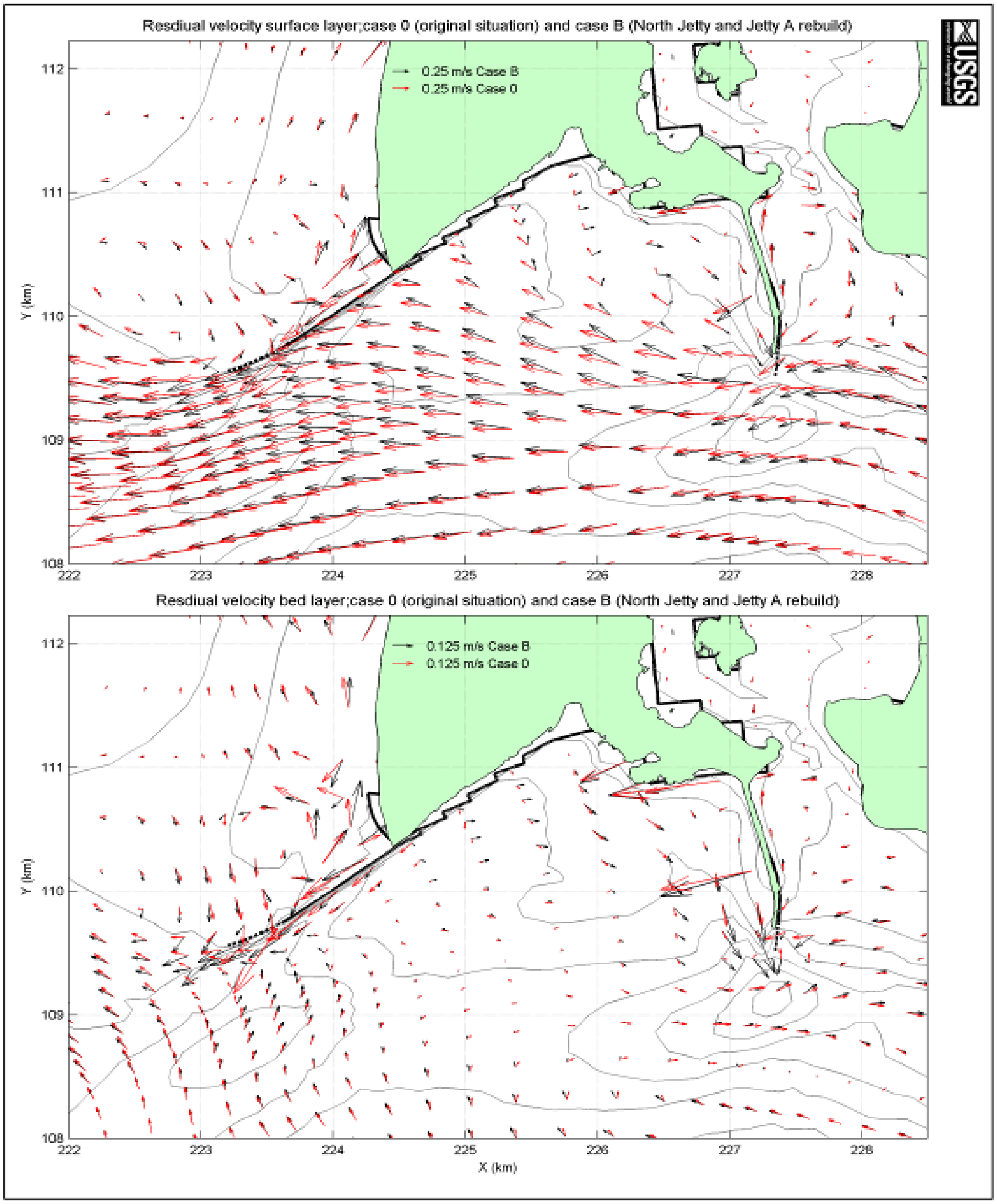
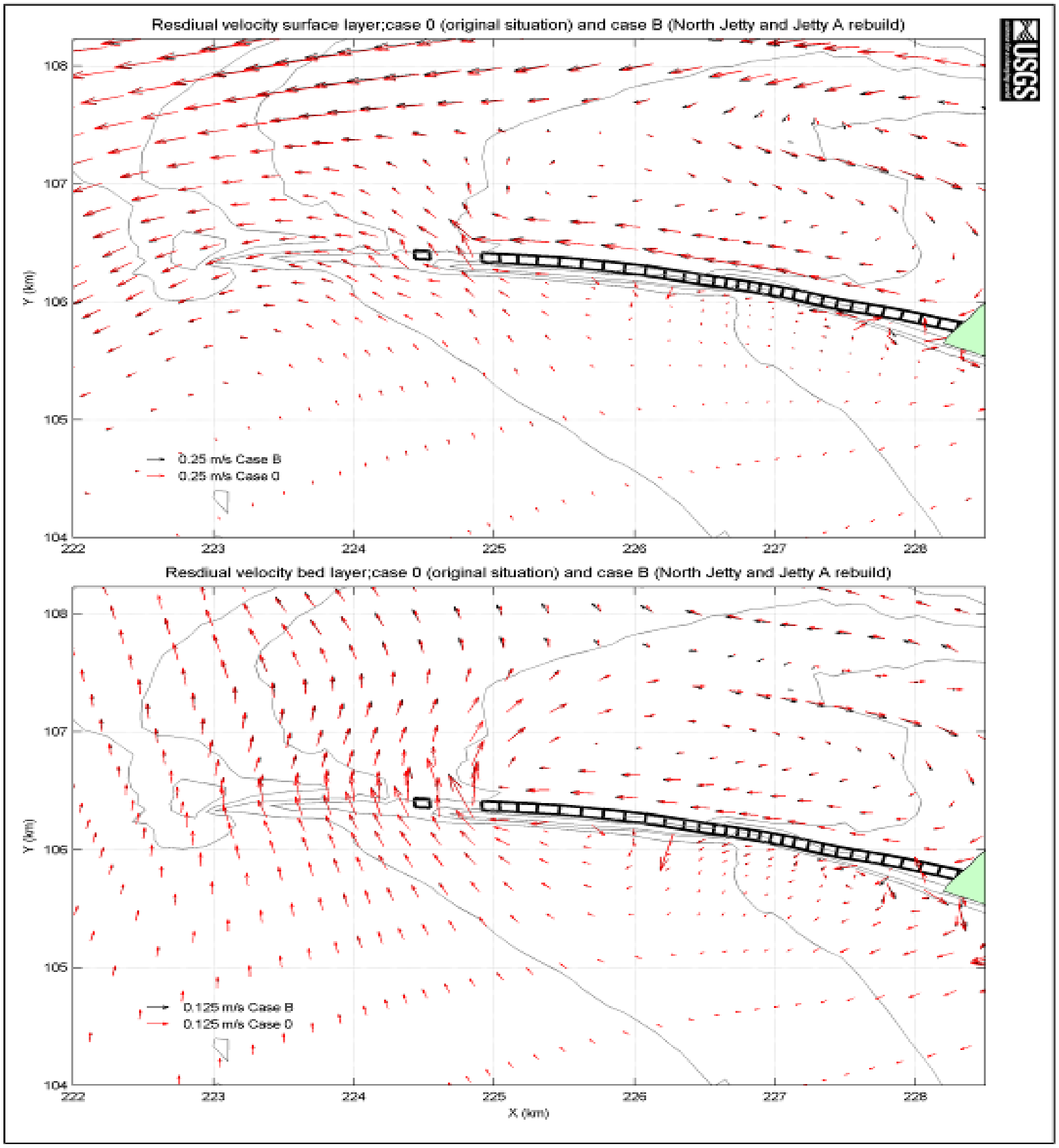


Figure 48. Residual Velocity near South Jetty for October/November Time Window



Salinity

As noted above, the primary factors controlling circulation in the Columbia River estuary are river flow, tides, and currents resulting from the pressure gradient force. Salinity distribution is, in turn, determined by the circulation patterns and the mixing process driven by tidal currents. The variability in the above mentioned parameters also result in large variability in salinity. The USGS modeling results, for example, showed that in near surface waters near the landward portions of the North Jetty, salinity naturally varies with tides to 20 parts per thousand (ppt) during October-November (Moritz 2010, USGS 2007).

As illustrated previously, earlier model results quantified changes to salinity for the length rebuild scenarios. Changes were again negligible despite the larger scale action than what is currently proposed. As before, figures represent changes predicted for action of a larger scope and scale. The representative original condition along with the spur groins is now more reflective of what the likely post-project conditions could entail.

Minor local changes to mean salinity was predicted as a result of implementation of the length rebuild proposed action. For the August-September timeframe, changes to bed layer salinity were predicted in waters between Jetty A and the North Jetty (Figure 49). An increase in mean salinity of 0-4 ppt from 26-28 ppt to 28-30 ppt was predicted to occur over some of this area (Moritz 2010, and USGS 2007) This could be calculated as up to ~ 15% change, but was still well under the 20 ppt (or up to 67%) change range of natural variability. A similar but less extensive salinity pattern was predicted for the near surface layer in waters between Jetty A and the North Jetty, where mean salinity was also predicted to increase 0-4 ppt from 18-20 ppt to 20-22 ppt (Figure 50). For the near surface layer, note that this increase in mean salinity included the area in close proximity to much of the landward portion of the North Jetty. For the near surface layer, a decrease in mean salinity of 0-4 ppt from 12-14 ppt to 14-16 ppt was predicted to occur over a relatively small area south of West Sand Island, which is located just east of Jetty A (Moritz 2010, USGS 2007).

For the October-November timeframe, small patterns of salinity change were also predicted. For the bed layer, a small-scale extrusion of higher salinity water was predicted for the main channel and along the South Jetty as a result of implementation of the proposed action (Figure 51). For example, for the existing condition, salinity in the range of 28-30 ppt occurs just upstream of Jetty A; whereas for the post-project condition, this zone of salinity ended directly south of Jetty A. Only small changes were predicted in the bed layer near the North Jetty. For the surface layer, extrusion of higher salinity water in the main channel was not predicted but was predicted for waters near the South Jetty (Figure 52). For the existing condition, salinity in the range of 24-26 ppt was predicted along the seaward 1/3 of the South Jetty, whereas for the post-project condition this area was predicted to support salinity in the range of 22-24 ppt. A minor reduction of lower salinity waters in the range of 18-20 ppt is predicted for along the landward half of the North Jetty (Moritz 2010, USGS 2007).

In summary, under the rebuild scenario minor local changes to mean salinity were predicted as a result of implementation of jetty build-outs. Even under a larger rebuild, the resulting changes to salinity were also negligible with respect to fluctuations that already occur. No rebuild is proposed under the current action, so any effects to water salinity and plume conditions are even more unlikely.

Figure 49. Mean Salinity for Bed Layer for August/September Time Window

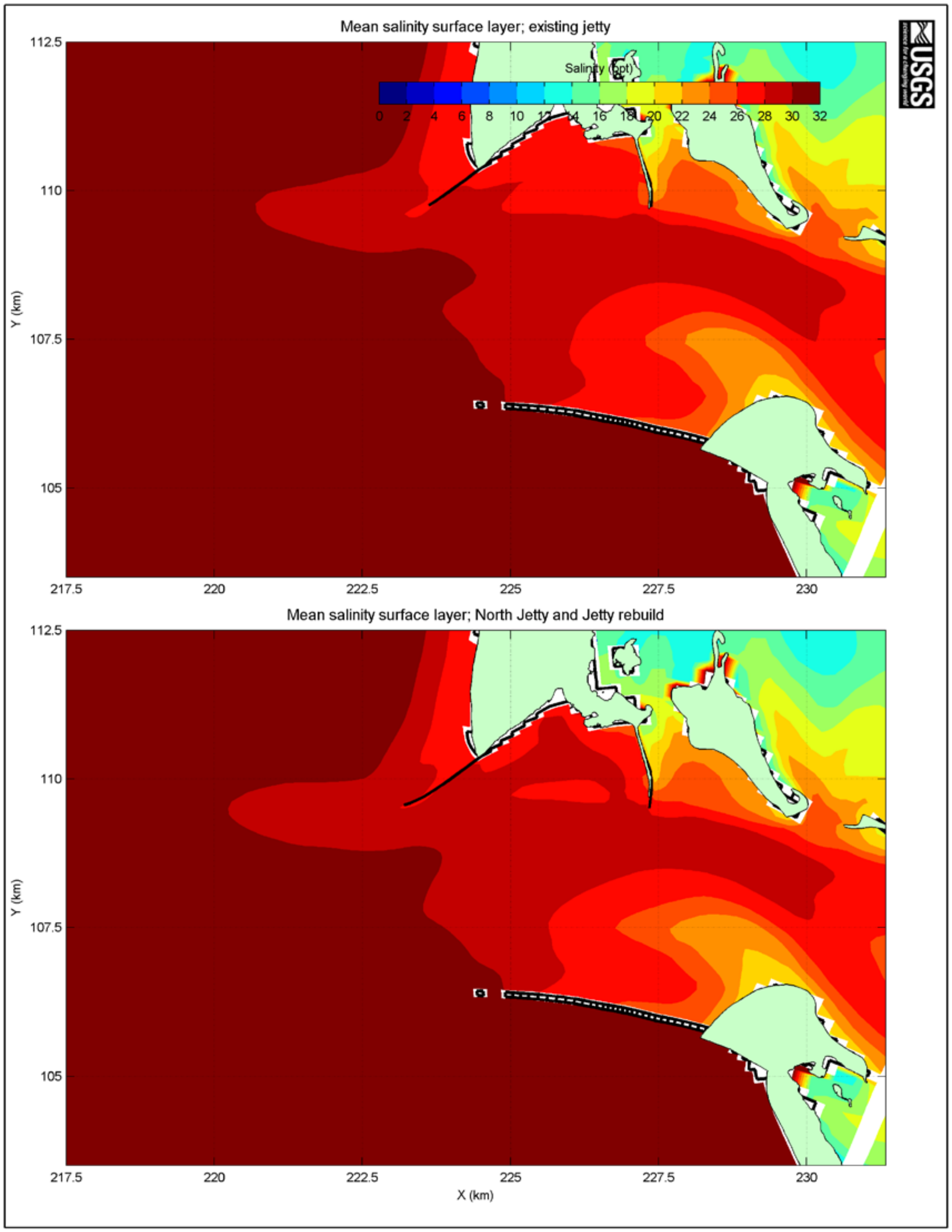


Figure 50. Mean Salinity for Surface Layer for August/September Time Window

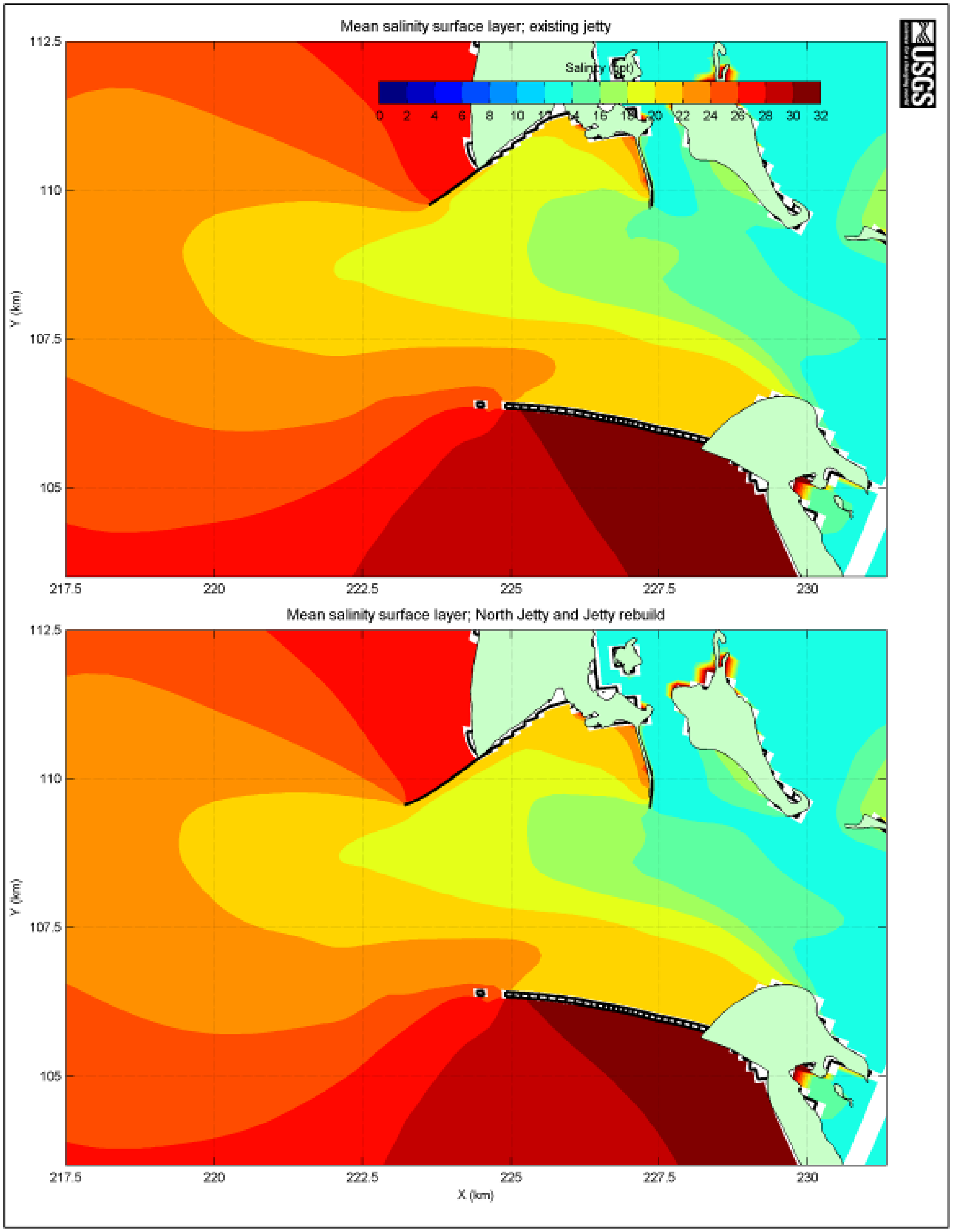


Figure 51. Mean Salinity for Surface Layer for October/November Time Window

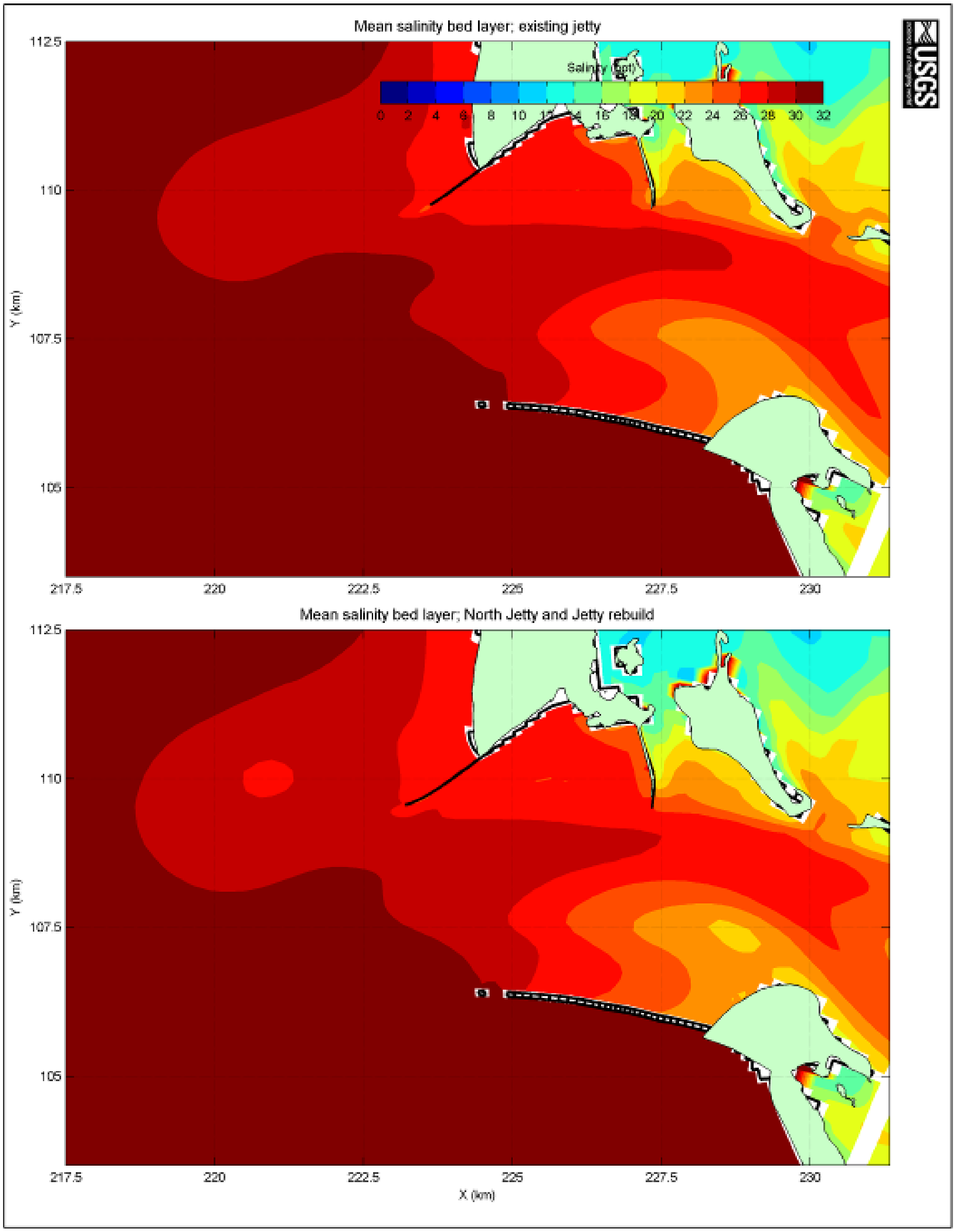
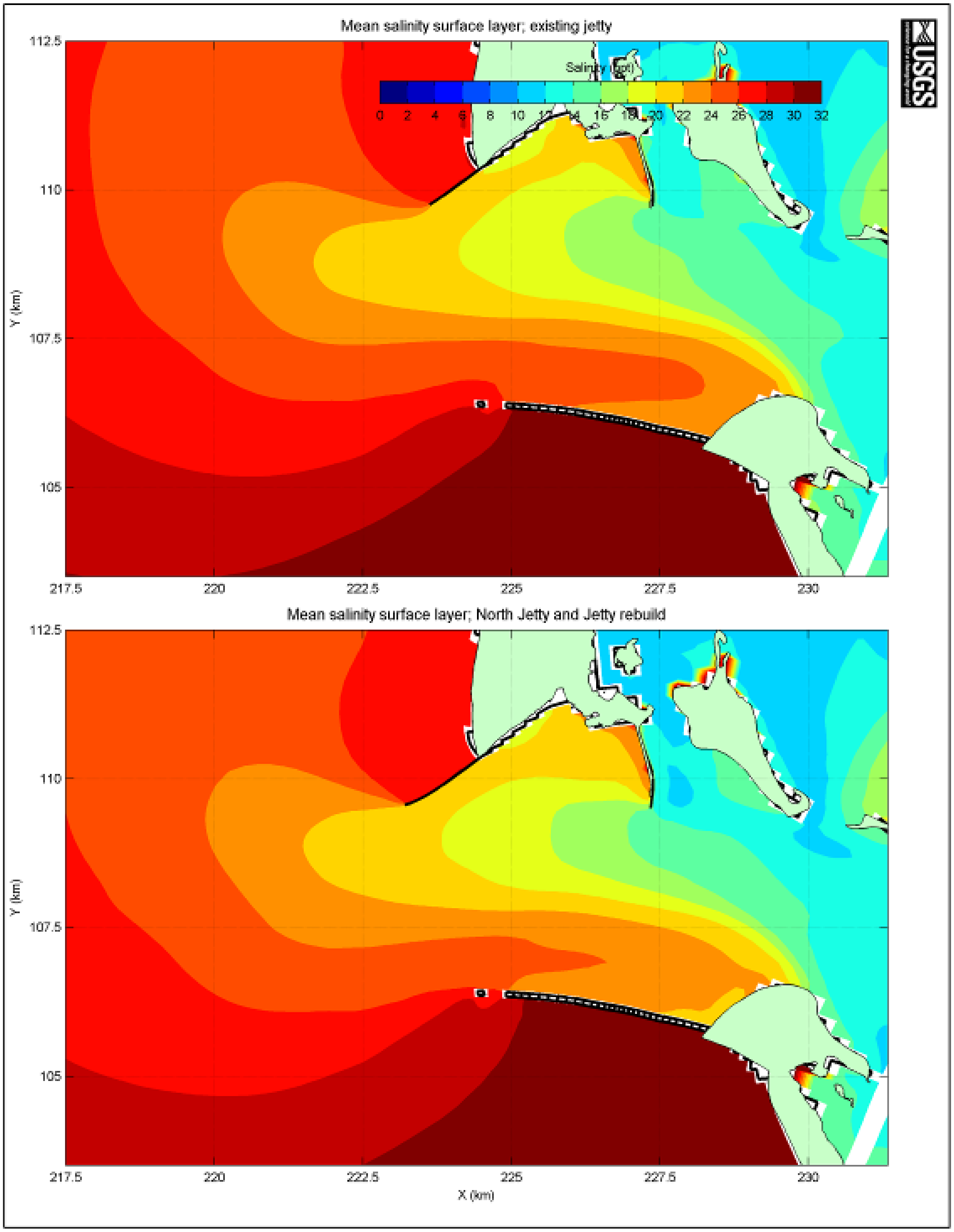


Figure 52. Mean Salinity for Surface Layer for October/November Time Window



Plume Dynamics

The parameters of study in the USGS modeling were predicted to be less affected in the plume than in the entrance itself from construction of the larger rebuild project. It was evident from the above figures that there would be only small predicted changes to residual velocity and current directions for both bed layer and near surface layer for the August-September and October-November timeframes in the plume. A decrease in bed layer salinity of 0-4 ppt (from 28-30 ppt to 26-28 ppt) was predicted in the plume over an oval area west of the terminus of the North Jetty. Only small changes were predicted to residual bed load transport and residual total load transport within the plume for the August-September and October-November timeframes (Moritz 2010, USGS 2007). Under the current proposed action, no length rebuild is included. Because of this smaller scale of action, any minimal changes that were previously predicted under the model comparison would be less likely. The existing conditions of the previous model are somewhat representative of the current proposed action with the addition of spur groins.

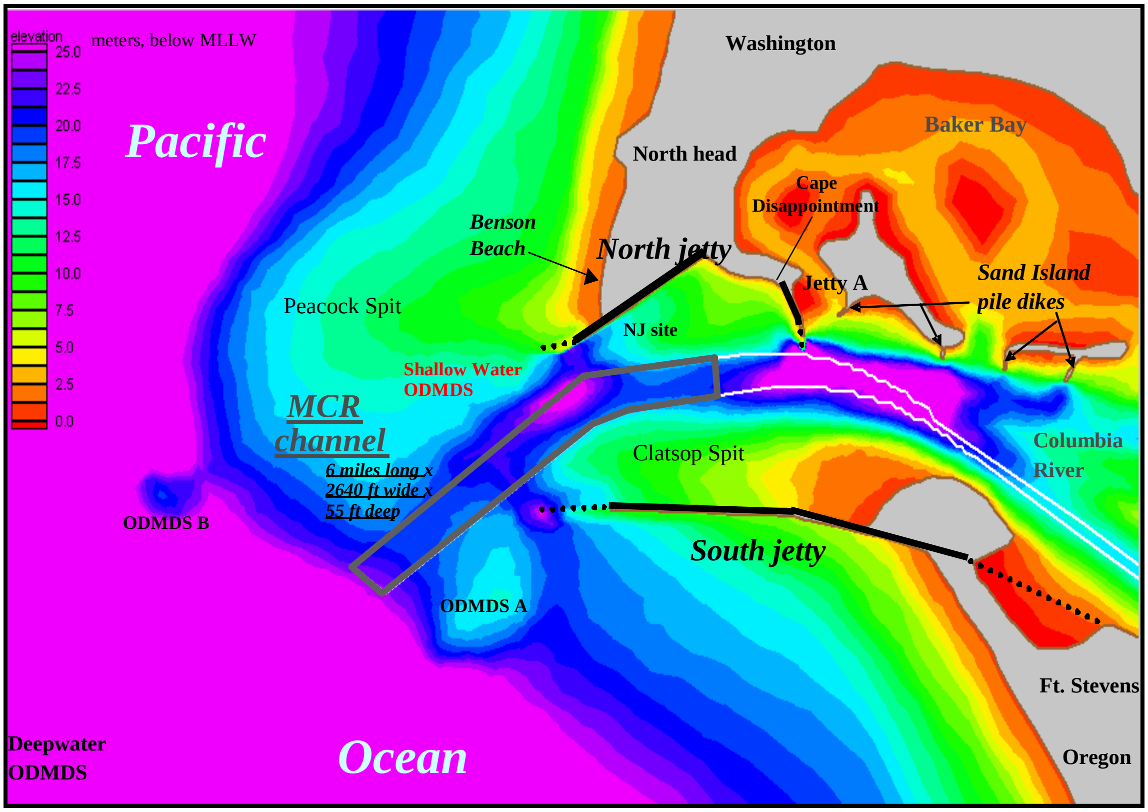
Bed Morphology

Modeling predicted some bed level changes along the seaward channel- side of the North Jetty due to the rebuilt lengths and implementation of spur groins. With longer jetties, change were predicted for both modeled timeframes, but was more pronounced in the winter, with an approximately 8.3% differences in bed elevation of 1.25 to 1.50 meters change from the existing 12 to 24 meters depth. This change is relatively small, however, considering the dynamic environment at the MCR (bathymetry at the MCR is shown in Figure 53). From the ERDC modeling results of the groin structures, it was predicted that a temporary increase in bed level due to sedimentation would occur upstream of the spurs, but that a temporary decrease in bed level due to erosion would occur immediately downstream of the spurs.

There were predicted changes that would occur to bed levels with implementation of the proposed length rebuild project. The most obvious change to bed level would have resulted in deeper water habitat than currently exists along the channel side of the seaward half of the North Jetty. This change was predicted to exist for both the August-September (Figure 54) and October-November (Figure 55) timeframes, but was more pronounced for the latter, with differences in bed elevation of 1.25 to 1.50 meters. This change is relatively small, however, considering that water here is 12 to 24 meters deep (Moritz 2010, Connell and Rosati 2007).

Bed morphology changes were predicted to occur in similar areas during the August-September and October-November timeframes but more scouring and deposition is predicted to occur during the latter. In addition to the result described above for the channel side of the seaward portion of the North Jetty, decreases to bed level with implementation of the proposed action were predicted for a broad area in deep waters of the navigation channel off of Jetty A and deep waters around the seaward portion of Jetty A and for locations north of the North Jetty, which includes shallow nearshore waters. Areas predicted to have an increase in bed level occurred upstream and downstream of Jetty A, downstream of the above-mentioned broad area in the navigation channel, on the ocean side of the North Jetty, and downstream of Clatsop Spit (Moritz 2010, Connell and Rosati 2007). As mentioned before, the scale of the current proposed action is much smaller and precludes a length rebuild. Therefore, any changes previously predicted would be even smaller or unlikely.

Figure 53. Bathymetry at the MCR



From the ERDC modeling results of the groin structures, it is predicted that a temporary increase in bed level due to sedimentation would occur upstream of the spurs, but that a temporary decrease in bed level due to erosion would occur immediately downstream of the spurs (Moritz 2010, Connell and Rosati 2007).

Temporally, effects from hydraulics and hydrologic process would occur as a single event with construction as described under Rock Placement. Any minor subsequent effects would be long-term, but are discountable within the range of natural dynamic conditions and are of limited geographical extent.

In summary, previous modeling results indicated the changes to velocities, currents, salinity, plume dynamics, and bed morphology were minimal under the much larger jetty length rebuild scenario. Also, the existing or “original” conditions of the previous model represented lengths that are retained under the current proposed action. Because of previous results, no significant overall changes to the hydraulics or hydrology of the MCR system are anticipated under the new, smaller proposed action.

Figure 54. Difference in Bed Level (meters) for August/September Time Window

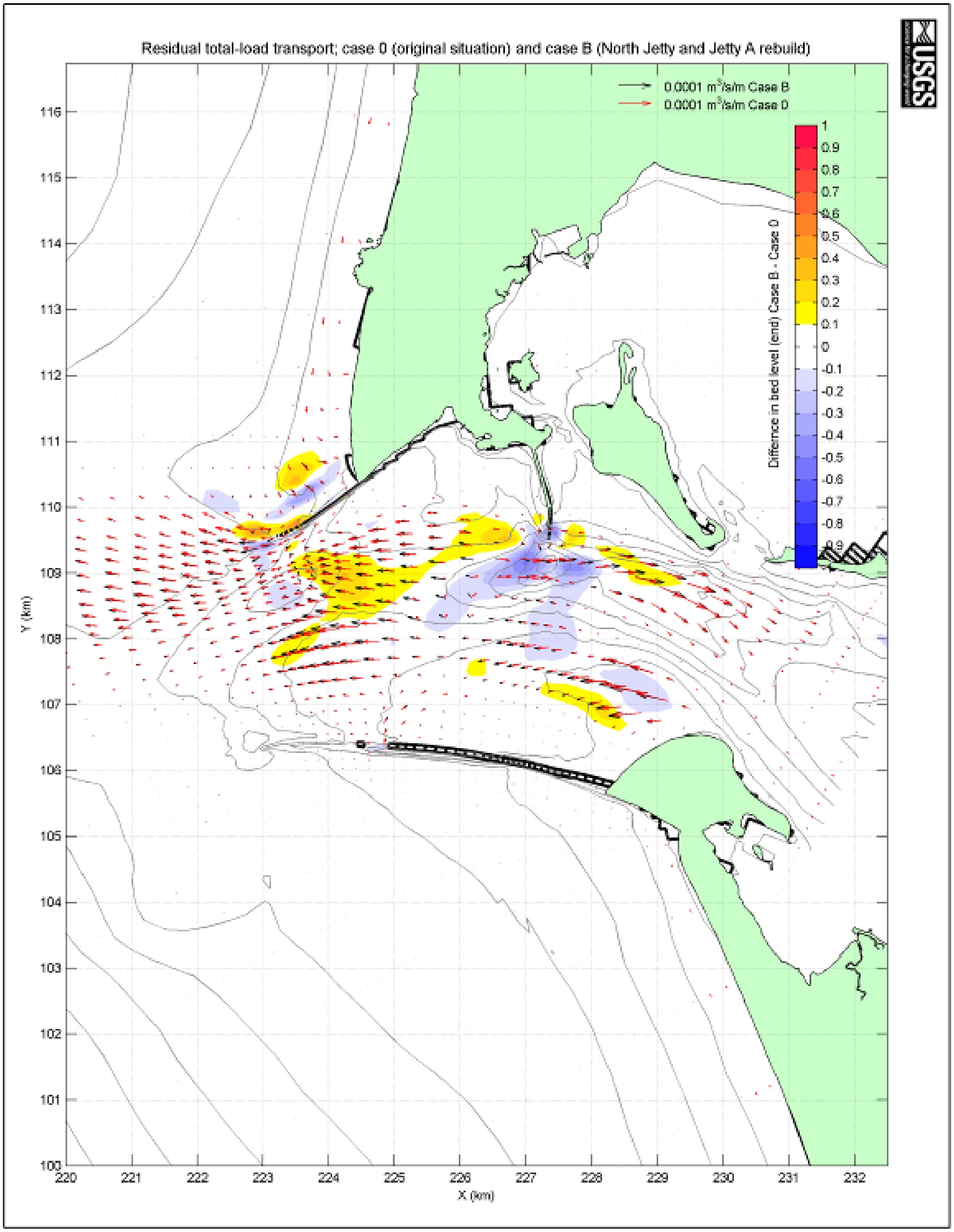
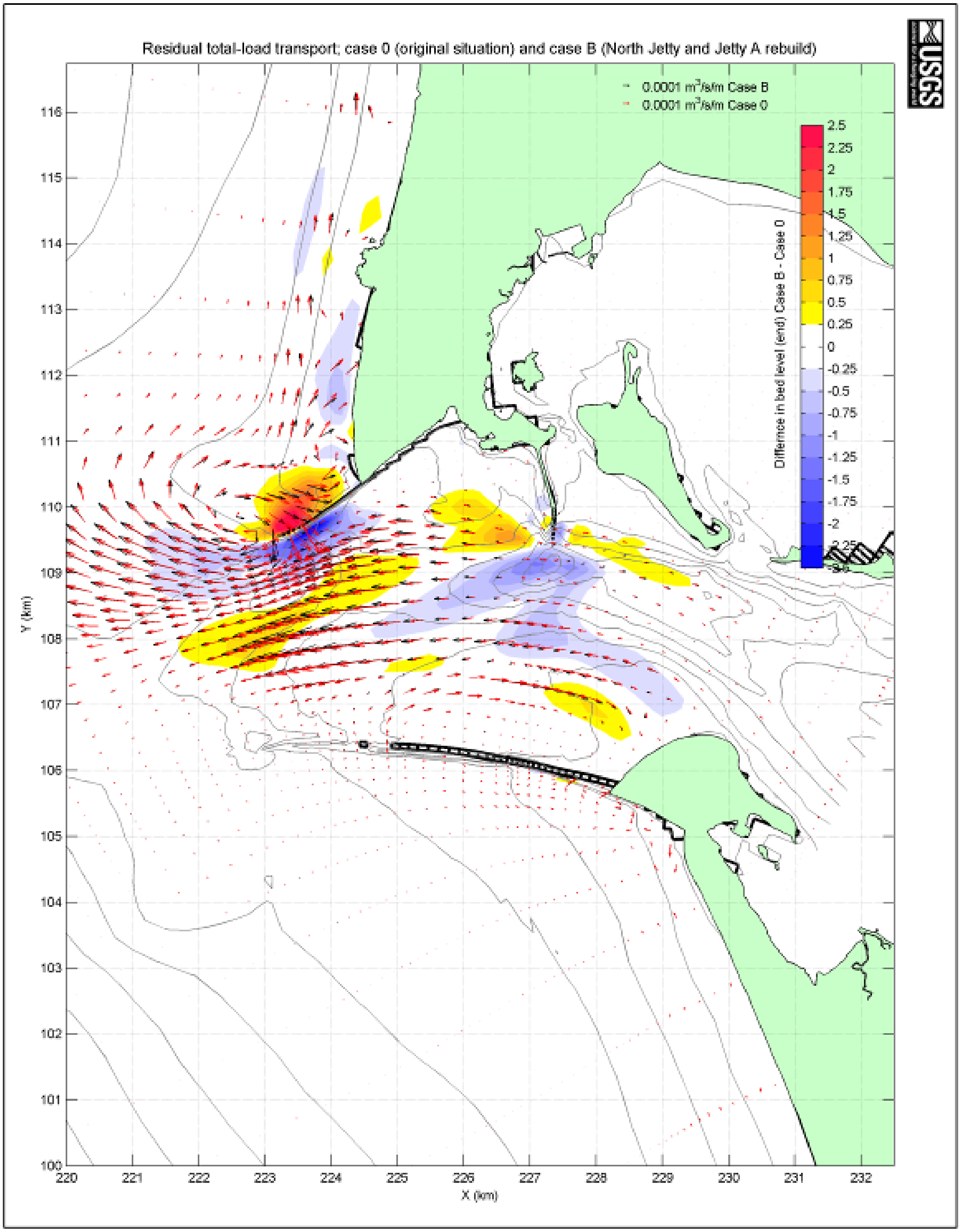


Figure 55. Difference in Bed Level (meters) for October/November Time Window



Wetland Mitigation and Habitat Improvements

In this BA, the Corps has proposed ecosystem restoration at its discretion under Section 7(a) (1) of the ESA. These actions will restore and improve the habitat for the benefit of listed and candidate salmonid species as well as other native species found in the lower Columbia River ecosystem. Under the Clean Water Act, the Corps is also required to provide mitigation for wetland impacts. The Corps will develop detailed proposals, which will be coordinated with the Services and State partners, and then work to implement them using the AMT.

As described in the proposed action, the Corps has developed a wetland mitigation and habitat improvement package with a suite of potential actions to offset wetland impacts and to improve shallow-water habitats. In the long term, implementation of wetland mitigation and habitat improvement actions along with upland plantings will increase the overall square footage of wetlands and improve uplands, potentially also improving wetland-stream hydrologic functions in the Columbia River estuary. Restoration of low saltwater marsh habitat will improve resting and rearing habitat access for juvenile fish, as well as improved and increased instream and riparian and estuarine functions; for example, creation of brackish intertidal and mudflat habitat, restoration of hydrologic regimes, and improvement of riparian and canopy cover. These actions will be focused on higher value habitats and functions than those which are being affected in the immediate vicinity of the jetties. Possible restoration of snowy plover habitat at the Clatsop Spit would be coordinated with OPRD and USFW to ensure that actions fit within the HCP and provided the necessary ecological elements.

Actions could also increase estuarine productivity lower in the Columbia River system for a wide range of species. Re-establishment of native plant communities and improvement of riparian functions would improve water quality function, habitat complexity, and trophic inputs. Reintroduction of a greater range of flows and more natural tidal regimes to uplands and diked pasturelands would also improve the likelihood of re-establishing native intertidal species. Re-establishing hydrologic and tidal regimes increases the opportunity to develop edge networks, dendritic channels, and mud flat habitats for use by listed species. Increased benthic habitat could also improve food web productivity. Dike breaches and tide and culvert retrofits would also increase adult fish passage and restore access to expanded spawning and rearing areas.

In relationship to the recovery plan in the estuary module (NMFS 2007c), the 7 (a) (1) actions being proposed by the Corps address threats identified in the recovery plan, and specifically relate to Columbia River Estuary (CRE) management actions. Depending on final plan selection, habitat improvements may specifically address the following CRE actions: 1 (riparian protection and restoration); 4 (restoring flow regimes via improved/restored tributary hydrologic connectivity); 5 (replenishment of littoral cell via beneficial use of dredged materials); 8 (removal of pile dikes); 9 (protection of remaining high-quality off-channel habitat from degradation), and; 10 (improvement of off-channel habitat via levee and dike breaches). Several of these CREs were also in the higher rankings for benefits with implementation, and higher percentages for Survival Improvement Targets (NMFS 2007c).

Therefore, the Corps expects these actions to have either direct or indirect long-term beneficial rather than adverse effects to most of the listed species and their designated critical habitat in the action area. In the short-term, temporary disturbance and increased suspended sediment may result in higher turbidity during in-water construction at restoration sites. This is not likely to occur during upland planting. However, these actions will be limited in duration and intensity, as BMPs to reduce and avoid pollutant runoff described in the proposed action would also be applicable to actions at restoration sites. Suspended sediments from in-water work will be monitored per State Certification conditions, and appropriate BMPs to minimize turbidity will also be implemented to ensure levels do not reach a duration or intensity that will harm species.

For invasive species removal, the Corps proposes to use no herbicides within 100 feet of the Columbia River or associated water bodies, and therefore, does not expect increased pollutant loads or effects on instream or riparian function. Short-term noise disturbances are likely to attenuate near the source and project locations are likely to be much further away from habitat used by marine mammals. These acoustic effects will likely be minimal and discountable.

Temporally, implementation of different components of wetland mitigation and habitat improvement projects could occur throughout the year. It would likely be possible to complete associate in-water work during the appropriate in-water work windows that protect listed species. Concurrent with initial impacts to wetlands, construction would likely occur in one or two seasons with subsequent monitoring. Temporally, this limits the repetition of disturbance activities associated with the construction of these projects. Short-term effects to water quality may occur on a daily basis, but would be limited and similar to those describe in the Water Quality effects discussion.

EFFECTS OF THE ACTION ON LISTED SPECIES

Harassment applies to actions that create the potential for injury by significantly disrupting normal behavioral patterns including breeding, spawning, rearing, migrating, feeding or sheltering. To be significant, harassment must be capable of resulting in the death or injury of fish or wildlife. Harm applies to actions that result in actual injury or death, including actions that cause environmental damage leading to injury or death.

Based on habitat needs, migratory patterns, and residence time, listed birds including marbled murrelets, snowy plover, and northern spotted owls may be present in the action area during the proposed period of jetty repair, rehabilitation, and maintenance operations. Similarly, listed mammals, fish, invertebrates, or plants, including Columbia white tailed deer may have potential or designated critical habitat in the vicinity of MCR.

Marbled Murrelet *(Brachyramphus marmoratus)* – Threatened

Occurrence and Discussion: The marbled murrelet is a small, robin-sized, diving, near-shore marine bird that is most frequently observed within 1.5 miles of shore (Marshall 1988). Marbled murrelets forage just beyond the breaker-line and along the sides of river mouths where greater upwelling and less turbulence occurs. Sealy (1975) cited in Marshall (1988) reported that murrelets foraged within 500 meters of shore. Murrelets forage within the water column; prey items include invertebrates and small fish such as anchovy, herring, and Pacific sandlance (Marshall 1988). Sandlance are known to occur in estuaries (NOAA Fisheries 1991). Murrelets spends the majority of time on the ocean, roosting and feeding, but come inland up to 80 kilometers (50 miles) to nest in forest stands with old growth forest characteristics (USFW 2010). Marbled murrelets nest from mid-April to late September, and adults feed the chick at least once per day, flying in (primarily at dawn and dusk) from feeding on the ocean, carrying one fish at a time (USFW 2010).

Currently, the largest concentrations of marbled murrelets in Oregon are thought to occur off the central coast (Marshall 1988) between Depoe Bay and Coos Bay. Lincoln and Lane Counties, which comprise a large block of the central Oregon coast, were historic centers of abundance for marbled murrelets in Oregon (FR 1991). Initial results from Strong (1992) indicate that abundance of murrelets is relatively higher on the central Oregon coast than the northern Oregon coast. Strong (1992) also found that murrelet occurrence was patchy and that use of specific locations was not consistent. Strong et al. (1995) recorded less than 10 marbled murrelets on average for boat and shore-based surveys of marbled murrelets off the MCR. They reported that murrelets were concentrated within 1 km of shore in 1992 but broadly scattered within 5 km of shore in 1993. Strong (1997; field notes on presence of marbled murrelets in the Umpqua River estuary and other Oregon coastal river mouths) noted that "Marbled murrelets in general are uncommon to absent in the river mouth/estuarine environment during summer in Oregon" (Bayer 1988).

Marbled murrelets nest in old growth/mature coniferous forests. The low incidence of marbled murrelets at coastal locations is probably related to the loss of old growth coniferous forest from harvest and/or fire on near-coastal lands (FR 1991). Marbled murrelets are expected to occur in the general vicinity of the MCR. The Cape Disappointment area contains suitable habitat for marbled murrelet nesting. While nesting has not been documented in the Cape Disappointment area, birds have frequently been noted in flight during the nesting season and doubtlessly nest in the area. This potential nesting area is located about 1.6 miles northeast of the South Jetty at Benson Beach.

Marbled murrelets are expected to occur in the general vicinity of the MCR, specifically on the Columbia River bar and nearshore (<5 km) waters. Their numbers are anticipated to be low throughout the general project area but activities within the MCR Navigation Channel may result in occasional disturbance of marbled murrelets on the water.

Previous modeling results predicted from a larger-scale, length-rebuild scenario indicated only minimal changes to hydrology and hydraulics in the larger MCR system. Results remain informative because the relatively small changes anticipated from a larger action were still not expected to have significant negative on sediment transport, plume dynamics, bed morphology, or velocities in the system. The smaller currently proposed action, which only includes spur groins and not additional lengths from the original model, would be expected to have even fewer effects. The most significant scouring effects that were predicted at the seaward half of the North Jetty and near the tip of Jetty A are no longer as likely under the current scenario, as no changes in lengths are proposed. Maximum change to bed level was predicted to be 1.25 to 1.50 meters in these areas, which was a small percentage (8%) of the existing 12-24m depth. This scouring was also predicted to occur in deep areas. Bed load effects from accretion on the leeward side of spur groins may be more relevant, but were not expected to be significant enough to alter habitat use or foraging opportunities. Presentation of predicted changes and an analysis of effects of changes to the MCR on anadromous fish and sea lions are presented in Corps (2007 and 2010) and available upon request. Changes in these parameters seaward of the tips of the jetties is predicted to be negligible and should have no adverse impact on feeding of marbled murrelets. Minor changes to salinities, current velocities and directions, and bed morphology are unlikely and discountable, especially relative to natural variation and should also have no adverse impact on feeding of murrelets that may occasionally occur in the Columbia River.

Murrelets are susceptible to noise disturbance. Adult murrelets typically switch incubation duties on the nest about 1 hour before sunrise, and this is the most critical time for impacts from noise (personal communication with Greg Smith, U.S. Fish and Wildlife Service on May 28, 2004). Though within the navigation channels, rock transport could increase the possible disturbance of murrelets, this is unlikely to occur. Adult species are likely already attuned to vessel traffic, and the proposed action will also not cause a significant increase in the intensity of barge traffic levels. Any encounters with barge traffic will be transitory and discountable. Vehicle traffic may cause some acoustic disturbance during the work day as trucks haul rock into the North Jetty site. However, sound levels are expected to return to near back-ground conditions a short distance from the source. Conservation measures limiting traffic timing and use of jake brakes will further reduce any possible exposure to acoustic effects. Therefore, exposure to acoustic effects would be geographically and temporally limited. Proposed actions are not expected to have significant long-term impacts to nesting or foraging behaviors.

Marbled Murrelet Critical Habitat:
According to USFW, nesting locations generally include dense shady forests characterized by large trees with large branches or deformities for use as nest platforms (2010). Murrelets nest in stands varying in size, however, larger, unfragmented stands of old growth Douglas fir appear to be the highest quality habitat for marbled murrelet nesting (USFW 2010). Benson Beach and the Clatsop Spit have large areas of land that have accreted since the construction of the jetty system and are not old enough to have evolved these forest characteristics. These nesting conditions do not exist in the immediate vicinity where a majority of the proposed construction activities will occur. Neither Benson Beach nor Clatsop Spit are designated Critical Habitat.

Actions are not expected to remove or kill trees with suitable platforms, and large diameter trees with well-developed canopies will not be impacted by construction activities. Therefore, actions will not reduce the suitability or development of the stand as nesting habitat. The Corps has determined the proposed actions will have ***No Effect*** on marbled murrelet critical habitat.

In addition to standard environmental protection measures to be included in the contract specifications, measures 1, 2, and 3 will be employed during the marbled murrelet nesting season (April 1 – September 15) to reduce impacts from noise to nesting marbled murrelets on the Washington side, and measure 4 will be considered to create western snowy plover nesting habitat:

1. Trucks will only be allowed to use the roads through Cape Disappointment State Park during daylight hours.

2. Trucks will not unnecessarily stop along the roads through Cape Disappointment State Park.

3. Trucks will be prohibited from using compression brakes (also known as jake brakes) on the roads through Cape Disappointment State Park.

Conclusion: The proposed work is located approximately 1.6 miles from potential nesting areas. Marbled murrelets likely will occur and nest in the project vicinity during construction, and periodic minor disturbance may occur due to noise generated from trucks on the haul roads through Washington State Parks property adjacent to probable nesting habitat. However, truck traffic will occur only during daylight hours (Conservation Measure 1 under the Proposed Action – Additional Conservation Measures section) and noise and disturbance-reducing measures will be implemented (Conservation Measures 2 and 3 also under the Proposed Action – Additional Conservation Measures section). Abundant foraging habitat is available adjacent to the activity and any disturbance on the water would be minor and temporary. Additionally, disturbance on the water by transitory ships will be intermittent and temporary, and is not expected to cause adverse impacts to feeding behaviors. Therefore, the Corps has determined that the proposed action ***May Affect but is Not Likely to Adversely Affect*** marbled murrelets.

Western Snowy Plover *(Charadrius alexandrinus nivosus)* – Threatened

Occurrence and Discussion: The western snowy plover is a small shorebird that nests above the high tide beside or near tidal waters and on the mainland coast, peninsulas, offshore islands, adjacent bays and estuaries from southern Washington to southern Baja California, Mexico, often returning to the same breeding site yearly (USFW 2010b). Snowy plovers are primarily visual foragers feeding on invertebrates in the wet sand and among surf-cast kelp within the intertidal zone, in dry, sandy areas above the high tide, on salt pans, and along the edges of salt marshes, salt ponds, and lagoons (USFW 2010b).

Plover nesting season extends from early March through late September when they lay their eggs in shallow depressions of loose soil or in sandy or salty areas with generally little vegetation or driftwood (USFW 2010b). Chicks are especially vulnerable to predation, as adult plovers do not feed them, but lead them to suitable feeding areas (USFW 2010b). Most chick mortality occurs within six days after hatching (USFW 2010b).

Western snowy plovers historically occurred in the vicinity of Clatsop Spit, Oregon. Mean averages from 1902-1985 estimated breeding and winter populations of about 9 and 1 respectively (ODFW 2005). No breeding or wintering populations have been reported from these beaches in recent years (U.S. Fish and Wildlife Service, 2001 and 2007). Prior surveys completed indicated that the last breeding population (late May/early June, (USFW 2010j)) was observed on the Clatsop Spit in 1984, and the last winter population (winter window- December 1 and January 31, (USFW 2010j)) in 1985 (ODFW 2005). In the more recent past, incidental observations occurred on January 13, 2008 – at river beach at South Jetty; in 2007 on September 5, - one plover, Clatsop Beach (a few miles s. of Peter Iredale), and November 29 – one plover Del Ray Beach; and on October 2003 - 8-10 unconfirmed plovers on a mud flat furthermost north from the jetty (Columbia River, S jetty). Evidence for the current lack of winter or breeding populations was supported by a survey completed by USFW and Corps representatives on May 20, 2010, when no plovers were observed. A small population of western snowy plovers occurs on beaches at Leadbetter Point, Washington, which is greater than 20 miles north of the general project vicinity. Other Washington locations where western snowy plovers are known to occur (e.g., Dammon Point, Conner Creek, and Midway Beach) are farther north. The nearest Oregon location is far south of the project site at Bayocean Spit in Tillamook County. Neither Benson Beach nor Clatsop Spit are designated Critical Habitat, though a Habitat Conservation Plan (HCP) has been developed for Clatsop Spit. This is illustrated in the following figure from the Final OPRD/USFW HCP (2010), and can be visually compared with the planned staging and storage areas illustrated in the Proposed Action.

Figure 56. Boundary of Habitat Conservation Plan at the Clatsop Spit

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Figure 2-2
Boundary of Snowy Plover Management Area
within Fort Stevens State Park

Most of the land-based construction activities will occur above the MHHW levels in the near and immediate vicinity of the jetties. The area proposed for construction, storage, and staging is mostly or completely outside of the area on Clatsop Spit identified in the HCP. If the northwestern most portions of the staging area are needed, a small portion of the southern-most border of the HCP may be affected. However, because habitat creation areas could occur anywhere within the polygon, there is unlikely to be overlap with adjacent construction activities. Additionally, Corps habitat improvement actions may improve nesting areas for snowy plover in the Clatsop Spit.

Except for areas near the offloading facility near Parking Area D and at the South Jetty and root foredune, the bulk of the construction, stockpile, and staging areas will be concentrated more towards the inland of the Spit. If snowy plover nesting were to occur, it is more likely that snowy plovers would use the river-side on the northern portion of the Spit in the area identified under the HCP and illustrated in the previous figure. Furthermore, in areas cleared for construction use, the presence of large machinery, human activity, and large stone likely reduces the suitability for immediate habitat usage, as these elements would create a higher density of activities, structure, and vertical complexity than seems to be preferred for nesting habitat. Therefore, this limits the geographical extent of the disturbance effects from construction clearing, and reduces the likelihood that actions would occur in areas preferred by snowy plover. According to USFW, introduced European beachgrass (*Ammophila arenaria*) reduces the amount of open, sandy habitat and contributes to steepened beaches, and increases habitat for predators (USFWb). These conditions are problematic at the Spit, and may actually be improved by the proposed clearing for stockpiling and construction staging and eventual replanting of native dune plants.

Recreation activities at the Spit have also increased the intensity of human use in the vicinity. Recreation will likely be somewhat impacted by periodic construction closures, when human activities would then be more concentrated in the areas previously identified for construction rather than recreational activities occurring on the beaches.

Furthermore, as described under the proposed actions, the Corps is currently investigating 7 (a) 1 opportunities to create plover nesting habitat on Clatsop Spit (Conservation Measure 4 under the Proposed Action – Additional Conservation Measures section and re-copied above). Details of this action including location and appropriate timing will be further developed and refined by the Corps and coordinated with the resources agencies through the use of the annual AMT. The Site Management Plan under development with Oregon Parks and Recreation will further inform this action. Additionally on December 17, 2010, the Corps joined the U.S. Fish and Wildlife Service, along with other federal agencies and the State of Oregon for sign-off on a Memorandum of Understanding regarding the statewide HCP for Snowy Plover.

Conclusion: Though construction activities are proposed in the vicinity of areas of historical winter and breeding snowy plover populations, there is no current plover use. The Spit has not been designated as Critical Habitat. Because activities are not proposed for below MHHW and are expected to be concentrated in the interior behind a protective vegetative buffer, there is little likelihood of impacting nesting habitat. Staging areas will contain associated construction elements and likely year-round human activity that will reduce the likelihood of nesting in the newly cleared areas. Proposed staging areas are excluded from the north end of the Spit, where the HCP boundary has been identified. Therefore, the likelihood of species presence and exposure to effects is very low. However, it is conceivable that throughout the lifetime of the project, species could be observed during implementation of the proposed action. If species nested within areas identified for activities under the proposed action, then they could experience disturbance effects. Should species be observed or should this occur, the Corps would immediately inform resource agencies and the AMT to discuss and determine next steps. Therefore, the Corps has concluded that because no plovers have been reported in the vicinity of the project in recent years but because the proposed action is within the range of historic use, the proposed project may affect, but is ***not likely to adversely affect*** western snowy plovers.

Short-tailed Albatross *(Phoebastria albatrus)* – Endangered

Occurrence and Discussion: The short-tailed albatross was listed as endangered in the U.S. in 2001. It has been listed since 1970 outside the U.S. and nests on islands south of Japan. The short-tailed albatross is a large pelagic bird with long narrow wings adapted for soaring just above the water surface, and its diet includes squid, fish, eggs of flying fish, shrimp, and other crustaceans (USFW 2010c). This species may occur off the Oregon and Washington coasts, though there is no critical habitat designation.

There have been three confirmed records of short-tailed albatross off the coast of Oregon. The closest was 20 miles southwest of the MCR (Marshall et al. 2003).

Conclusion: Since the short-tailed albatross is not expected in the vicinity of the MCR and there is no designated critical habitat at MCR, the proposed action would have ***No Effect*** on this species.

Northern Spotted Owl *(Strix occidentalis caurina)* – Threatened

The northern spotted owl was federally listed as threatened under the Endangered Species Act in 1990, with critical habitat designated in 1992 and revised in 2008 (USFWd). They are believed to have historically inhabited most forests throughout southwestern British Columbia, western Washington and Oregon, and northwestern California as far south as the San Francisco Bay, though today they are particularly rare in the Coast ranges of southwest Washington and northwest Oregon (USFWd).

Northern spotted owls are nocturnal "perch-and-pounce" predators that generally prey primarily on small forest mammals and nest from February to June, with parental care of the juveniles lasting into September (USFWd). Spotted owls live in forests characterized by dense canopy closure of mature and old-growth trees, abundant logs, standing snags, and live trees with broken tops and prefer older forest stands with variety: multi-layered canopies of several tree species of varying size and age, both standing and fallen dead trees, and open space among the lower branches to allow flight under the canopy (USFWd). Benson Beach and the Clatsop Spit have large areas of land that have accreted since the construction of the jetty system and are not old enough to have evolved these forest characteristics. These habitat conditions do not exist in the immediate vicinity where a majority of the proposed construction activities will occur. Neither Benson Beach nor Clatsop Spit are designated Critical Habitat

Conclusion: Since the northern spotted owls are not expected in the vicinity of the MCR and there is no designated or potential critical habitat at MCR, the proposed action would have ***No Effect*** on this species.

Columbian White-tailed Deer *(Odocoileus virginianus leucurus)* – Endangered

Occurrence and Discussion: Columbian white-tailed deer occur on the Oregon and Washington mainland and instream islands primarily from Skamokawa, Washington (CRM 34) upstream to Port Westward (CRM 54). Columbian white-tailed deer are closely associated with riparian habitats and use "tidal spruce" habitats characterized by densely forested swamps covered with tall shrubs and scattered spruce, alder, cottonwood and willows (USFWe). Though critical habitat has not been designated for this species, accreted land at both the north and the south jetties could provide suitable habitat. However, the proposed action is situated 34 miles downstream of the Julia Butler Hansen National Wildlife Refuge for Columbian White-tailed deer and would occur in an area that is not known to be inhabited by the species.

Conclusion: Since the Columbian white-tailed deer is not expected in the vicinity of the MCR, the proposed action would have ***No Effect*** on this species.

Oregon Silverspot Butterfly *(Speyeria zerene hippolyta)* – Threatened

Occurrence and Discussion: The Oregon silverspot butterfly occupies coastal headlands or Oregon Coast Range peaks that provide specific habitat features, primarily the presence of *Viola adunca*, the obligate plant species of this butterfly. The nearest populations of butterflies are the Camp Riles, Clatsop County, Oregon population to the south and the Long Beach, Washington population to the north.

The historical range of this subspecies extends from the Long Beach Peninsula, Pacific County, Washington, south to Del Norte County, California, and all of these populations were restricted to the immediate coast, centered around salt-spray meadows, or within a few miles of the coastline in similar meadow-type habitat (USFWf). The Oregon silverspot occurs in three types of grassland habitat including: marine terrace and coastal headland salt-spray meadows; stabilized dunes (with both of the former strongly influenced by proximity to the ocean, mild temperatures, high rainfall, and persist fog); and montane grasslands (USFWf). Though the proposed action does not occur in areas designated as critical habitat, portions of the action are may provide suitable habitat conditions for the species.

Conclusion: No Oregon silverspot butterfly populations are known from the project area, and actions will not affect areas of designated critical habitat. Therefore, the proposed project will have ***No Effect*** on the Oregon silverspot butterfly.

Bull Trout (*Salvelinus confluentus*) – Threatened

Occurrence and Discussion: Bull trout are endemic to western North America and were more widely distributed historically. The Columbia River may have provided important historical rearing habitat for migratory bull trout and overwintering habitat (Buchanan et al. 1997; U.S. Fish and Wildlife Service 2004). In the Columbia River, occurrence of bull trout now in the lower Columbia River below Bonneville Dam appears to be incidental and occurrence above Bonneville Dam appears to be limited. Bull trout are dependent on cool water and their movements are limited by the availability of cool water. Historic records have documented bull trout (or Dolly Varden as this species was previously known) passing the fish ladder at Bonneville Dam in 1941, 1947, 1982, 1986, and 1994 and in the lower Columbia River near Jones Beach. Historic records also indicate that Dolly Varden were caught in fishwheels operated on the mainstem Columbia River in the late 1800s (U.S. Fish and Wildlife Service 2004). Fossil fragments of trout identified as bull trout have been found in the "Bonneville Basin" (Tomelleri 2002).

High quality bull trout habitat is typically characterized by cold temperatures; abundant cover in the form of large wood, undercut banks, boulders, etc.; clean substrate for spawning; interstitial spaces large enough to conceal juvenile bull trout; and stable channels (U.S. Fish and Wildlife Service 2000). The Columbia River downstream of Bonneville Dam does not typically achieve water temperatures that would be suitable for bull trout. Bull trout exhibit patchy distribution even in pristine habitats (Rieman and McIntyre 1993). Bull trout are piscivorous and frequent areas with overhead cover and coarse substrate and have been observed overwintering in deep beaver ponds or pools containing large woody debris (U.S. Fish and Wildlife Service 2000; Federal Register 2002).

Critical Habitat: The proposed action will occur in areas designated as critical habitat for bull trout. The proposed action will not have any effects on the following Primary Constituent Elements (PCE): water temperature, channel complexity, spawning substrate, natural hydrograph, and water quantity. PCE's that may be affected include:

1. Food Resources – Minor and temporary impacts to benthic invertebrates are expected at localized dredging, disposal, and rock placement sites. Placement could occur during a limited time window on a seasonal daily basis, and the other actions are temporally limited to a few days only annually. However, this is not anticipated to limit productivity or to have any long-term effects on food availability or foraging behavior.
2. Migratory Corridors free of obstruction – Spur groins are small components of the jetty that will protrude slightly into the channel but are expected to accrete sand on their leeward sides, which may provide some resting area for out-migrating juveniles. Their depths and limited geographical effects are not expected to alter migration patterns of juveniles or adults. Pile structures will also be localized and of low density and are not expected to measurably interfere with migration patterns or behaviors.

3. Water quality – Minor, localized, and temporary effects from increased suspended sediment due to dredging, disposal, rock placement, and piling installation and removal are likely. Placement could occur during a limited time window on a seasonal daily basis, and the other actions are temporally limited to a few days only annually or a single event basis. There is also an increased potential for spills or leaks, but BMPs reduce the likelihood of this occurrence. Monitoring will limit the levels and durations of turbidity; therefore long-term or significant effects to water quality are not likely.
4. Springs, seeps, and ground water sources – Proposed fill will have effects on some of the wetlands and lagoon in the vicinity of the MCR. Although these wetlands are connected hydrologically to the Columbia River, fill impacts are expected to be insignificant on river functions. Wetland fill impacts are not likely to negatively alter groundwater-stream exchange or hyporheic flow because wetlands are on accreted land that has formed on stabilized sand shoals behind the jetties. Wetland hydrology is mostly elevation and rainfall dependent, and fill impacts will be relatively insignificant to the Columbia channel. Culverts will be installed to maintain wetland hydrology and connectivity with permanent replacement at the North Jetty and when temporary construction roadways cross wetlands. Any effects will be minimal and discountable.

Conclusion: Bull trout are known to have occurred in the Columbia River itself historically but now appear to occur only incidentally in the lower Columbia River. Water temperature and lack of spawning substrate likely limits their use at the MCR to migratory passage. Only sporadic records of bull trout in the Columbia River downstream of Bonneville Dam or passing through the dam have been documented dating to 1941. Proposed actions will occur within area designated as critical habitat for bull trout. The proposed action ***May Affect but is Not Likely to Adversely Affect*** bull trout and designated critical habitat for the following reasons: 1) it is unlikely bull trout will be within the action area; and 2) the primary constituent elements of critical habitat are not likely to be degraded to an extent that is measureable or permanent.

Nelson’s Checker-mallow *(Sidalcea nelsoniana)* – Threatened

Nelson's checker-mallow was federally listed as threatened in 1993. It is a perennial herb in the mallow family (Malvaceae) with tall, lavender to deep pink flowers with flowering occurring as early as mid-May and extend into September, though Coast Range populations generally flower later and produce seed earlier (USFWg). Nelson's checker-mallow most frequently occurs in Oregon ash swales and meadows with wet depressions, or along streams, and species also grow in wetlands within remnant prairie grasslands or along roadsides at stream crossings where non-native plants, such as reed canary grass, blackberry, and Queen Anne's lace, are also present (USFWg). Nelson's checker-mallow primarily occurs in open areas with little or no shade and will not tolerate encroachment of woody species (USFWg). Though some potential habitat may exist in the proposed action area, Nelson’s Checker-mallow is not known to occur in the vicinity of the MCR. Critical Habitat has not been designated for Nelson’s checker-mallow.

Conclusion: No Nelson’s Checker-mallow populations are known from the project area. Therefore, the proposed project will have ***No Effect*** on the Nelson’s Checker-mallow.

CUMULATIVE EFFECTS

Cumulative effects are those effects of future State or private activities, not involving Federal activities, that are reasonably certain to occur within the action area of the Federal action subject to consultation (50 CFR 402.02). For the proposed action, the action area previously defined, there are no foreseeable non-federal actions subject to their own ESA consultation that have the potential to increase the impacts of actions described in this BA on federally listed species.

CONCLUSION

Due to the minimal likelihood that species would be present or encounter any elements of the proposed action, or that actions would occur in or significantly affect any portion of their critical habitat, the Corps has determined that the proposed action will have **no effect** on the following species: short-tailed albatross, northern spotted owls, Columbian white-tailed deer, Oregon silverspot butterfly, Nelson's Checker-mallow, and the streaked horned lark. This Biological Analysis further demonstrates the Corps' determination that the proposed action is **not likely to adversely affect** (NLAA) western snowy plovers, marbled murrelets, and bull trout.

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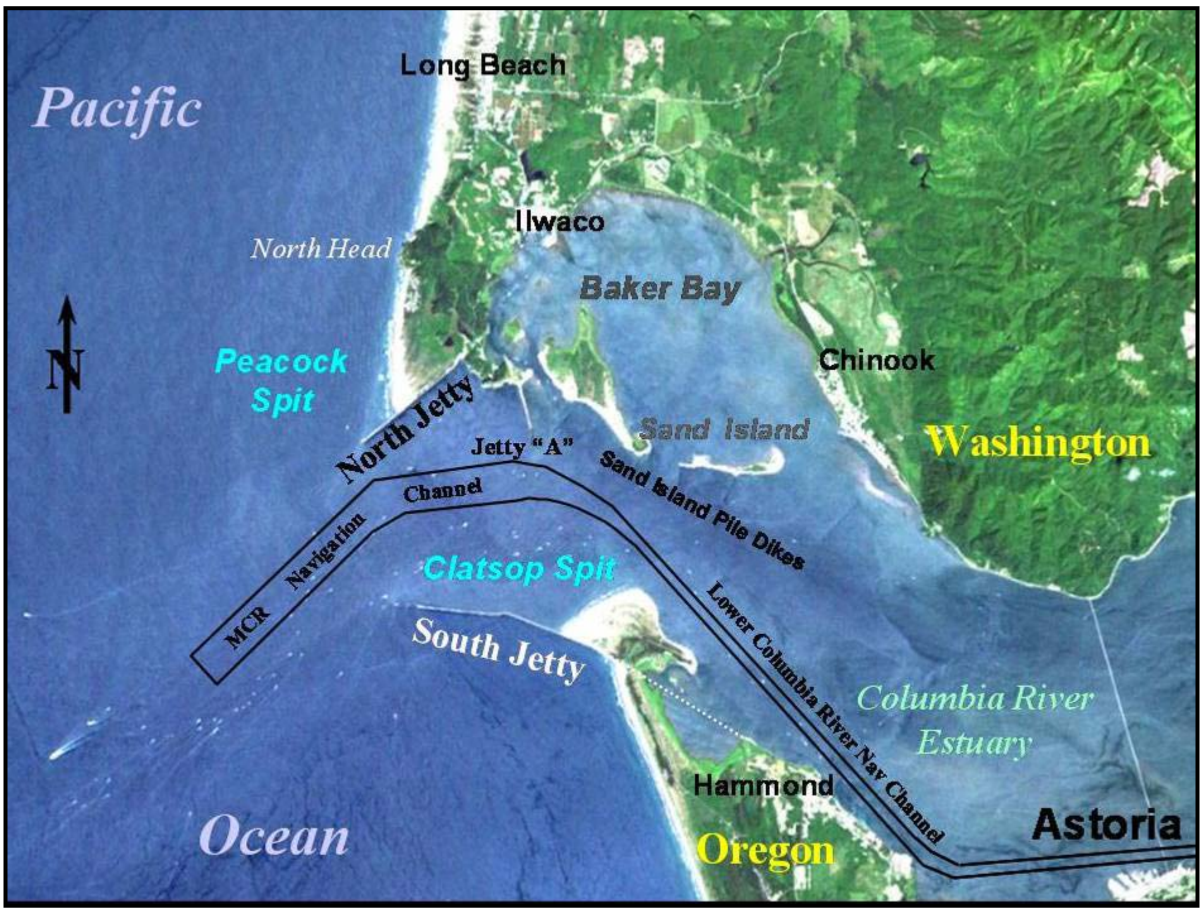
US Army Corps of Engineers ®
Portland District

Revised Final Environmental Assessment

Columbia River at the Mouth, Oregon and Washington

Rehabilitation of the Jetty System at the Mouth of the Columbia River



U.S. Army Corps of Engineers Jetty System at the Mouth of the Columbia River (MCR)

June 2012

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ABBREVIATIONS AND ACRONYMS

AMT	Adaptive Management Team
BA	Biological Assessment
BMP	best management practices
cfs	cubic feet per second
Corps	U.S. Army Corps of Engineers
CRE	Columbia River estuary
cy	cubic yard(s)
DDT	dichloro-diphenyl-trichloroethane
DPS	Distinct Population Segment
DMEF	Dredged Material Evaluation Framework
EIS	Environmental Impact Statement
ESA	Endangered Species Act
EA	Environmental Assessment
EFH	Essential Fish Habitat
ERDC	Engineer Research and Development Center
ESU	Evolutionarily Significant Unit(s)
FONSI	Finding of No Significant Impact
FR	Federal Register
ft	foot or feet
HCP	Habitat Conservation Plan
IHA	incidental harassment authorization
MCR	Mouth of the Columbia River
mcy	million cubic yard(s)
MHHW	mean higher high water
MLLW	mean lower low water
MTL	mean tidal low
NEPA	National Environmental Policy Act
NAVD	North American Vertical Datum
NMFS	National Marine Fisheries Service
ODEQ	Oregon Department of Environmental Quality
OPRD	Oregon Parks and Recreation Department
PAH	polynuclear aromatic hydrocarbon(s)
PCB	polychlorinated biphenyl(s)
PNNL	Pacific Northwest National Laboratory
ppt	parts per thousand
PSMFC	Pacific States Marine Fisheries Commission
RM	river mile
SEF	Sediment Evaluation Framework
SWS	Shallow Water (ocean disposal) Site
TMDL	total maximum daily loads
USEPA	U.S. Environmental Protection Agency
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
WDOE	Washington Department of Ecology

1. INTRODUCTION

This Revised Final Environmental Assessment (EA) evaluates the environmental effects for major rehabilitation and repairs of the North and South Jetties and Jetty A, which are part of the U.S. Army Corps of Engineers' (Corps) mouth of the Columbia River (MCR) navigation project (see cover photo and Figure 1). The EA provides a comprehensive analysis for all actions proposed at the MCR, including actions for the South Jetty dune augmentation, actions at the North Jetty described in the *North Jetty Major Maintenance Report* (MMR), May 2011, and actions described in the Major Rehabilitation Report (*MCR Jetty System Major Rehabilitation Evaluation Report*, June 2012). This document describes and evaluates all of these actions, and their associated cumulative effects are detailed here.

In June 2006, the Corps issued a draft EA (*Draft Environmental Assessment*, *Columbia River at the Mouth, Oregon and Washington, Rehabilitation of the Jetty System at the Mouth of the Columbia River, June 2006*) for public review and comment. This 2006 draft EA identified a proposed action for major rehabilitation and repairs including rebuilding the jetty lengths, adding spur groins, and capping the head at each of the jetties. In January 2010, the Corps issued a revised draft EA (*Revised Draft Environmental Assessment Columbia River at the Mouth, Oregon and Washington Rehabilitation of the Jetty System at the Mouth of the Columbia River*, *January 2010*) for public review and comment, which superseded the 2006 draft EA. The proposed action included a smaller-scaled project without the rebuilt lengths and included head-capping, spur groins, and repair and rehabilitation actions at the jetties. The 2010 revised draft EA also included the following actions: South Jetty foredune augmentation at the jetty root near the neck of Clatsop Spit; fill of the lagoon at the North Jetty; and critical repairs to Stations 86-99 of the North Jetty.

After public review of the 2010 draft EA, the Corps modified the proposed action for the North Jetty, South Jetty, and Jetty A. The modification also included avoidance of fill in Trestle Bay. These combined modifications avoided and minimized some of the formerly identified environmental impacts by reducing the final structure and construction footprints necessary to achieve a resilient jetty system at the MCR. The 2010 draft EA was finalized in May 2011, *Final Environmental Assessment Columbia River at the Mouth, Oregon and Washington Rehabilitation of the Jetty System at the Mouth of the Columbia River* and *Finding of No Significant Impact*, *May 31, 2011* (2011 final EA). In addition to avoiding fill in Trestle Bay, the proposed action in the 2011 final EA included: spur groin and head-capping features at all jetties; scheduled repairs as the South Jetty; North Jetty lagoon fill; dune augmentation at Clatsop spit; immediate rehabilitation at Jetty A; and a proposed schedule of activities in a 20-year period. The Corps signed a FONSI in 2011 for a subset of the proposed action described in the 2011 final EA, which included the following: critical repairs at the North Jetty (stations 86-99), North Jetty lagoon fill; and the dune augmentation at Clatsop spit.

This 2012 revised final EA updates the 2011 final EA. It makes the clarification that the No Action Alternative is not the same as the Base Condition, since the Base Condition in the 2011 final EA included some action (these were the selected course of action in the 2011 FONSI). The revised final EA also clarifies modifications to the Base Condition assumptions per suggestions from an Independent, External Peer Review (IEPR) team.

The cumulative effects evaluation has been updated in this revised final EA to incorporate the Corps' proposal to designate nearshore dredge disposal sites at the MCR (see the April 24, 2012 *Public Notice for: Nearshore Disposal Locations at the Mouth of Columbia River Federal Navigation Project Pacific County, Washington Clatsop County, Oregon*).

Currently the Corps has identified a preferred alternative addressing the rubble-mound structures at the MCR over the next 8 years. Because these structures are built on sand, are subject to extreme physical environmental conditions, and have been established for over 125 years, they would require work and repair beyond the 8-year period. Throughout and at the end of 8-years, via inspections and monitoring the Corps would need to examine any needed future maintenance, rehabilitation or reconstruction.

The duration and preferred alternative for all of these actions remain within the scope of effects previously evaluated in the 2011 Biological Opinion and Concurrence Letter, (May 18, 2011, *Endangered Species Act Biological Opinion and Conference Report and Magnuson-Stevens Fishery Conservation and Management Act Essential Fish Habitat Consultation for the Major Rehabilitation of the Jetty System at the Mouth of the Columbia River* – NMFS No 2010/06104, and; 2/23/2011, *Major Rehabilitation of the Jetty System at the Mouth of the Columbia River Navigation Channel, Clatsop County, Oregon and Pacific County, WA* USFWS # 13420-2011-I-0082).

1.1. Project Authority

The features of the MCR navigation project were authorized by the River and Harbor Acts of 1884, 1905, and 1954. The navigation project consists of a 0.5-mile wide navigation channel extending for about 6 miles through a jettied entrance between the Columbia River and the Pacific Ocean. The MCR is the ocean gateway for maritime navigation to and from the Columbia-Snake River navigation system. Approximately $20 billion of commerce passes through the MCR jetty system annually. The ocean entrance at the MCR is characterized by large waves and strong currents and is considered one of the world's most dangerous coastal inlets.

For the authorization for the actual construction of the MCR jetties, the present navigation channel and configuration of the inlet at the mouth of the Columbia River are the result of continuous improvement and maintenance efforts undertaken by the Corps Portland District since 1885. Congress has authorized the improvement of the MCR for navigation through the past legislation:

- Senate Executive Document 13, 47th Congress, 2nd Session (5 July 1884) authorized the Corps to construct the South Jetty (first 4.5 miles) for the purpose of attaining a 30-foot channel across the bar at the MCR.
- House Document 94, 56th Congress, 1st Session (3 March 1905) authorized the Corps to extend the South Jetty (to 6.62 miles) and construct a North Jetty (2.35 miles long) for the purpose of attaining a 40-foot channel (0.5 mile wide) across the bar at the MCR.
- House Document 249, 83rd Congress, 2nd Session (3 September 1954) authorized a bar channel of 48 feet in depth and a spur jetty ("B") on the north shore of the inlet. Funds for Jetty "B" construction were not appropriated.
- Public Law 98-63 (30 July 1983) authorized the deepening of the northern most 2,000 feet of the MCR channel to a depth of 55 feet below mean lower low water (MLLW).

The MCR federal navigation project was originally authorized (in 1884) before formulation of local sponsor cost sharing agreements; therefore, all navigation maintenance and improvements costs at MCR are borne by the Federal Government.

The authority for maintenance of the MCR jetties comes from its original authority for construction of the project and then with Corps' policies for the operations, maintenance, and management of a Corps' project (Chapter 11 of EP 1165-2-1). For navigation, completed projects like the MCR have established that operations and maintenance (O&M) is solely a federal responsibility to be accomplished at federal cost.

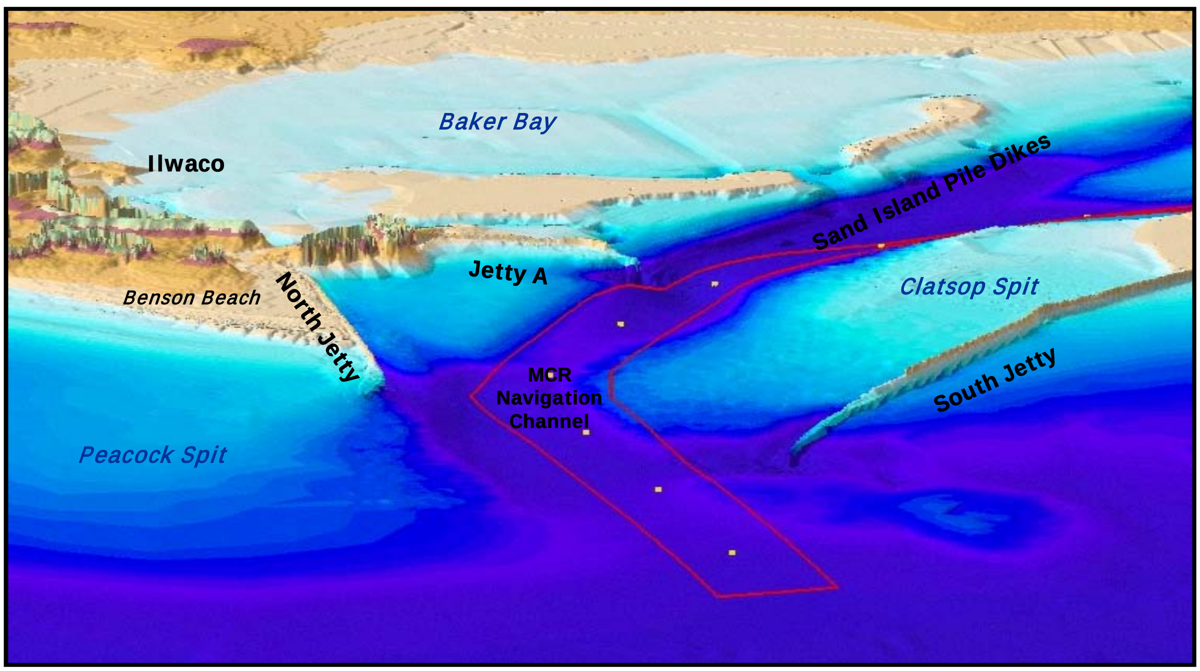
When maintaining a Corps' project, there is regular O&M, major maintenance, and major rehabilitation. Major rehabilitation consists of either one or both of two mutually exclusive categories, reliability or efficiency improvements.

- Reliability. Rehabilitation of a major project feature that consists of structural work on a Corps operated and maintained facility to improve reliability of an existing structure, the result of which would be a deferral of capital expenditures to replace the structure. Rehabilitation would be considered as an alternative when it can measurably extend the physical life of the feature (such as a jetty) and can be economically justified by a benefit/cost relationship. Each year the budget Engineering Circular (EC) delineates the dollar limits and construction seasons (usually two construction seasons).
- Efficiency Improvements. This category would enhance operational efficiency of major project components. Operational efficiency would increase outputs beyond the original project design. This category is typically used to evaluate hydropower production.

Thus, the authority for maintenance of the MCR jetties comes from the authorization documents for the project and/or the authority to operate and maintain the structures.

1.2. Background

Figure 1. Project Area Showing the MCR Jetties and Underwater Sand Shoals



From 1885 to 1917, the North and South jetties were constructed. Jetty construction realigned the ocean entrance to the Columbia River, established a consistent navigation channel that was 40-feet deep across the bar, and dramatically improved navigation through the MCR. Improvements made from 1930 to 1942 (including adding Jetty A and the Sand Island pile dikes) produced the present entrance configuration.

The MCR jetties are unique structures that help ocean-going vessels move between the Columbia River and Pacific Ocean. Simply put, a jetty is a rock finger that stretches out into the ocean from the shoreline, essentially extending the mouth of the river well into the sea. Where a river empties into the ocean, currents slow and sand bars develop, which cause a dangerous situation for ships trying to navigate through an ever-changing channel. Jetties create more defined and concentrated flows at the mouth of the river to help scour out the shallow sand deposits and maintain a stable channel location and depth.

The forces of nature have taken their toll on the structural integrity of the MCR jetties, and the Corps is working at restoring them to acceptable levels of reliability. Repairs were made in 1965 for the North Jetty, in 1962 for Jetty A, and in 1982 for the South Jetty. Additional repairs to address immediate needs were completed at the North Jetty in 2005 and at the South Jetty in 2007. Further details on repair history are described below.

From 1885 to 1939, three rubble-mound jetties with a total length of 9.7 miles were constructed at the MCR on massive tidal shoals. The jetties were constructed to accelerate the flow of the river, which helps maintain the depth and orientation of the navigation channel, and to provide protection for ships of all sizes (both commercial and recreational) entering and leaving the Columbia River. The intention was to secure a consistent navigation channel through the coastal inlet, though morphology of the inlet currently remains in a dynamic, high-energy state. Under such conditions, the jetties have experienced considerable deterioration since construction, mainly due to extreme wave attack and foundation instability associated with erosion of the tidal shoals on which the jetties were built.

The initial 4.5-mile section of the South Jetty was completed in 1895-1896. The Rivers and Harbor Act of 3 March 1905 authorized the extension of the South Jetty to 6.6 miles, with the 2.4-mile extension completed in 1913. Historical records show that six spur groins were constructed along the channel side of the South Jetty. Four of the groins were subsequently buried by accreted shoreline or sand shoal. Nine repairs to the South Jetty have been completed with the latest one in 2007. To date, jetty rock placement at the South Jetty totals approximately 8.8 million tons. In spite of these repairs and structural features, over 6,100 feet (1.1 miles) of loss has occurred at the South Jetty.

The North Jetty was completed in 1917. Three repairs to the North Jetty have been made with the last one completed in 2005. To date, jetty rock placement totals approximately 3.4 million tons. Since initial construction, about 2100 feet (0.4 mile) of the North Jetty has eroded.

Jetty A was constructed in 1939 to 1.1 miles in length in connection with rehabilitation of the North Jetty for the purpose of channel stabilization. Its purpose was to assist in controlling the location and direction of the ebb tidal flow through the navigation entrance. Improvements made from 1930 to 1942 (including addition of Jetty A and Sand Island pile dikes) produced the present entrance configuration.

The construction and repair history of the MCR jetties is summarized in Table 1.

Table 1. Construction And Repair History Of The MCR Jetties

1881: Proposed project to build a strong pile-dike, 3 feet high about at low tide, 8,000 feet long and 20 feet wide along a line previously established on the south side. The structure to start near the northeast corner of Fort Stevens, following the 12-foot curve, dike will be directed a little westward of the outer part of headland of Cape Hancock. It was stated that work commence soon (during summer and autumn) because channel maintenance is dependent upon building up Clatsop Spit.

1883: A jetty plan approved by the Board of Engineers from the south cape of the entrance on the spit. A survey was conducted in October-November of the south cape, Point Adams, to extreme low water. The jetty extends from Point Adams and makes the distance between the outer end of the jetty and Cape Disappointment the same as the distance between Chinook Point and Point Adams. The Board stated that any structures placed in-river should not harm the river and should keep the channel open using the tide; therefore, the jetty should not obstruct the entry of the flood tide. The jetty design called for a crest elevation at low water level. Estimated depths of various jetty sections from the landward end are: 5,000 feet - less than +6 feet; 7,500 feet – +6 to +11 feet; 4,000 feet – +11 to +16 feet; and 7,500 feet – +16 to +21 feet. Jetty crest elevation was designed to be at low water level because of wave violence that could harm a higher jetty. The logic was that a higher jetty could be built, if needed later, by placing more stone on the existing jetty. A jetty height to mid-tide level was suggested but not recommended because the lower jetty would be quite effective in directing the ebb tide and would interfere less with the flood tide. A higher jetty would result in higher maintenance costs due to the jetty being more exposed to wave action.

1884: The improvement plan for MCR was approved by the Rivers and Harbors Act of July 5, 1884 to maintain a channel 30 feet deep at mean low tide by constructing a low-tide jetty, about 4.5 miles long, from near Fort Stevens on the South Cape to a point about 3 miles south of Cape Disappointment.

1886-1896: Original construction South Jetty from Fort Stevens (station 25+80) across Trestle Bay and Clatsop Spit to station 250+20. Rock placed with a natural slope to an elevation from 4 to 12 feet, crest width roughly 10 feet. "The jetty, of a brush-mattress and stone ballast, was built for 1,020 feet from ordinary highest tide-line, and minor constructions added." Material has filled along the jetty's south side, moving the shoreline seaward. Highest tide-line is located at tramway station 30+50. A 115 feet long spur was built landward of the jetty for shore protection. A 510 feet long sand-catch, consisting of heavy beach drift and loose brush, was built on the south side of landward end of the jetty to continue filling the old outlet of a lagoon at extreme end of Point Adams. Jetty stone was originally dumped in ridges, but waves flattened and compacted the rocks to a width of 50 feet. The report indicated urgency to extend the jetty to prevent further deterioration of the bar channel.

1889: The South Jetty now under construction for 1.5 miles. Clatsop Spit has more material visible at low water and the river channel has a tendency towards a straight course out to sea. Tillamook Chute being closed. Sand building up south of the jetty adjacent to and in front of the mattresses as they are constructed.

1890: South Jetty construction is 3.25 miles underway. Jetty elevation at MLLW for about 3 miles. 1.25 miles of tramway to be constructed. Clatsop Spit building up, the outflowing waters being concentrated over the channel bar. Station 25+80 considered the beginning of the jetty. The jetty mattress has advanced from stations 99+04 to 194+08. The jetty elevation is at MLLW to station 170+00. From Station 170+00 to the end of mattress work, there is about 9 feet of rock on top of the mattress. At station 65+00, there were signs of sinking and a large amount of rock was dumped in place.

1903-1913: Extension of South Jetty. Crest elevation of jetty raised to 10 feet MLLW from stations 210+35 to 250+20, and rock placed from stations 250+20 to 375+52, elevation increasing in steps to 24 feet MLLW. Crest width is 25 feet and side slopes are natural slope of rock. Seaward bend in the jetty is added and called the "knuckle."

1913-1917: Original construction of North Jetty from stations 0+00 to 122+00. Side slopes are 1 vertical by 1.5 horizontal (1:1.5) and crest width is 25 feet. Crest elevation varies from 15 to 32 feet.

1931-1932: Repair South Jetty from stations 175+00 to 257+68.7 (shoreline to knuckle), side slopes 1:1.5, crest elevation 24 feet MLLW, and crest width 24 feet. This is first maintenance for South Jetty. The jetty had been flattened to about low water level. 2.2 million tons of stone placed in super-structure. The work completed in 1936. The end of jetty would unravel 300 feet or more, so a solid concrete terminal was constructed above low water level. The terminal was located 3,900 feet shoreward of the original jetty end that was completed in 1913.

1933-1934: Repair of South Jetty from stations 257+68.7 to 305+05 (knuckle to middle of outer segment). Two level cross section with crest elevations of 17 and 26 feet. Crest width of each level is 24 feet. Side slopes are 1:1.5 on channel side and vary from 1:1 to 1:1.75 to 1:2 on ocean side.

1935-1936: Repair South Jetty from stations 305+05 to 353+05 (middle of outer segment to existing end). Similar design to 1933-1934 repair.

Table 1 (Continued)

1936: Stone/asphalt cone-shaped terminal constructed on South Jetty from stations 340+30 to 344+30. Crest width of approximately 50 feet and elevation varied from 23 to 26 feet. Side slopes are 1:2.

1937-1939: Repair of North Jetty from stations 68+35 to 110+35. Crest elevation 26 feet and crest width 30 feet. Side slope 1:1.25 on ocean side and 1:1.5 on channel side.

1939: Original construction of Jetty A from stations 40+93.89 to 96+83. Crest width is 10 feet from beginning to station 53+00, 30 feet in width, and elevation at 20 feet from this point on. Four pile dikes completed at Sand Island.

1940: Repair of South Jetty with replacement rock in locations as needed.

1940-1942: South Jetty repair from stations 332+00 to 343+30. Concrete terminal/stone foundation added. Crest elevation from 8-20 feet and crest width from 50-75 feet, 10 inches. Side slopes determined by concrete terminal shape.

1945-1947: Repair Jetty A from stations 78+00 to 96+00. Crest elevation to 20 feet with crest width of 40 feet.

1948-1949: Repair 300 feet of Jetty A from stations 92+35 to 95+35 with a crest elevation of 20 feet, a crest width of 30 feet, and side slopes of 1:1.25.

1951: Repair Jetty A from stations 91+50 to 93+00 with a crest elevation of 20 feet MLLW, a crest width of 30 feet, and side slopes of 1:1.5.

1952: Repair of Jetty A from stations 90+00 to 94+00 with a crest elevation of 20 feet, a crest width of 30 feet, and side slopes of 1:1.5.

1958: Repair of Jetty A from Stations 41+00 to 79+00. Crest elevation raised to 20 feet and a crest width of 20 feet from Stations 41+00 to 56+00. Crest width is 30 feet from Stations 61+00 to 79+00.

1961-1962: Repair Jetty A from stations 50+00 to 90+50, with no repairs from Stations 68+00 to 76+50. Crest elevation built with a 10% grade from 20 feet to 24 feet from stations 50+00 to 68+00. The crest elevation was raised to 24 feet from stations 76+50 to 90+50.

1961: South Jetty repair from stations 194+00 to 249+00 (before knuckle, current stationing). Crest elevation varies from 24 to 28 feet and crest width is 30 feet. Channel side slope 1:1.25 and ocean side slope 1:1.5. Repairs from stations 38+00 to 93+00 (old stationing). Elevation at station 38+00 is +24 feet and then increased with a 0.5% grade up to +28 feet for the remainder of repair section. The repair centerline is located 13 feet north of the centerline of the original jetty design. The design crest width is 30 feet. North slope is 1:1.25 and south slope is 1:1.5.

1962-1965: South Jetty repair from stations 249+00 to 314+05 (beyond knuckle). Crest elevation begins at 28 feet and transitions to 25 feet for most of section. Side slopes vary from 1:1.5 to 1:2 and crest width is 40 feet (this appears to be the furthest seaward intact portion of current jetty). Repairs made from stations 93+00 to 157+50 (old stationing). The crest elevation is +28 feet at station 93+00, then decreases to +25 feet at station 95+00, and then continues with this elevation to end of the repairs. The crest width is 40 feet and has a slope of 1:1.5 from stations 93+00 to 152+00. Slope then transitions to 1:2 from stations 152+00 to 154+00. The centerline of the repair is 15 feet south of the trestle centerline.

1965: Repair North Jetty from stations 89+47 to 109+67 with a crest elevation of 24 feet and crest width is 30 feet. Side slopes vary from 1:1.5 to 1:2.

1982: Repair South Jetty from stations 194+00 to 249+00 (segment before knuckle). Crest elevation varies from 22 to 25 feet MLLW. Crest width varies from 25-30 feet and side slopes 1:1.5. Crest elevation varies from +22 feet at station 38+00 to +25 feet at station 80+35 (old stationing). From stations 44+50 to 80+35, crest width is 30 feet and slope is 1:1.5. Centerline of repairs has 10 feet maximum variance to the north for the South Jetty control line. From stations 80+35 to 93+00, centerline of repairs is the same as South Jetty control. Crest elevation +25 feet, width varies from 25-30 feet, side slope is 1:1.5.

2005: Interim repair of North Jetty (stations 55+00 to 86+00). Crest elevation +25 feet with side slope of 1:1.5.

2006: Interim repair of South Jetty (stations 223+00 to 245+00). Crest elevation +25 feet with side slope of 1:2.

2007: Interim repair of South Jetty (stations 255+00 to 285+00). Crest elevation +25 feet with side slope of 1:2.

The Corps' dredging and in-water disposal of dredged sediments to maintain the above referenced authorized navigation channel is conducted under the provisions of sections 102 and 103 of the Marine Protection Reserve and Sanctuaries Act of 1972, sections 401 and 404 of the Clean Water Act of 1977, and in accordance with applicable regulations.

1.3. Purpose and Need for Action

1.3.1. Purpose

The purpose of the proposed action is to perform modifications and repairs to the North and South jetties and Jetty A at the MCR that would strengthen the jetty structures, extend their functional life, and maintain deep-draft navigation.

1.3.2. Need

Structural degradation of the +100-year old MCR jetty system has accelerated in recent years because of increased storm activity and loss of sand shoal material upon which the jetties are constructed. In addition, beaches on the ocean sides of the North and South jetties, which formed as a result of jetty construction, have been receding gradually over the years, exposing previously protected sections of the jetties at the beach line to storm waves. Taking no action to protect and to extend the functional life of the jetties will result in further deterioration of the jetties and the sand shoals upon which they rest, increasing the likelihood of a jetty breach. Recent jetty repairs have addressed immediate critical needs. Additional modifications and repairs to the jetties are necessary to address important near- and long-term needs to keep the jetties functioning at an acceptable reliability and to reduce the potential for emergency repairs, emergency dredging, and impacts to navigation.

1.4. Project Area Description

The North Jetty and Jetty A are located in Pacific County, Washington, near Ilwaco and Long Beach on the Long Beach Peninsula (see cover photo). The North Jetty is located within Cape Disappointment State Park (formerly Fort Canby), and Jetty A is located near the Coast Guard station. The 2.3-mile long North Jetty was completed in 1917. Three repairs to the North Jetty have been made with the last one completed in 2005. To date, jetty rock placement totals approximately 3.4 million tons. Since initial construction, about 0.4 miles of the North Jetty head has eroded and is no longer functional. Jetty A, positioned on the south side of the North Jetty, was constructed in 1939 to a length of 1.1 miles and is located upstream of the North Jetty. Jetty A was constructed to direct river and tidal currents away from the North Jetty foundation.

The South Jetty is located in Clatsop County, Oregon near Warrenton/Hammond and Astoria (see cover photo). The South Jetty is located in Fort Clatsop State Park. The South Jetty is about 6.6 miles long. The initial 4.5-mile section of the South Jetty was completed in 1896, with a 2.4-mile extension completed in 1914. Currently, approximately 3 miles of jetty extends seaward of the shoreline. To stabilize the jetty foundation, six groins perpendicular to the South Jetty were constructed with lengths from about 100 to 1,000 feet (see Section 3.2.2). Over 6,100 feet of loss has occurred at the South Jetty. Nine repairs to the South Jetty have been completed with the latest one in 2007. To date, jetty rock placement at the South Jetty totals approximately 8.8 million tons.

2. AFFECTED ENVIRONMENT

2.1. Physical Characteristics

The MCR is a high-energy environment. Horizontal circulation in the estuary is generally clockwise (when viewed from above), with incoming ocean waters moving upstream in the northern portion of the estuary and river waters moving downstream in the southern portion of the estuary. Vertical circulation is variable, reflecting the complex interaction of tides with river flows and bottom topography and roughness (Corps 1983).

The Columbia River estuarine environment (based on salinity and tidal effects) extends from the mouth to river mile (RM) 38. The width of the river varies from 2 to 5 miles wide throughout the estuary and about 1 mile wide at RM 30. Tidal effect extends almost 150 miles upstream (Corps 1983), but the saltwater wedge is limited to about RM 20 (Corps 1999). The North and South Jetties and Jetty A were constructed at the MCR to help stabilize the channel, to reduce the need for dredging, and to provide protection for ships. The navigation channel is maintained at authorized depths of 48 to 55 feet below mean lower low water (MLLW)[1] and is 0.5-mile wide from RM -3 to RM 3. River flows are controlled by upstream storage dams.

A dredged material disposal site called the North Jetty Site is entirely within inland waters. It is located about 400 feet south of the North Jetty, occupies an area of 1,000 feet by 5,000 feet, and has an average water depth of 35-55 feet. This site was evaluated and established by the Corps in 1999 under Section 404 of Clean Water Act to allow the placement of dredged material along the toe of the North Jetty to protect it from excessive waves and current scour. Use of the site is limited to disposal of MCR dredged material. From 1999-2008, about 4.4 million cubic yards (mcy) of dredged material was placed in the North Jetty site.

An ocean disposal site called the Shallow Water Site (SWS) lies within 2 miles offshore from the MCR and was evaluated and designated in 2005 by the U.S. Environmental Protection Agency (USEPA) under Section 102 of the Marine Protection, Research and Sanctuaries Act. The SWS occupies a trapezoidal area of 3,100- to 5,600 feet in width by 11,500 feet in length and lies within a water depth of 45-75 feet. The SWS is used for disposal of material dredged from either the MCR or the lower Columbia River. The SWS is dispersive, which means that material placed there is transported away from the site by waves and currents. Active monitoring and evaluation determined that 80% to 95% of the dredged sand annually placed at the SWS moves northward onto Peacock Spit. From 1997-2008, approximately 29 mcy of dredged sand has been placed in the SWS. The SWS is of strategic importance to the region; its continual use has supplemented Peacock Spit with sand, sustained the littoral sediment budget north of the MCR, protected the North Jetty from scour and wave attack, and stabilized the MCR inlet.

There is also an active deep water disposal site 7 miles off shoreline in Pacific Ocean (Deep Water Site), west of the Columbia River, as well as an active disposal site in the estuary at RM 7 called the Chinook Channel Area D, the latter of which receives materials from the Columbia and Lower Willamette reaches.

These active disposal sites have undergone extensive evaluation and review regarding potential effects prior to their site designation. The Corps has recently proposed designating additional dredge material disposal sites near both the North and South Jetties. If designated, those sites may also be available. The

[1] In this EA, depth is expressed as MLLW or as North American Vertical Datum (NAVD); the difference between MLLW and NAVD is about 0.3 feet.

current proposed disposal actions for the MCR repairs and rehabilitation are congruent with these active projects and efforts. Dredged material from this proposal will likely be placed in the SWS or other preapproved locations. Disposal actions from this project will be similar to and in compliance with actions described in associated site designations and approvals.

The Corps is not proposing any new disposal sites specific to this jetty repair/rehabilitation action and will most likely use the SWS site, which is a designated Ocean Dredged Material Disposal Site (ODMDS). The EPA designates and manages the disposal of ocean dredged material pursuant to section 102 of the Marine Protection, Research, and Sanctuaries Act (MPRSA). The designation process for both the SWS and Deep Water Sites was finalized in 2005 and can be found at 70 FR 10041. As part of the associated Site Management and Monitoring Plan (SMMP) to ensure adaptive management and protection from adverse mounding and environmental impacts, the Corps submits an Annual Use Plan to EPA requesting use of the sites for placing materials before the beginning of dredge season and disposal at the site.

Approximately 19,575 acres of shallow-water habitat presently exist in the vicinity of the MCR project, some of which is intertidal sandflat and is periodically exposed. For the purposes of this analysis, shallow-water habitat was considered to include water 20-feet deep and shallower, whether or not it experienced periodic exposure at low tides. During the geospatial analysis, boundary conditions were set as closely as possible to match those which were used in the hydraulic and hydrologic analyses and modeling. This area roughly extends to RM 3, and 3 miles seaward. Generally, shallow-water habitat in the MCR is concentrated around the jetty structures and in adjacent coves and bays. The dominant substrate in vicinity of the jetties consists of relic rock and shifting sand, with little habitat heterogeneity due to the dynamic current, wind, and wave conditions.

2.1.1. Waves, Currents, and Morphology

The ocean entrance at the MCR is characterized by large waves and strong currents interacting with spatially variable bathymetry. The MCR entrance is considered one of the world's most dangerous coastal inlets for navigation. Approximately 70% of all waves approaching the MCR are from the west-northwest (Moritz and Moritz 2004). During winter storms, the ocean offshore of the jettied river entrance is characterized by high swells approaching from the northwest to southwest combined with locally generated wind waves from the south to southwest. From October to April, average offshore wave height and period is 9 feet and 12 seconds, respectively. From May to September, average offshore wave height and period is 5 feet and 9 seconds, respectively, and waves approach mostly from the west-northwest. Occasional summer storms produce waves approaching from the south-southwest with wave heights of 6.5 to 13 feet and wave periods of 7 to 12 seconds. The tides are mixed semi-diurnal with a diurnal range of 7.5 feet. The instantaneous flow rate of estuarine water through the MCR inlet during ebb tide can reach 1.8 million cubic feet per second (cfs). Tidally dominated currents at the MCR can exceed 8.2 feet per second. A large, clockwise-rotating eddy current has been observed to form between the North Jetty, the navigation channel, and Jetty A during ebb tide. A less pronounced counter-clockwise eddy forms in response to flood tide. The North Jetty eddy has varying strength and direction (based on location and timing of tide) ranging from 0.3 to 3.3 feet per second.

As waves propagate shoreward toward the MCR, the waves are modified by the asymmetry (irregularity) of the MCR's underwater morphology (form). The asymmetric configuration of the MCR and its morphology is characterized by the sizeable offshore extent of Peacock Spit on the north side of the North Jetty, southwesterly alignment of the North/South jetties and channel, and the absence of a large shoal on the south side of the MCR. Nearshore currents and tidal currents are also modified by the jetties and the MCR's morphology. These modified currents interact with the shoaling waves, river currents, and seasonal hydrograph to produce a complex and agitated wave environment at the MCR. The asymmetry of the MCR causes incoming waves to be focused onto areas which would not otherwise be exposed to direct wave action.

An example of this wave-focusing effect is the area along the south side of the North Jetty. Initially, it would appear that this area is most susceptible to wave action approaching the MCR from the southwest. However, this is not the case; the opposite is what occurs. The area located between the North Jetty, the navigation channel, and Jetty A is affected by wave action during conditions when the offshore wave direction is from the west-northwest, because of the refractive nature of Peacock Spit. Waves passing over Peacock Spit (approaching from the northwest) are focused to enter the MCR along the south side of the North Jetty. Conversely, large waves approaching the MCR from the southwest are refracted/diffracted (changed in direction) around the South Jetty and over Clatsop Spit, protecting the south side of the North Jetty from large, southerly waves.

The stability of the MCR channel is related to the jetties and the morphology of Peacock and Clatsop spits (Moritz et al., 2003). Through phased jetty construction from 1885 to 1939 and the associated response of MCR morphology, the project features at the MCR and the resultant morphology are now dependent on one another both in terms of structural integrity and project feature functional performance. If the jetties change over time (further recession of jetty head or breach within jetty trunk), the inlet's morphology will respond accordingly. For example, if the head of the North Jetty recedes landward by 100 feet, the morphology adjacent to the North Jetty will adjust accordingly, with much of the mobilized sediment entering the MCR navigation channel. The offshore extent of the North Jetty acts to retain Peacock Spit and to prevent its southward re-entry into the MCR inlet. The North Jetty acts to constrain current flow through the entrance to maintain a stable inlet.

Jetty A helps to reduce severe ebb tide circulation affecting the North Jetty, thereby protecting the North Jetty. Jetty A also protects Sand Island and Ilwaco channel from severe flood tide currents and storm wave action entering the inlet from the ocean. By effectively constraining currents within the inlet, Jetty A also reduces the likelihood of Clatsop Spit migrating northward into the inlet. The offshore extent of the South Jetty protects the MCR inlet from severe wave action and constrains destabilizing currents. The present condition of the South Jetty also acts to stabilize Clatsop Spit and shore land south of the jetty. In summary, the function of the MCR jetties is related to the offshore distance to which the jetties extend.

Potential long-term impacts of climate change were considered in the analysis of the MCR Jetties. Climate change impacts on coastal projects can potentially involve two separate factors, increased sea level and changes in the wave climate. Analysis of monthly mean sea level data from 1925 to 2006 at the National Weather Service's Astoria gauge has shown that the mean sea level trend is -0.31 millimeters/year, which is equivalent to a change of -0.05 feet in 50 years. The trend is negative because of the opposing effect of rebound of the landmass in the area. Overall, water levels along the Oregon Coast are primarily a function of astronomical tide influences with a representative tidal range of approximately 7 feet. Other factors that can influence water levels are atmospheric pressure, El Nino/La Nina cycles, wind set-up, and wave set-up. Those values can combine with a high tide level to approximate an extreme high water level (during storm wave action) of approximately 15.8 feet MLLW. The extreme low water level (during storm wave action) was estimated to be 1.3 feet MLLW. Overall, since the projected historical trend of sea level at the project site is estimated to be -0.05 feet in 50 years, sea level rise is not projected to be a dominant climate change factors at the project site.

Another concern regarding climate change is wave height trends. Waves that affect each jetty are a function of deepwater waves and water depths at each jetty. Shallower water depths may limit wave heights along a given section of a jetty. The potential for future changes in wave climate along each jetty was addressed by estimating two factors: 1) increases in present offshore storm wave height, and 2) reduction in the MCR inlet morphology. The latter could increase depth-limited wave height. Analysis of deep water wave data near the project site may indicate increasing trends in height of storm-related waves and frequency of storms. Due to the relatively short data record (1984 to 2009), it is not known whether this trend accurately represents a one-way increase, or is simply a subset of a larger, wider-ranging database of wave heights. The comprehensive analysis of historical storm events is expected to adequately capture the present deep water contribution of potential wave height variation for this project site. The above approach forms the basis for estimating the potential changes in wave climate that could affect the MCR jetty system.

2.1.2. Foundation Conditions

The MCR jetties were constructed on underwater sand shoals. These shoals are considered to be crucial project elements. These shoals and adjacent morphology are receding. As the morphology near the MCR jetties experiences measurable recession (erosion), the jetties will be undermined by waves and currents.

2.1.3. Landforms

Near the Oregon shore of the estuary, Clatsop Spit is a coastal plain. On the Washington shore, Cape Disappointment is a narrow, rocky headland. Extensive accretion of land has occurred north of the North Jetty since its construction. This accreted land, however, is now in the process of recession as is evident by erosion at Benson Beach. The Corps is in the process of evaluating possible use of Columbia River sand to place back into the littoral drift north of the North Jetty, and some sand has been placed at Benson Beach. Behind the headland is beach dune and swale. Wetlands occur on accreted land north of the North Jetty and on Clatsop Spit, and depressional wetlands also occur at Jetty A. On the Oregon shore, Fort Clatsop State Park is also mostly on accreted land formed with construction of the South Jetty, and depressional wetlands occur throughout this area as well.

Wetlands near North Jetty. Scouring has taken place on the north side of the North Jetty resulting in formation of wetlands and a backwater lagoon within the approximately 16-acre wedge of land between North Jetty and the North Jetty Access Road. Lagoons are typically characterized by shallow water and intermittent ocean connectivity and are often oriented parallel to the shoreline. Because of their interface location between land and sea, their exposure to rapidly changing physical and chemical influences, their short and varied water residence time, and their wind and weather dependent vertical and horizontal stratification, these lagoon features can be very dynamic and productive based on these natural constraints (Troussellier 2007). However, a recently repaired sand berm now currently separates the western entrance of the North Jetty lagoon from tidal flows along the south end of Benson Beach, and there is very little aquatic vegetation within or around the channel. The North Jetty lagoon is often inundated both by tidal waters that come through the jetty and by freshwater from wetlands that have formed in accreted lands north of the North Jetty Access Road and which drain through a culvert into the lagoon and its few adjacent wetlands. The lagoon and wetland areas on the south side of the North Jetty Access Road were originally delineated in this wedge of land and equaled approximately 6.5 acres total of both wetlands (1.78) and waters of the United States (4.71). Updated and expanded delineations indicate that scour has increased the size of the lagoon, while storms have covered some of the previously identified wetlands at the western end of the lagoon. Currently, south of the North Jetty Access Road there are a total of 8.86 acres of both wetlands (0.84) and waters of the U.S. (8.02).

2007 Delineations: Wetlands south of the North Jetty Access Road were originally delineated by Tetra Tech (2007a, b) in accordance with the Corps' Wetlands Delineation Manual (Corps 1987). The following three distinct wetlands were identified in the earlier delineation.

Wetland 1 (0.61 acre). These disjunct wetlands were classified as estuarine emergent, persistently regularly flooded. These patches of wetlands fringe the scoured-out tidal channel and were characterized by bighead sedge, American dune grass, Baltic rush, and tufted hairgrass. These fringe wetlands were ephemeral in nature and could be affected by moving sand. This was evident during a field visit in fall of 2007 when sand from a storm during the previous winter washed sand eastward covering nearly all of a patch of wetlands that occurred near Benson Beach.

Wetland 2 (0.97 acre). These wetlands were classified as palustrine emergent, persistently seasonally flooded and as palustrine scrub-shrub broad-leaved deciduous seasonally flooded. They occurred adjacent to the beach access road in drainage ditches. Three plant communities characterized this wetland: Baltic rush-velvet grass emergent, slough sedge emergent, and willow shrub.

Wetland 3 (0.20 acre). This wetland was classified as palustrine scrub-shrub, broad-leaved deciduous, seasonally flooded. This bowl-shaped wetland occurred toward the west end of the area projected for filling and is characterized by a thick understory of slough sedge and an over-story mainly of alder. Pacific crabapple and Sitka spruce were also present.

Other Waters of the U.S. The surrounding lagoon resembled a scoured-out tidal channel and was a non-vegetated (and non-wetland) area of bare sand comprising approximately 4.71 acres.

Previous 2007 North Jetty Wetland Ratings

Two of the three wetlands described above were rated by the Washington Department of Ecology and the Corps on November 16, 2007 in accordance with the Washington State Wetland Rating System (Hruby 2004). Wetland 1, the tidal fringe wetlands, was not rated by this system because they were considered estuarine wetlands. Because of lack of hydrologic connection, Wetland 2 (consisting of two ditches) was broken out into discrete wetlands for rating purposes (referred to here as Wetland 2a and Wetland 2b). Wetland 2a was between the east parking lot and the beach access road and Wetland 2b was just west of Wetland 2a.

Categories were assigned by the rating system and were as follows: Category I (score ≥ 70), Category II (score 51-69), Category III (score 30-50), and Category IV (score < 30). All three wetlands rated were considered depressional wetlands and qualified as Category III wetlands. Original scores for the wetlands are shown in Table 2.

Table 2. 2007 Wetland Scores, North Jetty

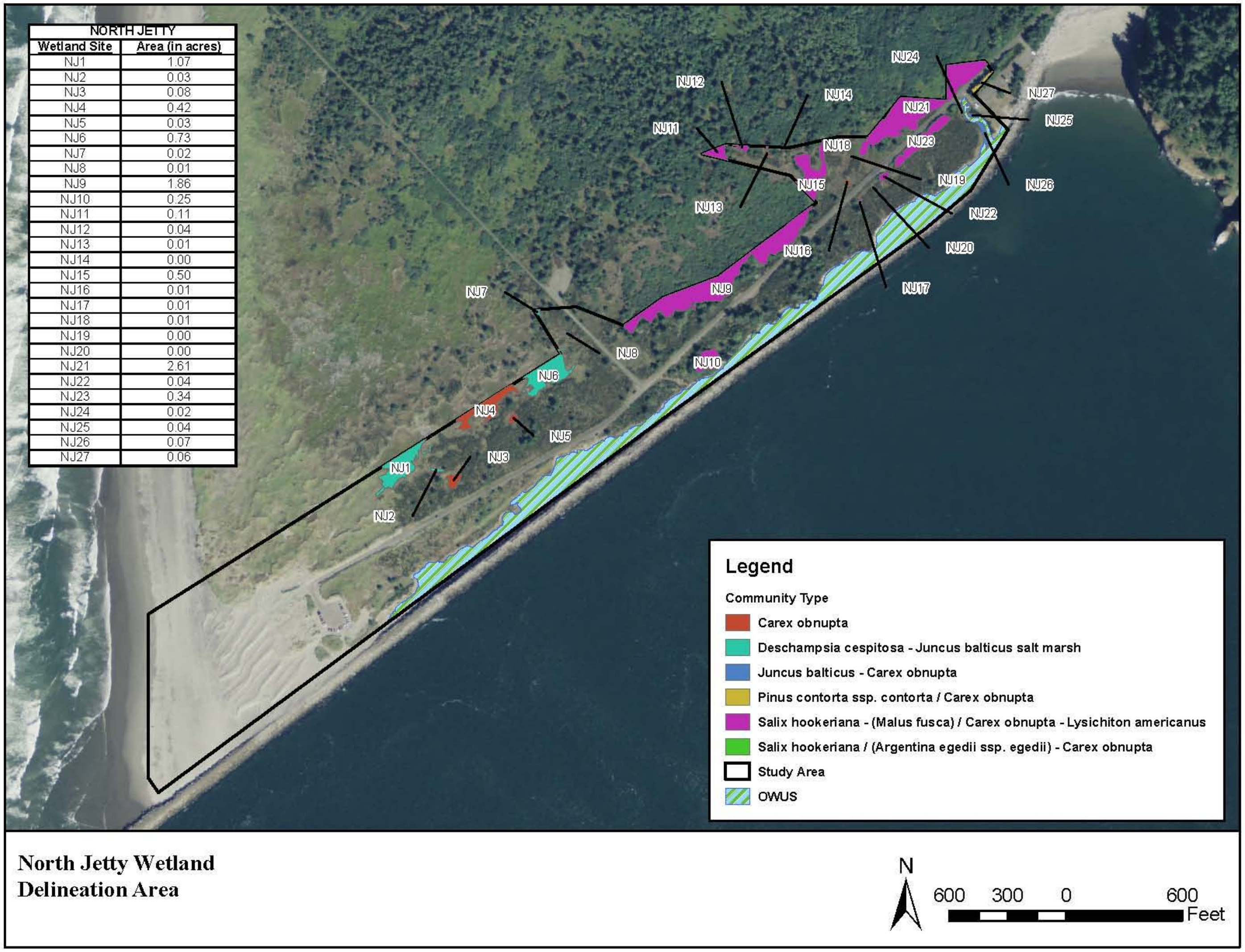
Function	Wetland		
	2a	2b	3
Water Quality Functions	12	20	12
Hydrologic Functions	5	10	12
Habitat Functions	13	13	15
Total Score	30	43	39

Note: Rating by Washington State Wetland Rating System

2011 Delineations: In 2011, the Corps contracted with Tetra Tech and updated the delineations for the area south of the North Jetty Access Road, and also delineated wetlands north of the North Jetty Access Road in order to locate additional necessary construction staging areas as well as identify potential wetland mitigation sites. As a result, it was discovered that several of the previously-delineated westernmost wetlands south of the North Jetty Access Road had disappeared due to storm and wind activity, and the remaining wetlands were somewhat smaller for the same reasons. In contrast, the lagoon area increased due to scour action at the interior jetty root.

The following figure indicates the wetlands or wetland mosaics that were identified both north and south of the North Jetty Access Road.

Figure 2. 2011 Wetland Delineations at the North Jetty



NORTH JETTY	
Wetland Site	Area (in acres)
NJ1	1.07
NJ2	0.03
NJ3	0.08
NJ4	0.42
NJ5	0.03
NJ6	0.73
NJ7	0.02
NJ8	0.01
NJ9	1.86
NJ10	0.25
NJ11	0.11
NJ12	0.04
NJ13	0.01
NJ14	0.00
NJ15	0.50
NJ16	0.01
NJ17	0.01
NJ18	0.01
NJ19	0.00
NJ20	0.00
NJ21	2.61
NJ22	0.04
NJ23	0.34
NJ24	0.02
NJ25	0.04
NJ26	0.07
NJ27	0.06

(TetraTech 2011)

These wetlands were also classified per the Cowardin system as follows (TetraTech 2011).

Table 3. 2011 Wetland Classifications, North Jetty

Site	Wetland Polygon	Acres	Wetland Classification[a]	Vegetation Classification[b/c]	Total Wetland Acres
North Jetty					8.38
	NJ1	1.074	Palustrine emergent nonpersistent	Deschampsia cespitosa - Juncus balticus salt marsh	ok
	NJ2	0.026	Palustrine emergent nonpersistent	Deschampsia cespitosa - Juncus balticus salt marsh	ok
	NJ3	0.083	Palustrine emergent nonpersistent	Carex obnupta	ok
	NJ4	0.417	Palustrine emergent nonpersistent	Carex obnupta	ok
	NJ5	0.033	Palustrine emergent nonpersistent	Carex obnupta	ok
	NJ6	0.733	Palustrine emergent nonpersistent	Deschampsia cespitosa - Juncus balticus salt marsh	ok
	NJ7	0.015	Palustrine emergent nonpersistent	Deschampsia cespitosa - Juncus balticus salt marsh	ok
	NJ8	0.007	Palustrine emergent nonpersistent	Juncus balticus - Carex obnupta	ok
	NJ9	1.864	Palustrine forested broad-leaved deciduous	Salix hookeriana - (Malus fusca) / Carex obnupta - Lysichiton americanus	ok
	NJ10	0.247	Palustrine forested broad-leaved deciduous	Salix hookeriana - (Malus fusca) / Carex obnupta - Lysichiton americanus	ok
	NJ11	0.109	Palustrine forested broad-leaved deciduous	Salix hookeriana - (Malus fusca) / Carex obnupta - Lysichiton americanus	ok
	NJ12	0.038	Palustrine forested broad-leaved deciduous	Salix hookeriana - (Malus fusca) / Carex obnupta - Lysichiton americanus	ok
	NJ13	0.015	Palustrine emergent nonpersistent	Carex obnupta	ok
	NJ14	0.002	Palustrine forested broad-leaved deciduous	Salix hookeriana / (Argentina egedii ssp. egedii) - Carex obnupta	ok
	NJ15	0.502	Palustrine forested broad-leaved deciduous	Salix hookeriana - (Malus fusca) / Carex obnupta - Lysichiton americanus	ok
	NJ16	0.015	Palustrine emergent nonpersistent	Carex obnupta	ok
	NJ17	0.012	Palustrine forested broad-leaved deciduous	Salix hookeriana - (Malus fusca) / Carex obnupta - Lysichiton americanus	ok
	NJ18	0.010	Palustrine forested broad-leaved deciduous	Salix hookeriana - (Malus fusca) / Carex obnupta - Lysichiton americanus	ok
	NJ19	0.003	Palustrine forested broad-leaved deciduous	Salix hookeriana - (Malus fusca) / Carex obnupta - Lysichiton americanus	ok
	NJ20	0.003	Palustrine emergent nonpersistent	Carex obnupta	ok
	NJ21	2.612	Palustrine forested broad-leaved deciduous	Salix hookeriana - (Malus fusca) / Carex obnupta - Lysichiton americanus	ok
	NJ22	0.036	Palustrine forested broad-leaved deciduous	Salix hookeriana - (Malus fusca) / Carex obnupta - Lysichiton americanus	ok
	NJ23	0.337	Palustrine forested broad-leaved deciduous	Salix hookeriana - (Malus fusca) / Carex obnupta - Lysichiton americanus	ok
	NJ24	0.018	Estuarine intertidal emergent persistent	Juncus balticus - Carex obnupta	ok
	NJ25	0.041	Estuarine intertidal emergent persistent	Juncus balticus - Carex obnupta	ok
	NJ26	0.070	Estuarine intertidal emergent persistent	Juncus balticus - Carex obnupta	ok
	NJ27	0.062	Palustrine forested needle-leaved evergreen	Picea sitchensis / Carex obnupta - Lysichiton americanus	ok

[a] Cowardin, L.M., V. Carter, F.C. Golet, and E.T. LaRoe. 1979. Classification of Wetlands and Deepwater Habitats of the United States. U.S. Fish and Wildlife Service publication FWS/OBS-79/31. Washing

[b] Kagan, J.S., J.A. Christy, M.P. Murray, and J.A. Titus. 2004. Classification of Native Vegetation of Oregon. Oregon Natural Heritage Information Center.

[c] OR classifications were applied to WA wetland polygons because of their similarities in vegetation and function and lack of appropriate classifications specific to WA.

(TetraTech 2011)

Using the Washington State Wetland Rating System, delineated wetlands were also categorized, functionally scored, and rated as illustrated below. These ratings and categories help to develop appropriate wetland mitigation, which is further discussed in the pertinent section.

Table 4. 2011 Wetland Rating Scores, North Jetty

Function	Wetland												
	NJ1	NJ2	NJ3	NJ4	NJ5	NJ6-7	NJ8	NJ9,11-16,18,21	NJ10	NJ17,20,22,23	NJ19	NJ24-26	NJ27
Water Quality Functions	6	10	10	6	10	6	10	14	10	10	10	NA	5
Hydrologic Functions	7	4	4	7	4	7	4	11	7	7	4	NA	2
Habitat Functions	15	13	13	15	13	16	13	26	13	13	13	NA	11
Total Score	28	27	27	28	27	29	27	51	30	30	27	NA	18
Special Characteristics & HGM Class	Interdunal Depressional	Interdunal Depressional	Interdunal Depressional	Interdunal Depressional	Interdunal Depressional	Interdunal Depressional	Interdunal Depressional	Interdunal Riverine	Interdunal Depressional	Interdunal Depressional	Interdunal Depressional	Estuarine	Interdunal Depressional
Final Category	II	IV	IV	II	IV	II	IV	II	III	III	IV	I	III

Note: Rating by Washington State Wetland Rating System, (*Tetra Tech 2011*)

Wetlands near Jetty A. Land around the base of Jetty A received a cursory inspection on January 22, 2007 and again on September 13, 2010. An official wetland delineation was completed in 2011 to assess rock storage and construction staging operations that will occur in the vicinity of Jetty A. The following figure below indicates wetlands in the vicinity of Jetty A.

These wetlands were also classified per the Cowardin system, and then given a rating score per the WA State rating system as follows (TetraTech 2011).

Table 5. 2011 Wetland Classifications, Jetty A

Site	Wetland Polygon	Acres	Wetland Classification[a]	Vegetation Classification[b/c]	Total Wetland Acres
Jetty A					0.91
	JA1	0.611	Palustrine forested broad-leaved deciduous	Salix hookeriana / (Argentina egedii ssp. egedii) - Carex obnupta	
	JA2	0.126	Palustrine forested broad-leaved deciduous	Salix hookeriana / (Argentina egedii ssp. egedii) - Carex obnupta	
	JA3	0.168	Palustrine emergent nonpersistent	Deschampsia cespitosa - (Carex lyngbyei - Distichlis spicata) salt marsh	

[a] Cowardin, L.M., V. Carter, F.C. Golet, and E.T. LaRoe. 1979. Classification of Wetlands and Deepwater Habitats of the United States. U.S. Fish and Wildlife Service publication FWS/OBS-79/31. Washing

[b] Kagan, J.S., J.A. Christy, M.P. Murray, and J.A. Titus. 2004. Classification of Native Vegetation of Oregon. Oregon Natural Heritage Information Center.

[c] OR classifications were applied to WA wetland polygons because of their similarities in vegetation and function and lack of appropriate classifications specific to WA.

(TetraTech 2011)

Table 6. 2011 Wetland Rating Scores, Jetty A

Function	Wetland		
	JA1	JA2	JA3
Water Quality Functions	8	7	NA
Hydrologic Functions	7	5	NA
Habitat Functions	11	10	NA
Total Score	26	22	NA
Special Characteristics & HGM Class	Interdunal Depressional	Interdunal Depressional	Estuarine
Final Category	III	III	I

Note: Rating by Washington State Wetland Rating System, (*Tetra tech 2011*)

Figure 3. 2011 Wetland Delineations at the Jetty A

JETTY A	
Wetland Site	Area (in acres)
JA1	0.61
JA2	0.13
JA3	0.17

(TetraTech 2011)

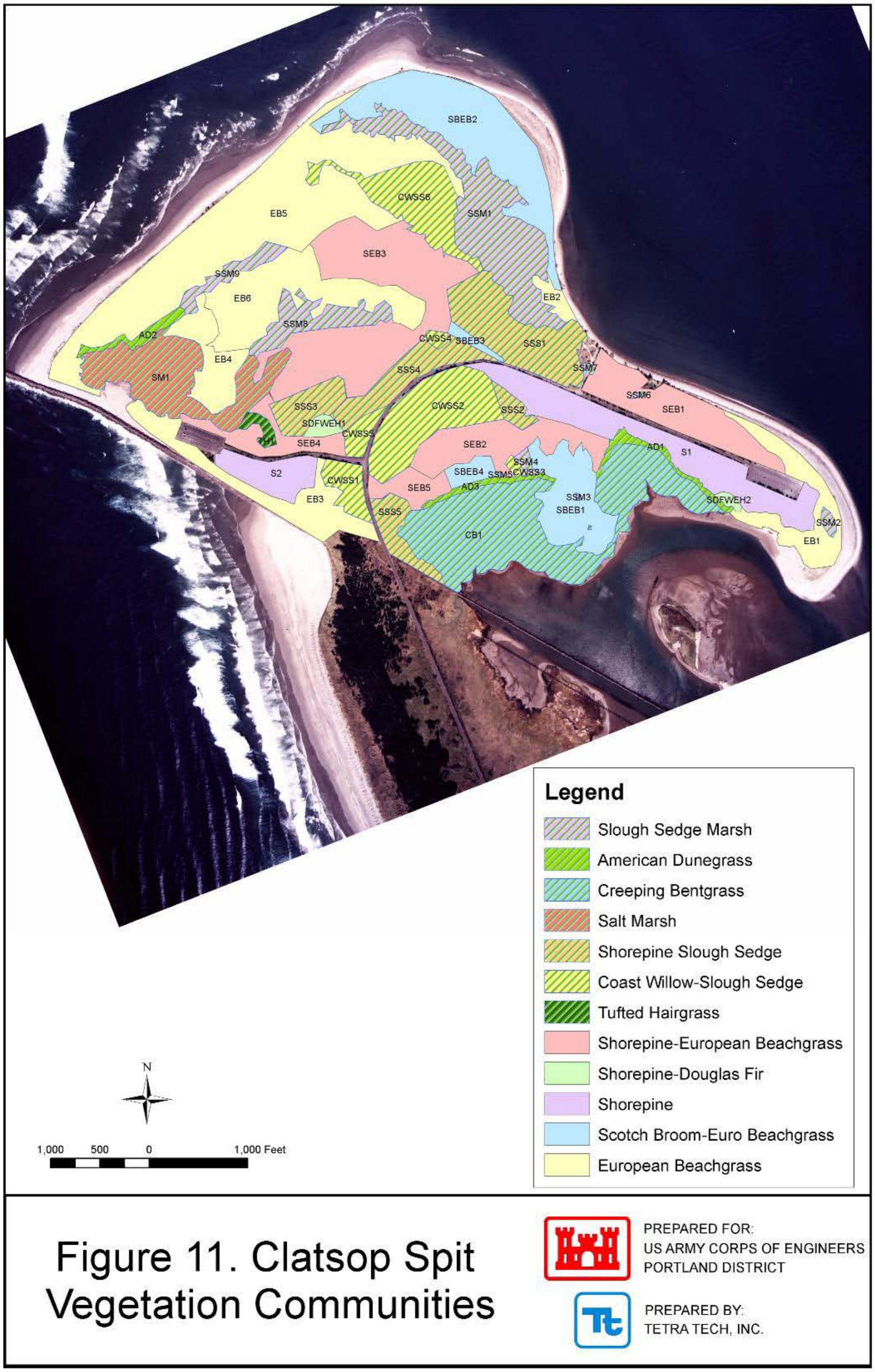
Wetlands near South Jetty (on Clatsop Spit). An investigation into vegetation communities on Clatsop Spit was conducted in spring of 2007 (Tetra Tech 2007b). See the first figure below. Though not official delineations, these habitat surveys suggested that of the 600-acres of Clatsop Spit investigated, 193-acres were likely wetlands (Tetra Tech 2007b). The topography of the area is complex with dunes and intertidal swales forming a mosaic of various vegetation communities including shorepine-slough sedge, slough sedge marsh, American dune grass, creeping bent grass, salt marsh, coast willow-slough sedge, tufted hair grass, shorepine-European beach grass, shorepine-Douglas fir, shorepine, Scotch broom-European beach grass, and European beach grass (Figure 2). At least three of these communities (shorepine-slough sedge, shorepine-Douglas fir, and coast willow-slough sedge) have been ranked globally and by the State for their rarity and vulnerability to extinction and should be protected from impacts (Tetra Tech 2007b).

It is anticipated that the proposed action will avoid most impacts to wetlands and waters of the United States in this area to the maximum degree feasible. The vegetation surveys allowed initial identification of possible locations for construction storage, staging, and stockpiling areas. In order to further avoid and minimize impacts, wetland delineations were also completed by Tetra Tech at the South Jetty in 2011 in the vicinity of the areas under consideration for construction staging and stockpiling as well as mitigation. The following series of figures after the Vegetative Communities figure indicate areas in which wetlands were identified.

The Cowardin classifications and vegetative communities for each class are also described in the tables below. Wetlands at the South Jetty and South Jetty mitigation area were also scored based on their functional conditions and values, though differently than the process used in Washington. The method used to evaluate wetlands at the Clatsop Spit was Oregon Rapid Wetlands Assessment Protocol (ORWAP) 2.0.2, which was developed in partnership by the OR Department of State Lands (DSL), the US EPA, and the Portland District Regulatory Branch (ORWAP 2010). Functional output scores are based on the following parameters: Water Storage; Sediment Retention; Phosphorus Retention; Nitrate Removal; Thermoregulation; Carbon Sequestration; Organic Matter Export; Aquatic Invertebrate Habitat; Anadromous Fish Habitat; Non-anadromous Fish Habitat; Amphibian and Reptile Habitat; Waterbird Feeding Habitat; Waterbird Nesting Habitat; Songbird, Raptor, and Mammal Habitat; Pollinator Habitat; and Native Plant Diversity. Grouped Service Functions include: Hydrologic; Water Quality Support; Fish Support; Aquatic Support; Terrestrial Support; and Carbon Sequestration. Value scores include the same categories, with the following exceptions: Carbon Sequestration and Organic Matter Export are not included; and in the Grouped Service Values, Carbon Sequestration is replaced by Public Use and Recognition, and Provisioning.

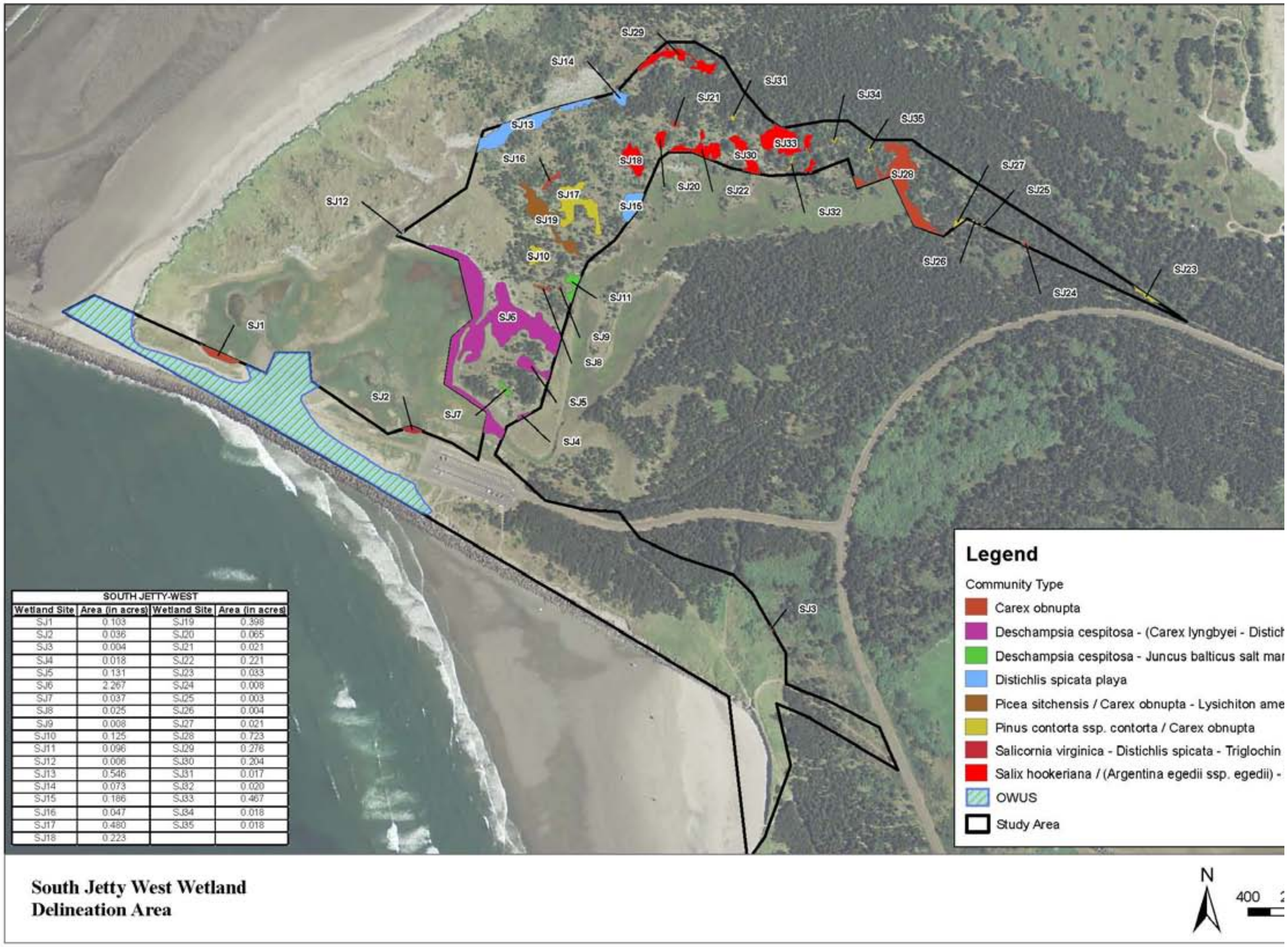
Functions are considered the physical, chemical, and biological processes that characterize the wetland ecosystem; while values reflect the importance or worth of wetland functions to societal needs (ORWAP 2010). According to ORWAP guidance, scores that rank above the median threshold relative to 221 state-scored wetlands can be considered “relatively high” for that output, and conversely, “relatively low” if the opposite is true (ORWAP 2010).

Figure 4. Clatsop Spit Vegetative Communities



Source: (Tetra Tech 2007b)

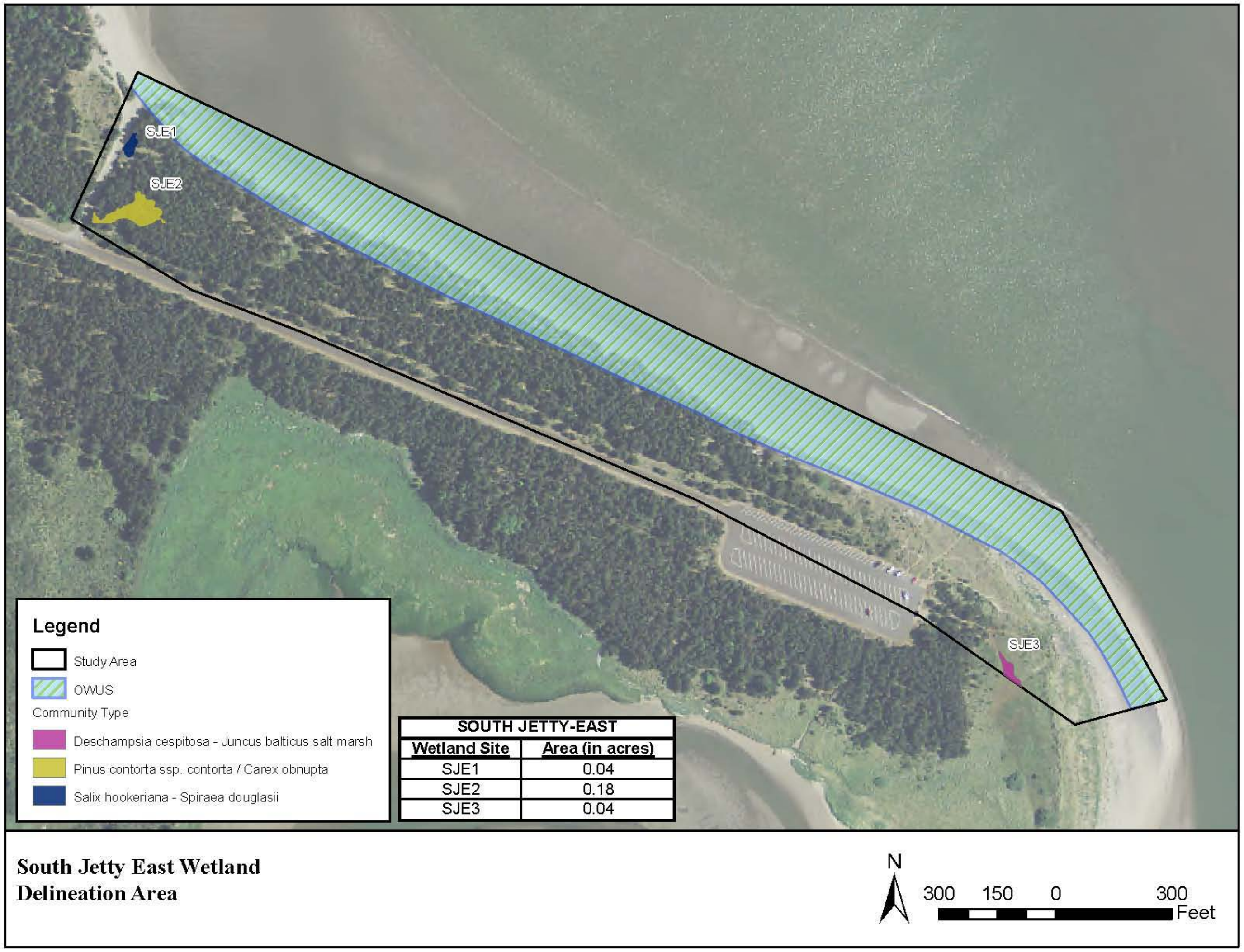
Figure 5. 2011 Wetland Delineations, Clatsop Spit West, South Jetty



SOUTH JETTY-WEST			
Wetland Site	Area (in acres)	Wetland Site	Area (in acres)
SJ1	0.103	SJ19	0.398
SJ2	0.036	SJ20	0.065
SJ3	0.004	SJ21	0.021
SJ4	0.018	SJ22	0.221
SJ5	0.131	SJ23	0.033
SJ6	2.267	SJ24	0.008
SJ7	0.037	SJ25	0.003
SJ8	0.025	SJ26	0.004
SJ9	0.008	SJ27	0.021
SJ10	0.125	SJ28	0.723
SJ11	0.096	SJ29	0.276
SJ12	0.006	SJ30	0.204
SJ13	0.546	SJ31	0.017
SJ14	0.073	SJ32	0.020
SJ15	0.186	SJ33	0.467
SJ16	0.047	SJ34	0.018
SJ17	0.480	SJ35	0.018
SJ18	0.223		

(TetraTech 2011)

Figure 6. 2011 Wetland Delineations, Clatsop Spit West, South Jetty



SOUTH JETTY-EAST	
Wetland Site	Area (in acres)
SJE1	0.04
SJE2	0.18
SJE3	0.04

(TetraTech 2011)

Table 7. 2011 Wetland Classifications, South Jetty and Mitigation Area

Site	Wetland Polygon	Acres	Wetland Classification[a]	Vegetation Classification[b/c]	Total Wetland Acres
South Jetty					6.93
	SJ1	0.103	Estuarine intertidal emergent persistent	Carex obnupta	ok
	SJ2	0.036	Estuarine intertidal emergent persistent	Salicornia virginica - Distichlis spicata - Triglochin maritima - (Jaumea carnosa)	ok
	SJ3	0.004	Palustrine forested broad-leaved deciduous	Salix hookeriana / (Argentina egedii ssp. egedii) - Carex obnupta	ok
	SJ4	0.018	Estuarine intertidal emergent persistent	Deschampsia cespitosa - (Carex lyngbyei - Distichlis spicata) salt marsh	ok
	SJ5	0.131	Estuarine intertidal emergent persistent	Deschampsia cespitosa - (Carex lyngbyei - Distichlis spicata) salt marsh	ok
	SJ6	2.267	Estuarine intertidal emergent persistent	Deschampsia cespitosa - (Carex lyngbyei - Distichlis spicata) salt marsh	ok
	SJ7	0.037	Palustrine emergent nonpersistent	Deschampsia cespitosa - Juncus balticus salt marsh	ok
	SJ8	0.025	Palustrine emergent nonpersistent	Carex obnupta	ok
	SJ9	0.008	Palustrine emergent nonpersistent	Carex obnupta	ok
	SJ10	0.125	Palustrine forested needle-leaved evergreen	Pinus contorta ssp. contorta / Carex obnupta	ok
	SJ11	0.096	Estuarine intertidal emergent persistent	Deschampsia cespitosa - Juncus balticus salt marsh	ok
	SJ12	0.006	Estuarine intertidal emergent persistent	Distichlis spicata playa	ok
	SJ13	0.546	Estuarine intertidal emergent persistent	Distichlis spicata playa	ok
	SJ14	0.073	Estuarine intertidal emergent persistent	Distichlis spicata playa	ok
	SJ15	0.186	Estuarine intertidal emergent persistent	Distichlis spicata playa	ok
	SJ16	0.047	Palustrine forested needle-leaved evergreen	Pinus contorta ssp. contorta / Carex obnupta	ok
	SJ17	0.480	Palustrine emergent nonpersistent	Carex obnupta	ok
	SJ18	0.223	Palustrine forested broad-leaved deciduous	Salix hookeriana / (Argentina egedii ssp. egedii) - Carex obnupta	ok
	SJ19	0.398	Palustrine forested needle-leaved evergreen	Picea sitchensis / Carex obnupta - Lysichiton americanus	ok
	SJ20	0.065	Palustrine forested broad-leaved deciduous	Salix hookeriana / (Argentina egedii ssp. egedii) - Carex obnupta	ok
	SJ21	0.021	Palustrine emergent nonpersistent	Carex obnupta	ok
	SJ22	0.221	Palustrine forested broad-leaved deciduous	Salix hookeriana / (Argentina egedii ssp. egedii) - Carex obnupta	ok
	SJ23	0.033	Palustrine forested needle-leaved evergreen	Pinus contorta ssp. contorta / Carex obnupta	ok
	SJ24	0.008	Palustrine emergent nonpersistent	Carex obnupta	ok
	SJ25	0.003	Palustrine forested needle-leaved evergreen	Pinus contorta ssp. contorta / Carex obnupta	ok
	SJ26	0.004	Palustrine forested needle-leaved evergreen	Pinus contorta ssp. contorta / Carex obnupta	ok
	SJ27	0.021	Palustrine forested needle-leaved evergreen	Pinus contorta ssp. contorta / Carex obnupta	ok
	SJ28	0.723	Palustrine emergent nonpersistent	Carex obnupta	ok
	SJ29	0.276	Palustrine forested broad-leaved deciduous	Salix hookeriana / (Argentina egedii ssp. egedii) - Carex obnupta	ok
	SJ30	0.204	Palustrine forested broad-leaved deciduous	Salix hookeriana / (Argentina egedii ssp. egedii) - Carex obnupta	ok
	SJ31	0.017	Palustrine forested needle-leaved evergreen	Pinus contorta ssp. contorta / Carex obnupta	ok
	SJ32	0.020	Palustrine forested needle-leaved evergreen	Pinus contorta ssp. contorta / Carex obnupta	ok
	SJ33	0.467	Palustrine forested broad-leaved deciduous	Salix hookeriana / (Argentina egedii ssp. egedii) - Carex obnupta	ok
	SJ34	0.018	Palustrine forested needle-leaved evergreen	Pinus contorta ssp. contorta / Carex obnupta	ok
	SJ35	0.018	Palustrine forested needle-leaved evergreen	Pinus contorta ssp. contorta / Carex obnupta	ok
South Jetty East					0.25
	SJE1	0.036	Palustrine forested broad-leaved deciduous	Salix hookeriana - Spiraea douglasii	ok
	SJE3	0.037	Palustrine emergent nonpersistent	Deschampsia cespitosa - Juncus balticus salt marsh	ok
	SJE2	0.179	Palustrine forested needle-leaved evergreen	Pinus contorta ssp. contorta / Carex obnupta	ok
Mitigation					7.55
	MA2	0.227	Palustrine forested needle-leaved evergreen	Pinus contorta ssp. contorta / Carex obnupta	ok
	MA1	2.640	Palustrine forested broad-leaved deciduous	Salix hookeriana - (Malus fusca) / Carex obnupta - Lysichiton americanus	ok
	MA3	4.680	Estuarine intertidal emergent persistent	Deschampsia cespitosa - (Carex lyngbyei - Distichlis spicata) salt marsh	ok

[a] Cowardin, L.M., V. Carter, F.C. Golet, and E.T. LaRoe. 1979. Classification of Wetlands and Deepwater Habitats of the United States. U.S. Fish and Wildlife Service publication FWS/OBS-79/31. Washing

[b] Kagan, J.S., J.A. Christy, M.P. Murray, and J.A. Titus. 2004. Classification of Native Vegetation of Oregon. Oregon Natural Heritage Information Center.

[c] OR classifications were applied to WA wetland polygons because of their similarities in vegetation and function and lack of appropriate classifications specific to WA.

(TetraTech 2011)

Table 8. 2011 Wetland Functions and Values, South Jetty Depressional – Sheet A

CoverPg: Basic Description of Assessment	**ORWAP version 2.0.2**
Site Name:	South Jetty*
Investigator Name:	Jeff Barna
Date of Field Assessment:	4-17 March 2011
County:	Clatsop
Nearest Town:	Warrenton, OR
Latitude (decimal degrees):	46.227276°
Longitude (decimal degrees):	neg 124.003985°
TRS, quarter/quarter section and tax lot(s)	Washington, Willamette Meridian T9N,R11W,sec26
Approximate size of the Assessment Area (AA, in acres)	44.00
AA as percent of entire wetland (approx.)	50%
If delineated, DSL file number (WD #) if known	Has not yet been provided
Soil Map Units within the AA (list these in approx. rank order by area, from WSS web site or published county survey; see manual)	Heceta-Waldport fine sands, 0 to 15 percent slopes
Soil Map Units surrounding and contiguous to the AA (list all present in approx. rank order by area; see manual)	Dune land
	Coquille-Clatsop complex, 0 to 1 percent slopes
	Beaches
Cowardin Systems & Classes (indicate all present, based on field visit and/or aerial imagery): Systems: Palustrine =P, Riverine =R, Lacustrine =L, Estuarine =E Classes: Emergent =EM, Scrub-Shrub =SS, Forested =FO, Aquatic Bed (incl. SAV) =AB, Open Water =OW, Unconsolidated Bottom =UB, Unconsolidated Shore =US	P, EM
	P, SS
	P, FO
HGM Class (Scores worksheet will suggest a class; see manual section 2.4.2)	Depressional
If tidal, the tidal phase during most of visit:	All tidal phases were present
What percent (approx.) of the **wetland** were you able to visit?	10
What percent (approx.) of the **AA** were you able to visit?	100
Have you attended an ORWAP training session? If so, indicate approximate month & year.	No
How many wetlands have you assessed previously using ORWAP (approx.)?	None

Comments about the site or this ORWAP assessment (attach extra page if desired):

* Wetlands included in this ORWAP assessment are South Jetty West SJ3, 7, 8, 9, 10, 16, 17, 18, 19, 20, 21, 23, 31, 32, 33, 34, and 35 and South Jetty East SJE1, 2, and 3 (see maps; South Jetty West Delineation Area and South Jetty East Wetland Delineation Area). These wetlands all share the same functional characteristics including soil, landform, primary water source, and level of disturbance.

Comment:
Although the wetland unit received a HGM class of "estuarine" from ORWAP, it is actually a depressional wetland unit that occurs in interdunal swales near but disconnected from the tidal system. Function for anadromous fish appears to be substantially inflated by ORWAP; although extensive high quality habitat does exist in the AA (in the area of estuarine HGM class rated separately), the presences of a rock jetty (South Jetty of the Columbia River) at the interface between the ocean/river and the estuary limits passage to only small fry and creates an attractive nuisance . Regardless, since all depressional wetlands found in this AA are hydrologically disconnected from the tidal/stream system, no access to these areas is available to fish.

(Tetra Tech 2011)

Table 9. 2011 Wetland Functions and Values, South Jetty Depressional – Sheet B

ORWAP SCORES SHEET	version 2.0.2		
Site Name:	South Jetty		
Investigator Name:	Jeff Barna		
Date of Field Assessment:	4-17 March 2011		
Latitude (decimal degrees):	46.227276°	Longitude (decimal degrees):	neg 124.003985°

Specific Functions:	Relative Effectiveness of the Function	Relative Values of the Function
Water Storage & Delay (WS)	2.25	2.50
Sediment Retention & Stabilization (SR)	10.00	5.68
Phosphorus Retention (PR)	10.00	6.33
Nitrate Removal & Retention (NR)	10.00	4.33
Thermoregulation (T)	0.00	3.33
Carbon Sequestration (CS)	3.04	
Organic Matter Export (OE)	0.00	
Aquatic Invertebrate Habitat (INV)	7.37	7.23
Anadromous Fish Habitat (FA)	0.00	10.00
Non-anadromous Fish Habitat (FR)	2.67	6.67
Amphibian & Reptile Habitat (AM)	7.23	4.00
Waterbird Feeding Habitat (WBF)	6.26	4.00
Waterbird Nesting Habitat (WBN)	5.84	6.67
Songbird, Raptor, & Mammal Habitat (SBM)	6.28	6.67
Pollinator Habitat (POL)	5.81	1.67
Native Plant Diversity (PD)	6.53	6.67

GROUPED FUNCTIONS	Group Scores (functions)	Group Scores (values)	
Hydrologic Function (WS)	2.25	2.50	(identical to Water Storage and Delay function and value scores)
Water Quality Group (WQ)	10.00	6.33	(maximum of scores for SR, PR, NR, and T)
Carbon Sequestration (CS)	3.04		(identical to Carbon Sequestration score above)
Fish Support Group (FISH)	2.67	10.00	(maximum of scores for FA and FR)
Aquatic Support Group (AQ)	7.37	6.67	(maximum of scores for OE, AM, INV, WBF, and WBN)
Terrestrial Support Group (TERR)	6.53	6.67	(maximum of scores for PD, POL, and SBM)
Public Use & Recognition (PU)		0.48	(click on this cell to see this attribute defined)
Provisioning Services (PS)		0.00	(click on this cell to see this attribute defined)

OTHER ATTRIBUTES		
Wetland Ecological Condition		6.31
Wetland Stressors		3.42
Wetland Sensitivity		10.00

HGM Class - Relative Probabilities (select max)	
Estuarine	0.00
Riverine	0.00
Slope	0.00
Flat	10.00
Depressional	0.00
Lacustrine	0.00

(Tetra Tech 2011)

In comparison to State wetland scores for grouped service functions as define by ORWAP (2010), depressional wetlands at the South Jetty are ranked relatively as follows: low for hydrologic function and fish support group; and high for water quality, carbon sequestration, aquatic support, and terrestrial support. Alternatively, the relative scores for the grouped service values were: low for hydrologic function, terrestrial support, and public use and recognition; equal for provisioning services, and high for water quality, fish support, and aquatic support. The wetlands also ranked relatively high for ecological condition and sensitivity, and low for stressors.

Table 10. 2011 Wetland Functions and Values, South Jetty Estuarine – Sheet A

CoverPg: Basic Description of Assessment	ORWAP version 2.0.2
Site Name:	South Jetty*
Investigator Name:	Jeff Barna
Date of Field Assessment:	4-17 March 2011
County:	Clatsop
Nearest Town:	Warrenton, OR
Latitude (decimal degrees):	46.227276°
Longitude (decimal degrees):	neg 124.003985°
TRS, quarter/quarter section and tax lot(s)	Washington, Willamette Meridian T9N,R11W,sec26
Approximate size of the Assessment Area (AA, in acres)	44.00
AA as percent of entire wetland (approx.)	50%
If delineated, DSL file number (WD #) if known	Has not yet been provided
Soil Map Units within the AA (list these in approx. rank order by area, from WSS web site or published county survey; see manual)	Heceta-Waldport fine sands, 0 to 15 percent slopes
Soil Map Units surrounding and contiguous to the AA (list all present in approx. rank order by area; see manual)	Dune land Coquille-Clatsop complex, 0 to 1 percent slopes Beaches
Cowardin Systems & Classes (indicate all present, based on field visit and/or aerial imagery): Systems: Palustrine =P, Riverine =R, Lacustrine =L, Estuarine =E Classes: Emergent =EM, Scrub-Shrub =SS, Forested =FO, Aquatic Bed (incl. SAV) =AB, Open Water =OW, Unconsolidated Bottom =UB, Unconsolidated Shore =US	E, EM P, EM
HGM Class (Scores worksheet will suggest a class; see manual section 2.4.2)	Esturine
If tidal, the tidal phase during most of visit:	All tidal phases were present
What percent (approx.) of the **wetland** were you able to visit?	10
What percent (approx.) of the **AA** were you able to visit?	100
Have you attended an ORWAP training session? If so, indicate approximate month & year.	No
How many wetlands have you assessed previously using ORWAP (approx.)?	None

Comments about the site or this ORWAP assessment (attach extra page if desired):

* Wetlands included in this ORWAP assessment are South Jetty West SJ1, 2, 4, 5, 6, 11, 12, 13, 14, 15, 22, 24, 25, 26, 27, 28, 29, and 30 (see map; South Jetty West Delineation Area). These wetlands all share the same functional characteristics including soil, landform, primary water source, and level of disturbance.

Comment:
Function for anadromous fish appears to be substantially inflated by ORWAP; although extensive high quality habitat does exist in this wetland unit, the presences of a rock jetty (South Jetty of the Columbia River) at the interface between the ocean/river and the estuary limits passage to only small fry and creates an attractive nuisance.

(Tetra Tech 2011)

Table 11. 2011 Wetland Functions and Values, South Jetty Estuarine – Sheet B

ORWAP SCORES SHEET	version 2.0.2		
Site Name:	South Jetty		
Investigator Name:	Jeff Barna		
Date of Field Assessment:	4-17 March 2011		
Latitude (decimal degrees):	46.227276°	Longitude (decimal degrees):	neg 124.003985°

Specific Functions:	Relative Effectiveness of the Function	Relative Values of the Function
Water Storage & Delay (WS)	0.00	1.50
Sediment Retention & Stabilization (SR)	7.96	3.31
Phosphorus Retention (PR)	3.53	3.83
Nitrate Removal & Retention (NR)	7.21	2.33
Thermoregulation (T)	0.00	6.67
Carbon Sequestration (CS)	7.31	
Organic Matter Export (OE)	5.77	
Aquatic Invertebrate Habitat (INV)	6.30	4.54
Anadromous Fish Habitat (FA)	0.00	10.00
Non-anadromous Fish Habitat (FR)	3.11	6.67
Amphibian & Reptile Habitat (AM)	0.00	0.67
Waterbird Feeding Habitat (WBF)	4.54	0.67
Waterbird Nesting Habitat (WBN)	0.00	6.67
Songbird, Raptor, & Mammal Habitat (SBM)	3.00	6.67
Pollinator Habitat (POL)	5.58	1.67
Native Plant Diversity (PD)	5.36	6.67

GROUPED FUNCTIONS	Group Scores (functions)	Group Scores (values)	
Hydrologic Function (WS)	0.00	1.50	(identical to Water Storage and Delay function and value scores)
Water Quality Group (WQ)	7.96	6.67	(maximum of scores for SR, PR, NR, and T)
Carbon Sequestration (CS)	7.31		(identical to Carbon Sequestration score above)
Fish Support Group (FISH)	3.11	10.00	(maximum of scores for FA and FR)
Aquatic Support Group (AQ)	6.30	6.67	(maximum of scores for OE, AM, INV, WBF, and WBN)
Terrestrial Support Group (TERR)	5.58	6.67	(maximum of scores for PD, POL, and SBM)
Public Use & Recognition (PU)		1.19	(click on this cell to see this attribute defined)
Provisioning Services (PS)		0.00	(click on this cell to see this attribute defined)

OTHER ATTRIBUTES		
Wetland Ecological Condition		7.56
Wetland Stressors		3.89
Wetland Sensitivity		4.26

HGM Class - Relative Probabilities (select max)	
Estuarine	10.00
Riverine	0.00
Slope	0.00
Flat	0.00
Depressional	0.00
Lacustrine	0.00

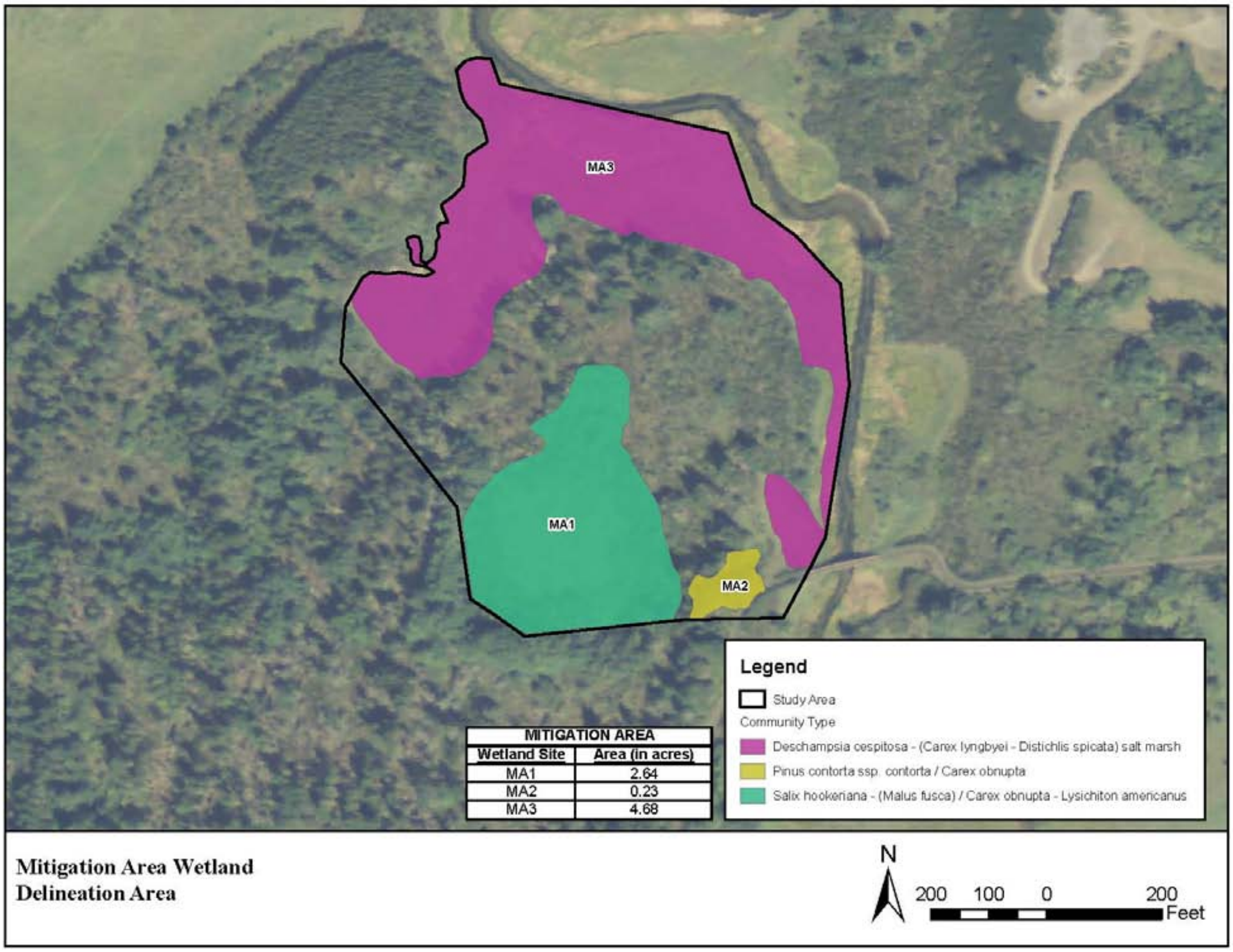
(Tetra Tech 2011)

When reviewing these particular ratings for South Jetty estuarine wetlands, it is notable that some of the wetlands (22-30) classified as Palustrine under the Cowardin system, were scored as Estuarine in ORWAP. These wetlands have characteristics that fit under both categories. Salinities and connectivity are likely low enough that they most closely resemble the Cowardin palustrine class, but because of the tidal connectivity and because they are a portion of a larger wetland area, they may be more accurately scored under ORWAP's estuarine classification.

In comparison to State wetland scores for grouped service functions as define by ORWAP (2010), estuarine wetlands at the South Jetty are ranked relatively as follows: low for hydrologic function, aquatic support, and terrestrial support; and high for water quality, carbon sequestration, and fish support group. Alternatively, the relative scores for the grouped service values were: low for hydrologic function, aquatic support, terrestrial support, and public use and recognition; equal for provisioning services, and high for water quality and fish support. The wetlands also ranked relatively high for ecological condition, and low for stressors and sensitivity.

Wetlands at Trestle Bay Near the Potential Mitigation Site. In order to determine the appropriateness and ability to mitigate for wetland impacts at the South Jetty, an area near Trestle Bay was delineated as a possible mitigation site. The following information was obtained regarding functions and values of the wetlands, which are surrounded by uplands. Anecdotally, the uplands are old fill from dredging for Battery Russell. The upland areas offer a wetland restoration opportunity that is proximate with higher quality wetlands, and would be less accessible to disturbance by park recreationalists compared to potential sites on the Spit itself. The functional scores are described below, and the Cowardin Class was included in the Table of South Jetty Cowardin classes.

Figure 7. 2011 Wetland Delineations, Clatsop Spit West, South Jetty



(TetraTech 2011)

Table 12. 2011 Wetland Functions and Values, Mitigation Area Depressional – Sheet A

CoverPg: Basic Description of Assessment	**ORWAP version 2.0.2**
Site Name:	Mitigation Area*
Investigator Name:	Darlene Siegel
Date of Field Assessment:	3/14/2011
County:	Clatsop
Nearest Town:	Warrenton, OR
Latitude (decimal degrees):	46.227276°
Longitude (decimal degrees):	-124.003985°
TRS, quarter/quarter section and tax lot(s)	T8N,R10W,sec6
Approximate size of the Assessment Area (AA, in acres)	15.00
AA as percent of entire wetland (approx.)	15%
If delineated, DSL file number (WD #) if known	Has not yet been provided
Soil Map Units within the AA (list these in approx. rank order by area, from WSS web site or published county survey; see manual)	Coquille-Clatsop complex, 0 to 1 percent slopes Heceta-Waldport fine sands, 0 to 15 percent slopes
Soil Map Units surrounding and contiguous to the AA (list all present in approx. rank order by area; see manual)	Tropopsamments, 0 to 15 percent slopes Waldport fine sand, 3 to 15 percent slopes
Cowardin Systems & Classes (indicate all present, based on field visit and/or aerial imagery): Systems: Palustrine =P, Riverine =R, Lacustrine =L, Estuarine =E Classes: Emergent =EM, Scrub-Shrub =SS, Forested =FO, Aquatic Bed (incl. SAV) =AB, Open Water =OW, Unconsolidated Bottom =UB, Unconsolidated Shore =US	P, EM P, SS P, FO
HGM Class (Scores worksheet will suggest a class; see manual section 2.4.2)	Depressional
If tidal, the tidal phase during most of visit:	All tidal phases were present
What percent (approx.) of the **wetland** were you able to visit?	5
What percent (approx.) of the **AA** were you able to visit?	100
Have you attended an ORWAP training session? If so, indicate approximate month & year.	No
How many wetlands have you assessed previously using ORWAP (approx.)?	None

Comments about the site or this ORWAP assessment (attach extra page if desired):

* Wetlands included in this ORWAP assessment are Mitigation Area MA1 and 2 (see map; Mitigation Area Wetland Delineation Area). These wetlands share the same functional characteristics including soil, landform, primary water source, and level of disturbance.

Comment:
Although the wetland unit received a HGM class of "estuarine" from ORWAP, it is actually a depressional wetland unit that occurs in interdunal swales near but disconnected from the tidal system. Function for anadromous fish appears to be substantially inflated by ORWAP; this depressional wetland unit is disconnected from the tidal/stream system preventing anadromous fish from accessing the habitat.

(Tetra Tech 2011)

Table 13. 2011 Wetland Functions and Values, Mitigation Area Depressional – Sheet B

ORWAP SCORES SHEET	**version 2.0.2**		
Site Name:	Mitigation Area		
Investigator Name:	Darlene Siegel		
Date of Field Assessment:	3/14/2011		
Latitude (decimal degrees):	42.2273	Longitude (decimal degrees):	-124.003985°

Specific Functions:	Relative Effectiveness of the Function	Relative Values of the Function
Water Storage & Delay (WS)	1.07	2.50
Sediment Retention & Stabilization (SR)	7.00	5.63
Phosphorus Retention (PR)	2.89	6.33
Nitrate Removal & Retention (NR)	6.71	4.00
Thermoregulation (T)	0.00	3.33
Carbon Sequestration (CS)	3.50	
Organic Matter Export (OE)	3.90	
Aquatic Invertebrate Habitat (INV)	5.00	6.00
Anadromous Fish Habitat (FA)	0.00	10.00
Non-anadromous Fish Habitat (FR)	0.00	6.67
Amphibian & Reptile Habitat (AM)	0.00	4.00
Waterbird Feeding Habitat (WBF)	4.50	4.00
Waterbird Nesting Habitat (WBN)	0.00	3.00
Songbird, Raptor, & Mammal Habitat (SBM)	2.00	6.67
Pollinator Habitat (POL)	6.24	0.83
Native Plant Diversity (PD)	4.87	6.00

GROUPED FUNCTIONS	**Group Scores (functions)**	**Group Scores (values)**	
Hydrologic Function (WS)	1.07	2.50	(identical to Water Storage and Delay function and value scores)
Water Quality Group (WQ)	7.00	6.33	(maximum of scores for SR, PR, NR, and T)
Carbon Sequestration (CS)	3.50		(identical to Carbon Sequestration score above)
Fish Support Group (FISH)	0.00	10.00	(maximum of scores for FA and FR)
Aquatic Support Group (AQ)	5.00	4.00	(maximum of scores for OE, AM, INV, WBF, and WBN)
Terrestrial Support Group (TERR)	6.24	6.67	(maximum of scores for PD, POL, and SBM)
Public Use & Recognition (PU)		1.90	(click on this cell to see this attribute defined)
Provisioning Services (PS)		0.00	(click on this cell to see this attribute defined)

OTHER ATTRIBUTES		
Wetland Ecological Condition		6.07
Wetland Stressors		0.52
Wetland Sensitivity		10.00

HGM Class - Relative Probabilities (select max)	
Estuarine	10.00
Riverine	0.00
Slope	0.00
Flat	0.00
Depressional	0.00
Lacustrine	0.00

(Tetra Tech 2011)

In comparison to State wetland scores for grouped service functions as define by ORWAP (2010), depressional wetlands at the South Jetty mitigation area are ranked relatively as follows: low for hydrologic function, carbon sequestration, fish support group, and aquatic support; and high for terrestrial support; and equal for water quality. Alternatively, the relative scores for the grouped service values were: low for hydrologic function, aquatic support, terrestrial support, and public use and recognition; equal for provisioning services, and high for water quality and fish support. The wetlands also ranked relatively high for ecological condition and sensitivity, and low for stressors.

Table 14. 2011 Wetland Functions and Values, Mitigation Area Estuarine – Sheet A

CoverPg: Basic Description of Assessment	**ORWAP version 2.0.2**
Site Name:	Mitigation Area*
Investigator Name:	Darlene Siegel
Date of Field Assessment:	3/14/2011
County:	Clatsop
Nearest Town:	Warrenton, OR
Latitude (decimal degrees):	46.227276°
Longitude (decimal degrees):	-124.003985°
TRS, quarter/quarter section and tax lot(s)	T8N,R10W,sec6
Approximate size of the Assessment Area (AA, in acres)	15.00
AA as percent of entire wetland (approx.)	30%
If delineated, DSL file number (WD #) if known	Has not yet been provided
Soil Map Units within the AA (list these in approx. rank order by area, from WSS web site or published county survey; see manual)	Coquille-Clatsop complex, 0 to 1 percent slopes Heceta-Waldport fine sands, 0 to 15 percent slopes
Soil Map Units surrounding and contiguous to the AA (list all present in approx. rank order by area; see manual)	Tropopsamments, 0 to 15 percent slopes Waldport fine sand, 3 to 15 percent slopes
Cowardin Systems & Classes (indicate all present, based on field visit and/or aerial imagery): <u>Systems</u>: Palustrine =P, Riverine =R, Lacustrine =L, Estuarine =E <u>Classes</u>: Emergent =EM, Scrub-Shrub =SS, Forested =FO, Aquatic Bed (incl. SAV) =AB, Open Water =OW, Unconsolidated Bottom =UB, Unconsolidated Shore =US	E, EM
HGM Class (Scores worksheet will suggest a class; see manual section 2.4.2)	Estuarine
If tidal, the tidal phase during most of visit:	Low to mid-tide
What percent (approx.) of the **wetland** were you able to visit?	5
What percent (approx.) of the **AA** were you able to visit?	100
Have you attended an ORWAP training session? If so, indicate approximate month & year.	No
How many wetlands have you assessed previously using ORWAP (approx.)?	None
Comments about the site or this ORWAP assessment (attach extra page if desired): * The wetland included in this ORWAP assessment is Mitigation Area MA3 (see map; Mitigation Area Wetland Delineation Area). Scores for FISH and FA appear to be higher than what we would have assumed.	

(Tetra Tech 2011)

Table 15. 2011 Wetland Functions and Values, Mitigation Area Estuarine – Sheet B

ORWAP SCORES SHEET	**version 2.0.2**			
Site Name:	Mitigation Area			
Investigator Name:	Darlene Siegel			
Date of Field Assessment:	3/14/2011			
Latitude (decimal degrees):	46.2273		Longitude (decimal degrees):	-124.003985°

Specific Functions:	Relative Effectiveness of the Function	Relative Values of the Function
Water Storage & Delay (WS)	0.00	2.50
Sediment Retention & Stabilization (SR)	6.71	5.92
Phosphorus Retention (PR)	2.97	6.33
Nitrate Removal & Retention (NR)	6.03	4.33
Thermoregulation (T)	0.00	6.67
Carbon Sequestration (CS)	7.31	
Organic Matter Export (OE)	7.65	
Aquatic Invertebrate Habitat (INV)	5.50	7.00
Anadromous Fish Habitat (FA)	5.36	10.00
Non-anadromous Fish Habitat (FR)	4.21	6.67
Amphibian & Reptile Habitat (AM)	0.00	4.00
Waterbird Feeding Habitat (WBF)	5.29	4.00
Waterbird Nesting Habitat (WBN)	0.00	3.00
Songbird, Raptor, & Mammal Habitat (SBM)	7.00	6.67
Pollinator Habitat (POL)	6.33	0.83
Native Plant Diversity (PD)	6.69	6.00

GROUPED FUNCTIONS	Group Scores (functions)	Group Scores (values)	
Hydrologic Function (WS)	0.00	2.50	(identical to Water Storage and Delay function and value scores)
Water Quality Group (WQ)	6.71	6.67	(maximum of scores for SR, PR, NR, and T)
Carbon Sequestration (CS)	7.31		(identical to Carbon Sequestration score above)
Fish Support Group (FISH)	5.36	10.00	(maximum of scores for FA and FR)
Aquatic Support Group (AQ)	7.65	4.00	(maximum of scores for OE, AM, INV, WBF, and WBN)
Terrestrial Support Group (TERR)	7.00	6.67	(maximum of scores for PD, POL, and SBM)
Public Use & Recognition (PU)		1.90	(click on this cell to see this attribute defined)
Provisioning Services (PS)		0.00	(click on this cell to see this attribute defined)

OTHER ATTRIBUTES		
Wetland Ecological Condition		7.74
Wetland Stressors		5.68
Wetland Sensitivity		3.53

HGM Class - Relative Probabilities (select max)	
Estuarine	10.00
Riverine	0.00
Slope	0.00
Flat	0.00
Depressional	0.00
Lacustrine	0.00

(Tetra Tech 2011)

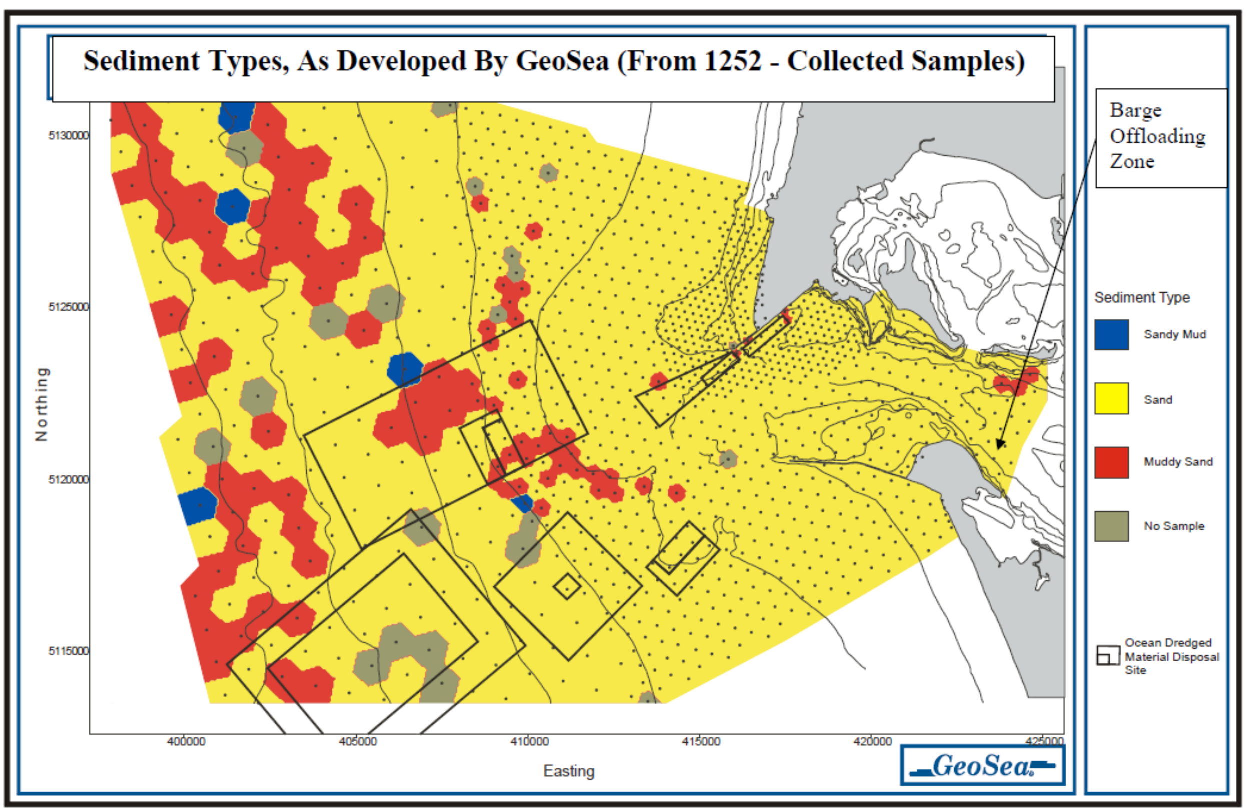
In comparison to State wetland scores for grouped service functions as define by ORWAP (2010), estuarine wetlands at the South Jetty mitigation area are ranked relatively as follows: low for hydrologic function and water quality; and high for carbon sequestration, fish support group, aquatic support, and terrestrial support. Alternatively, the relative scores for the grouped service values were: low for hydrologic function, aquatic support, terrestrial support, and public use and recognition; equal for provisioning services, and high for water quality and fish support. The wetlands also ranked relatively high for ecological condition and stressors, and low for sensitivity.

2.1.4. Sediment, Water Quality, and Spill History at the MCR

In 2000, a sediment trend analysis was conducted in the MCR and surrounding off-shore locations (Figure 8) by GeoSea Consulting, under contract to the Corps (McLaren and Hill 2000, Corps 2005). Over twelve hundred (1,252) samples were collected. Physical analyses of the samples surrounding the area (6 samples selected) indicated that the sediments consisted of +99% sand. Select samples from study in the MCR area were analyzed for physical and chemical contamination. Results indicated that no contaminates were detected at or near the screening levels in the *Dredge Material Evaluation Framework for the Lower Columbia River Management Area* (DMEF 1998). For a complete report on chemical results, see http://www.nwp.usace.army.mil/docs/d_sediment/Reports/Mcr/mouth00.pdf

In 2005, the Corps conducted a Tier I evaluation near the proposed the South Jetty barge offloading site following procedures set forth in the Inland Testing Manual and the Upland Testing Manual (Corps October 2005). The methodologies used were those adopted for use in the 1998 DMEF and its update, the *Northwest Regional Sediment Evaluation Framework, Interim Final* (SEF 2006). This Tier I evaluation of the proposed dredged material showed that the material was acceptable for both unconfined in-water and upland placement. No adverse ecological impacts in terms of sediment toxicity were expected from disposal.

Figure 8. Sediment Trend Analysis in the MCR Area



In 2008 using USEPA's *OSV Bold*, 10 sediment grab samples were collected from sites previously sampled in the 2000 sediment trend analysis (Corps 2008). In 2008, percent sand averaged 98.45% with a range of 99.3% to 97.0% and percent silt and clay averaged 1.59% (range from 3.0% to 0.7%). Per the Project Review Group approved Sediment Analysis Plan, no chemical analyses were conducted. Physical results for the 2000 and 2008 sampling events were compared. The mean percent sand for all samples in September 2000 was 98.11% and for June 2008 was 98.45%. In both data sets, sediments towards the outer portion of the mouth are finer than sediments towards the center of the mouth.

Oregon and Washington have classified the lower Columbia River as water quality-limited and placed it on the Clean Water Act Section 303(d) list for the following parameters: RM 0 to 35.2 for temperature and polychlorinated biphenyls (PCBs); RM 35.2 to 98 for arsenic, dichlorodiphenyl trichloroethane (DDT), PCBs, and temperature; and RM 98 to 142 for temperature, arsenic, DDT, PCBs, and polynuclear aromatic hydrocarbons (PAHs). In Washington, the river also is on the Section 303(d) list for dichloro-diphenyl-dichloroethane, Alpha BHC (a pesticide), mercury, dissolved gas, dieldrin, chlordane, aldrin, dichloro-diphenyl-dichloroethylene, fecal coliforms, and sediment bioassay. In addition, the entire river is subject to an USEPA total maximum daily load for dioxin.

According to the Lower Columbia River Geographic Response Plan (GRP) (WADOE 2003), routes for major shipping traffic keep super tankers 50-60 Nautical Miles (NM) offshore, minimizing potential coastal effects from a catastrophic spill. Up until 2003, the GRP also quantified the volume of potential spilled material as follows. Refined product in barges and small tankers transported closer to the shoreline and up the Columbia River averaging 160 tank barge movements as well as 50-60 bunkering operations by barge to a variety of vessels per month. The majority of these bunker barges had a capacity of 15,000 barrels. Annually, self propelled tankers made approximately 100 port calls to the Portland area. The majority of the tank vessels were approximately 39,000 deadweight tonnage, having had capacity of approximately 275,000 barrels, although the largest had a capacity of 400,000 barrels. Supertankers in ballast also transited the river enroute to the Portland Ship yard for routine inspections and maintenance. Approximately 2,000 general cargo, bulk, and container vessels entered the river annually, carrying bunker fuels of approximately 15,000 barrels capacity (WADOE 2003).

According to information in the Oregon Department of Environmental Quality's spill tracking database, between 1998 and March 2011, 63 spills were reported in Clatsop County in the vicinity of the Columbia River from Astoria downriver (DEQ 2011). Of these 63 spills, 43 were less than 50 gallons and were mostly the result of equipment malfunctions and minor spills and vessel leakage. Five spills were between 50 and 100 gal; 6 between 100 and 200 gallons; 2 between 200 and 800 gallons; then up to 6 at 1000 gallons; and one over 10,000 gallons (DEQ 2011). The incidents with the highest level of spill discharge generally involved storm sewage overflows or sewage release, followed by the sinking, grounding, or capsizing of fishing vessels, then land to surface water releases from other facility malfunctions (DEQ 2011). Washington Department of Ecology's Environmental Reports Tracking System (ERTS) shows about 145 incidences between January 2000 and December 2010, with the majority of the sources indicated from various size vessels (WADOE 2011). Of these, most were petroleum products in the following quantities: 63 incidences were under 5 gallons; 11 were between 6-30 gallons; 9 were between 50-100 gallons; 3 were 101-300 gallons; and the largest quantified was 1 at 1500 gallons; 57 incidences did not have any associated quantities (WADOE 2011). The GRP also further describes several of the most prominent spills on the Columbia prior to 2003, including: the1984 T/V Mobiloil spill of 200,000 gallons; the 1991 discharge of 11,000 gallons of Intermediate Fuel Oil (IFO) 380 from the M/V Tai Chung at the Columbia Aluminum Facility; two similar bunkering mishaps within six months of each other at Longview Anchorage; the 1993 M/V Central spill of approximately 3,000 gallons of IFO 180; and the 1994 M/V An Ping 6 spill of a similar amount of product at the same location as M/V Central (WADOE 2003). It is notable that none of the identified spills occurred in the vicinity of the MCR, but rather further inland and upriver.

With specific regards to Corps activities, from the time span between September 2006 and August 2010, dredging operations had 21 reportable spills ranging from 0.5 gallons to 25 gallons (Corps 2011). Of these spills, 12 occurred in the vicinity of Astoria or downriver towards the mouth (Corps 2011).

2.2. Fish and Wildlife

A variety of anadromous and resident fish species occur within the Columbia River offshore area, including several listed under the Endangered Species Act (ESA). Both the North and South Jetties are located in high-energy areas subject to strong tidal and river currents and wave action. These high-energy conditions contribute to continual movement of sediments with both deposition and erosion occurring. The continual disturbance limits biological productivity and use by fish and other marine organisms along the vicinity of the jetty structures themselves.

The occurrence of adult anadromous salmonids in the offshore area is correlated primarily with their period of upstream migration. Juvenile salmonids are present following their migration out of the Columbia River estuary primarily in the spring and fall. The southern distinct population segment (DPS) of green sturgeon also occurs in the estuary, which is included as part of its designated critical habitat. Its specific distribution and habitat use in the Columbia River estuary is not well known, but is being studied by the U.S. Geological Survey (USGS) under contract with the Corps. However, green sturgeon would be expected to occur in the more tranquil estuary proper to a greater extent than in the vicinity of the jetties. Anadromous Pacific lamprey (*Lampetra tridentate)* may be present in the vicinity of the MCR as they return to freshwater during spawning migration from July to October. Lampreys typically spend about 4 to 6 years rearing in freshwater, returning to the ocean during spring high flows where they would also occur in the vicinity of the jetties. During their 2 to 3 years in the ocean, lampreys act as scavengers, parasites, or predators on larger prey such as salmon and marine mammals (PSMFC 2009). The Southern DPS of eulachon (or smelt) have also been recently listed as Threatened under the ESA, though critical habitat has yet to be designated. Eulachon are anadromous and spend 3-5 year is saltwater before returning to freshwater in late winter to spawn in the early spring.

Resident fish species occur throughout the year with many using the estuary as a rearing and nursery area. Resident fish species that may be present in the jetty areas include various groundfish species, such as California skate (*Raja inornata*), soupfin shark (*Galeorhinus galeus*), spiny dogfish (*Squalus acanthias*), lingcod (*Ophiodon elongates*), Pacific cod (*Gadus macrocephalus*), butter sole (*Isopsetta isolepis*), English sole (*Parophyrs vetulus*), Pacific sanddab (*Citharichthys sordidus*), rex sole (*Glyptocephalus zachirus*), rock sole (*Lepidopsetta bilineata*), sand sole (*Psettichthys melanostictus*), starry flounder (*Platichthys stellatus*), black rockfish (*Sebastes melanops*), brown rockfish (*Sebastes auriculatus*), and copper rockfish (*Sebastes caurinus*). Some species use the MCR as a migratory corridor when traveling to rearing areas in bays and intertidal areas where there are larger concentrations of food organisms (e.g., *Corophium salmonis*). Other groundfish species, principally rockfish, may use the jetties as habitat.

Almost all of the Columbia River offshore area experiences some type of commercial fishing activity. The major fisheries are for bottom fish, salmon, Dungeness crab (*Cancer magister*), and other shellfish species. Crab fishing occurs from December to September with the majority of the catch occurring early in the season. Most crab fishing occurs north of the Columbia River mouth at water depths ranging from 25-250 feet. Dungeness crab population numbers are subject to large cyclic fluctuations in abundance. Catch records for the fishery are generally believed to represent actual population fluctuations. Modeling studies by Higgins and others (1997) have shown that small scale environmental changes, such as delay in the onshore currents in the spring by a short period of time, can dramatically impact survival of young-of-the-year crab but have no effect on adults and older juveniles inshore. Bottom fishing by trawl for flatfish, rockfish, and shrimp occurs year-round over the entire offshore area, primarily at depths offshore from the jetties. Commercial and recreational salmon fishing occurs over much of the offshore area.

The areas around Clatsop Spit south of the Jetty are known to have razor clam beds, and clamming occurs regularly in the vicinity of MCR.

Marine mammals known to occur in the offshore area include gray whales, orcas, dolphins, porpoises, sea lions, and harbor seals. Most cetacean species observed by Green and others (1991) occurred in Pacific slope or offshore waters (600 to 6,000 feet in depth). Harbor porpoises (*Phocoena phocoena*) and gray whales (*Eschrichtius robustus*) were prevalent in shelf waters less than 600 feet in depth. Pinniped species that may occur in the vicinity of the jetties include Pacific harbor seals (*Phoca vitulina richardsi*), California sea lions (*Zalophus californianus*), and Steller (northern) sea lions (*Eumetopias jubatus*).

Pelagic birds are numerous off the Columbia River including gulls, auklets, common murres, fulmars, phalaropes, and kittiwakes. Briggs and others (1992) found that seabird populations were most densely concentrated over the continental shelf (< 600 feet in depth). Brown pelicans (*Pelecanus occidentalis*) typically occur from late spring to mid-fall along the Oregon and Washington coasts. Three species of cormorants occur and forage in nearshore Pacific Ocean waters, the estuary, or upriver. Three species of terns occur in the Columbia River or over nearshore waters. Caspian terns (*Hydroprogne caspia*) are present from April to September and have established large colonies on islands in the estuary. Shorebirds found on beaches include sanderlings and various species of sandpipers, dunlins, and plovers.

Four bald eagle (*Haliaeetus leucocephalus*) territories, two at Cape Disappointment, Washington (Cape Disappointment and Fort Canby pairs) and two on Clatsop Spit, Oregon (Fort Stevens and Tansy Point/Clear Lake pairs), occur in the general vicinity of the proposed project (Isaacs and Anthony 2005). Bald eagles have multiple (alternate) nest sites; the nearest nest location for the Fort Canby pair is approximately 1.6 miles northeast of Benson Beach. The nearest nest location for the Cape Disappointment pair is about 2.2 miles northeast of Benson Beach. The Fort Stevens and Tansy Point/Clear Lake pairs are more than 3 miles from the South Jetty. The territories on Cape Disappointment lie adjacent to Baker Bay, a shallow subtidal and intertidal bay adjacent to Ilwaco and Chinook, Washington. Baker Bay probably represents the focal area for foraging by these pairs as waterfowl and fisheries resources are plentiful in the bay. Bald eagles have been observed foraging along the shoreline from Ilwaco to the Fort Canby boat launch, on or adjacent to West Sand Island, and from pilings scattered throughout the western portion of Baker Bay. Foraging activities along the North Jetty and Benson Beach may occur infrequently. Bald eagles from territories on Clatsop Spit appear to forage in Trestle Bay. Other probable foraging locations include the various lakes scattered throughout Clatsop Spit and the shorelines and intertidal mudflats of the Columbia River estuary.

2.2.1. ESA-listed Species under NMFS Jurisdiction

Federally listed threatened and endangered species under the jurisdiction of the National Marine Fisheries Service (NMFS) that may occur in the MCR project area include 13 salmonid stocks and other fish and marine wildlife species (Table 16). A Biological Assessment (BA) was prepared and provided to the NMFS to evaluate the effects of the proposed project on the anadromous salmonids, marine mammal, and marine turtle species. Critical habitat and essential fish habitat (EFH) were also addressed in the BA. The EFH species present in the vicinity of the project area include five coastal pelagic fish species, numerous Pacific Coast groundfish species, and coho and Chinook salmon.

Table 16. Threatened and Endangered Species under NMFS Jurisdiction

Listing status: 'T' means listed as threatened under the ESA; 'E' means listed as endangered.
FR = Federal Register

Species	Listing Status	Critical Habitat	Protective Regulations
Marine and Anadromous Fish			
Chinook salmon (*Oncorhynchus tshawytscha*)			
Lower Columbia River	T 6/28/05; 70 FR 37160	9/02/05; 70 FR 52630	6/28/05; 70 FR 37160
Upper Willamette River	T 6/28/05; 70 FR 37160	9/02/05; 70 FR 52630	6/28/05; 70 FR 37160
Upper Columbia River spring-run	E 6/28/05; 70 FR 37160	9/02/05; 70 FR 52630	ESA section 9 applies
Snake River spring/summer run	T 6/28/05; 70 FR 37160	10/25/99; 64 FR 57399	6/28/05; 70 FR 37160
Snake River fall-run	T 6/28/05; 70 FR 37160	12/28/93; 58 FR 68543	6/28/05; 70 FR 37160
Chum salmon (*O. keta*)			
Columbia River	T 6/28/05; 70 FR 37160	9/02/05; 70 FR 52630	6/28/05; 70 FR 37160
Coho salmon (*O. kisutch*)			
Lower Columbia River	T 6/28/05; 70 FR 37160	Not applicable	6/28/05; 70 FR 37160
Oregon Coast	T 2/11/08; 73 FR 7816	2/11/08; 73 FR 7816	2/11/08; 73 FR 7816
S. Oregon/N. California Coasts	T 6/28/05; 70 FR 37160	5/5/99; 64 FR 24049	6/28/05; 70 FR 37160
Sockeye salmon (*O. nerka*)			
Snake River	E 6/28/05; 70 FR 37160	12/28/93; 58 FR 68543	ESA section 9 applies
Steelhead (*O. mykiss*)			
Lower Columbia River	T 1/05/06; 71 FR 834	9/02/05; 70 FR 52630	6/28/05; 70 FR 37160
Upper Willamette River	T 1/05/06; 71 FR 834	9/02/05; 70 FR 52630	6/28/05; 70 FR 37160
Middle Columbia River	T 1/05/06; 71 FR 834	9/02/05; 70 FR 52630	6/28/05; 70 FR 37160
Upper Columbia River	T 1/05/06; 71 FR 834	9/02/05; 70 FR 52630	2/018/06; 71 FR 5178
Snake River Basin	T 1/05/06; 71 FR 834	9/02/05; 70 FR 52630	6/28/05; 70 FR 37160
Green sturgeon (*Acipenser medirosris)*			
Southern	T 4/07/06; 71 FR 17757	10/09/09; 74 FR 52300	P 5/21/09; 74 FR 23822
Eulachon (*Thaleichthys pacificus*)	T 3/18/10; 75 FR 13012	Not applicable	Not applicable
Marine Mammals			
Steller sea lion (*Eumetopias jubatus*)			
Eastern	T 5/5/1997; 63 FR 24345	8/ 27/93; 58 FR 45269	11/26/90; 55 FR 49204 10/1/09; 50 CFR 223.202
Blue whale (*Balaenoptera musculus*)			
	E 12/02/70; 35 FR 18319	Not applicable	ESA section 9 applies
Fin whale (*Balaenoptera physalus*)			
	E 12/02/70; 35 FR 18319	Not applicable	ESA section 9 applies
Humpback whale (*Megaptera novaeangliae*)			
	E 12/02/70; 35 FR 18319	Not applicable	ESA section 9 applies
Killer whale (*Orcinus orca*)			
Southern Resident	E 11/18/05; 70 FR 69903	11/26/06; 71 FR 69054	ESA section 9 applies
Sei whale (*Balaenoptera borealis*)			
	E 12/02/70; 35 FR 18319	Not applicable	ESA section 9 applies
Sperm whale (*Physeter macrocephalus*)			
	E 12/02/70; 35 FR 18319	Not applicable	ESA section 9 applies
Marine Turtles			
Green turtle (*Chelonia mydas*)			
Excludes Pacific Coast of Mexico & FL	ET 7/28/78; 43 FR 32800	9/02/98; 63 FR 46693	ESA section 9 applies
Leatherback turtle (*Dermochelys coriacea*)	E 6/02/70 ; 39 FR 19320	1/5/10; 75FR319	ESA section 9 applies
Loggerhead turtle (*Caretta caretta*)	T 7/28/78; 43 FR 32800	Not applicable	7/28/78; 43 FR 32800
Olive ridley turtle (*Lepidochelys olivacea*)	ET 7/28/78; 43 FR 32800	Not applicable	ESA section 9 applies

On March 18, 2011, The Corps received a Biological Opinion from NMFS indicating that the Corps' proposed actions were not likely to adversely affect any of the listed species, with the exception of eulachon, humpback whales, and Stellar sea lions (2010/06104). For these species, NMFS determined that Corps actions were not likely to jeopardize the existence of the species. NMFS also concluded that the Corps' actions were not likely to adversely affect any of the current or proposed critical habitats.

Anadromous Salmonids

In 2005, critical habitat was designated for all Columbia River steelhead and Columbia River salmon Evolutionarily Significant Units (ESU), with the exception of lower Columbia River coho salmon ESU. General run-specific life history descriptions for the various salmonid ESUs shown in Table 1 are provided below.

<u>Snake River Spring and Summer Run Chinook Salmon</u>. Fish from this ESU occur in the mainstem Snake River and sub-basins including the Tucannon, Grande Ronde, Imnaha, and Salmon Rivers. Adults migrate in late winter to spring and spawn from late August to November. Spawning occurs in tributaries to the Snake River. Juveniles remain in freshwater from 1-3 years and out-migrate from early spring to summer.

<u>Snake River Fall Run Chinook Salmon</u>. Fish from this ESU occur in the mainstem Snake River and sub basins including the Tucannon, Grande Ronde, Imnaha, and Salmon Rivers. Adults migrate from mid-August to October and spawn from late August to November. Spawning occurs in the Snake River and lower reaches of tributaries to the Snake River. Juveniles rear in freshwater from 1-3 years and out-migrate from early spring to summer.

<u>Lower Columbia River Chinook Salmon</u>. Fish from this ESU occur from the MCR upstream to Little White Salmon River, Washington and Hood River, Oregon and including the Willamette River upstream to Willamette Falls. Adults migrate in mid-August through October (fall run) and late winter to spring (spring run). Spawning occurs from late August to November. Spawning occurs in the mainstem Columbia River to upper reaches of tributaries. Juveniles out-migrate from early spring to fall.

<u>Upper Columbia River Spring Run Chinook Salmon</u>. Fish from this ESU occur in Columbia River tributaries upstream of the Rock Island Dam and downstream of Chief Joseph Dam in Washington, excluding the Okanogan River. Adults migrate from late winter to spring and spawn from late August to November. Spawning occurs in the mainstem Columbia River to upper reaches of tributaries. Juveniles out-migrate from early spring to summer.

<u>Upper Willamette River Chinook Salmon</u>. Fish from this ESU migrate upstream from late winter to spring and spawn from late August to November. Juveniles migrate from early spring to summer, some rearing in the Columbia River estuary and some in freshwater.

<u>Lower Columbia River Coho Salmon</u>. It is believed that the majority of fish from this ESU return to the lower Columbia River to spawn between early December and March. Spawning occurs in tributaries to the Columbia River. Young hatch in spring, rear in freshwater for one year, and out-migrate to the ocean the following spring. Most juveniles out-migrate from April to August, with a peak in May. Coho salmon occur in the Columbia River estuary as smolts and limited estuarine rearing occurs (more extensive estuarine rearing occurs in Puget Sound).

<u>Oregon Coast Coho Salmon</u>. Fish from this ESU are found in Oregon coastal streams south of the Columbia River and North of Cape Blanco. They generally migrate up spawning streams from August

through November, and spawning takes place from late September through January in shallow tributaries with gravel bottoms. Fry emerge from the redd in May or June and remain in fresh water from one to four winters before going to sea. Coho salmon smolts tend to stay close to shore at first, feeding on plankton. As they grow larger, they move farther out into the ocean and switch to a diet of small fish. Coho salmon can stay at sea for two to three years.

Southern Oregon/N. California Coasts Coho Salmon. The SONCC coho ESU includes all naturally spawned populations of coho salmon in coastal streams between Cape Blanco, Oregon, and Punta Gorda, California. Spawning runs occur throughout the year, varying in time by species and location. Depending on temperatures, eggs incubate for several weeks to months before hatching. Then juveniles may spend from a few hours to several years in freshwater before migrating to the ocean. En route to the ocean the juveniles may spend from a few days to several weeks in the estuary. Juveniles and sub-adults typically spend from 1 to 5 years foraging in the ocean before returning to freshwater to spawn.

Columbia River Chum Salmon. Fish from this ESU are distributed from Bonneville Dam to the MCR. Adults migrate from early October through November and spawning occurs in November and December. Spawning habitat includes lower portions of rivers just above tidewater and in the side channel near Hamilton Island below Bonneville Dam. Juveniles enter estuaries from March to mid-May and most chum salmon leave Oregon estuaries by mid-May. Most juveniles spend little time in freshwater and rear extensively in estuaries.

Snake River Sockeye Salmon. Fish from this ESU occur in the Salmon River, a tributary to the Snake River. This population migrates in spring and summer and spawning occurs in February and March. Spawning occurs in inlets or outlets of lakes or in river systems. Juveniles rear in freshwater and out-migrate in spring and early summer, out-migrating primarily between April and early June. They spend little time in estuaries as smolts and are guided to ocean waters by salinity gradients.

Snake River Basin Steelhead. Fish from this ESU occur in all accessible tributaries of the Snake River. Upstream migration occurs in spring and summer and spawning occurs in February and March. Spawning habitat includes upper reaches of tributaries. Juveniles spend from 1-7 years (average 2 years) in freshwater and out-migrate during spring and early summer.

Middle Columbia River Steelhead. Fish from this ESU are distributed from Wind River, Washington and Hood River, Oregon upstream to the Yakima River, Washington. These fish migrate in winter and summer and spawning occurs in February and March. Spawning habitat includes upper reaches of tributaries. Juveniles spend from 1 to 7 years (average 2 years) in freshwater and out-migrate during spring and early summer.

Upper Willamette River Steelhead. Fish from this ESU are a late-migrating winter group, rearing 2 years in freshwater and 2 years in the Pacific Ocean before returning to spawn. The run timing appears to be an adaptation to ascending Willamette Falls at Oregon City.

Lower Columbia River Steelhead. Fish from this ESU are distributed from Wind River, Washington and Hood River, Oregon downstream to the MCR. These fish migrate in winter and spring/summer and spawning occurs in February and March. Spawning habitat includes upper reaches of tributaries. Juveniles spend from 1-7 years (average 2 years) in freshwater and out-migrate during spring and early summer.

Upper Columbia River Steelhead. Fish from this ESU are distributed from the Yakima River upstream to the Canadian border. These fish migrate in spring and summer and spawning occurs in February and

March. Spawning habitat includes upper reaches of tributaries. Juveniles spend from 1-7 years (average 2 years) in freshwater and out-migrate during spring and early summer.

<u>Salmon Ecology in the MCR Area</u>. Adult ESA-listed anadromous salmonids use the MCR area as a migration corridor to spawning areas throughout much of the Columbia River Basin. They are actively migrating and are not expected to use the area for resting or feeding, although they would spend time in the MCR to physiologically acclimate to freshwater. Chum, coho and Chinook salmon and steelhead populations spawn in tributaries to the Columbia River, and chum and Chinook salmon spawn in the mainstem Columbia River in appropriately sized gravels. No spawning would occur in the vicinity of the MCR for these species because of the lack of tributaries and appropriate spawning substrate.

Juvenile ESA-listed anadromous salmonids occur in the MCR area during their out-migration to the ocean. Juveniles that have already become smolts are present in the lower river for a short time period. Juveniles that have not become smolts, such as Chinook salmon sub yearlings, spend extended periods of time rearing in the lower river. They normally remain in the lower river or estuary until summer or fall, or even to the following spring when they smoltify and then migrate to the ocean. Rearing occurs primarily in shallow backwater areas. The majority of juvenile salmonids out-migrate in late spring and early summer, although fall Chinook salmon typically have a more extended outmigration period than other Columbia Basin salmonids and commonly out-migrate in late summer as well.

A recent study on acoustically tagged sub-yearling and yearling Chinook salmon and steelhead was conducted in the vicinity of the North and South jetties (PNNL 2005). Detection nodes were placed across the channel at RM 5.6 (primary node) and at RM 1.8 (secondary node). The secondary node did not extend all the way to the south side of the channel, however. As a result, fish could pass close to the South Jetty without being detected. A third set of detection nodes were placed near the North Jetty disposal area. Chinook salmon, both sub-yearling and yearling, were run-of-the-river fish tagged and released at the Bonneville Second Powerhouse juvenile bypass facility. Steelhead were Snake River-origin hatchery fish that were collected from fish transport barges between John Day and Bonneville dams and released mainly at Skamania Landing downstream of Bonneville Dam (some were transported and released at the Astoria-Megler Bridge).

Sub-yearling Chinook salmon were shown to move back and forth past the nodes, remaining longer in the vicinity of the nodes than yearling Chinook salmon and steelhead. They also tended to use nearshore areas (closer to the North Jetty) more than yearling Chinook salmon and steelhead. Yearling Chinook salmon and steelhead were concentrated more in deeper waters near the navigation channel. Of the salmonid species, sub-yearling Chinook salmon stay in the estuary for the longest period of time and use the greatest variety of estuarine habitats (Bottom et al., 2001), mainly slower, shallower, backwater areas. Healey (1982) proposed that Chinook salmon is the most estuarine dependent of salmonid species. These slow water areas are not typically available in close proximity to the jetties, but even in this high energy environment, sub-yearling Chinook still show a tendency to linger and to use nearshore areas. According to PNNL studies, sub-yearling Chinook residence times within the detection areas were up to five times longer than yearling Chinook salmon and steelhead, averaging up to 14.8 hours and usually passing on two to three ebb tides instead of one for yearlings. Also, they took longer to reach the MCR from Bonneville Dam (average 4.8 days) than yearling Chinook salmon and steelhead. Juvenile salmon movement toward the ocean is facilitated by ebb tides when current movement in the channel is generally in an east to west direction (PNNL 2005).

<u>Salmon Ecology in the Columbia River Plume</u>. The Columbia River plume is the zone of freshwater/saltwater interface where the freshwater exiting the Columbia River meets and rises above the denser saltwater of the Pacific Ocean, just seaward of the MCR. This multi-layered mixing zone plays an

important role as habitat for juvenile salmonids. The first few weeks of their ocean life, some of which is spent in the plume, are critical for recruitment success of salmonids (Pearcy 1992). The Columbia River plume provides a high turbidity refuge from predation, provides fronts and eddies where prey become concentrated, and provides a stable habitat for northern anchovy spawning (Richardson 1981, Bakun 1996). A strong, quickly moving plume also helps juvenile salmonids move rapidly offshore. Studies in the Columbia River plume show that juvenile salmonids typically use upper waters, above about 39 feet (Emmett et al., 2004). Many Columbia River Basin salmonids enter the ocean when river flow is high and frontal formation is intensified, during spring and early summer.

De Robertis and others (2005) found that juvenile salmonids tended to be abundant in the frontal and plume regions compared to the more marine shelf waters, but this pattern differed among species and was not consistent across two study years. Juvenile chum and yearling coho salmon were more abundant in the front than adjacent plume or ocean, while juvenile steelhead were more abundant in the front and plume than adjacent ocean. No statistically significant differences were observed in Chinook habitat use during 2001. In 2002, both yearling coho and Chinook were more abundant in the plume than adjacent front and ocean, whereas juvenile steelhead was more abundant in the front than adjacent plume and ocean. Small numbers of chum captured in 2002 precluded statistical analysis. There was no statistically significant difference in the fraction of marked (hatchery) fish among ocean, front, and plume habitats (appears to indicate that hatchery fish did not use habitats differently than wild fish). This study did not support the hypothesis that juvenile salmonids congregate to feed at the plume fronts. De Robertis and others (2005) postulated that the short persistence time of these ephemeral fronts may prevent juveniles from exploiting this food-rich zone. They caution that given that the plume is the first area salmon encounter during ocean entry, changes in plume structure may markedly influence the distribution and survival of salmon.

<u>Green Sturgeon</u>. Green sturgeon is a widely distributed, marine-oriented sturgeon found in nearshore waters from Baja California to Canada (NMFS 2007). They are anadromous, spawning in the Sacramento, Klamath and Rogue rivers in the spring (NMFS 2007). Spawning occurs in deep pools or holes in large, turbulent river mainstreams. Two DPSs have been defined, a northern DPS with spawning populations in the Klamath and Rogue rivers and a southern DPS that spawns in the Sacramento River (NMFS 2007). The southern DPS was listed as threatened in 2006. The northern DPS remains a species of concern. Critical habitat for southern DPS green sturgeon was designated in 2009 and includes all tidally-influenced areas of the Columbia River to approximately RM 46 and up to MHHW and includes adjacent coastal marine areas [74 Federal Register (FR) 52300].

Green sturgeons congregate in coastal waters and estuaries, including non-natal estuaries, where they are vulnerable to capture in salmon gillnet and white sturgeon sport fisheries. Green sturgeon are known to enter Washington estuaries during summer when water temperatures are more than 2°C warmer than adjacent coastal waters (Moser and Lindley 2007). Sturgeon migrations are thought to be related to feeding and spawning (Bemis and Kynard 1997). They suggested that green sturgeon move into estuaries of non-natal rivers to feed. However, the empty gut contents of green sturgeon captured in the Columbia River gillnet fishery suggests that these green sturgeon were not actively foraging in the estuary [T. Rien, ODFW, pers. comm. in Moser and Lindley (2007)]. That they are caught on baited hooks incidentally during the sport season for white sturgeon suggests they are feeding in the estuaries.

Moser and Lindley (2007) used acoustic telemetry to document the timing of green sturgeon use of Washington estuaries. Sturgeon they captured were tagged, and released in both Willapa Bay and Columbia River estuaries. They deployed an array of four fixed-site acoustic receivers in Willapa Bay to detect the estuarine entry and exit of these and any of over 100 additional green sturgeon tagged in other systems during 2003 and 2004. Green sturgeon occurred in Willapa Bay in summer when estuarine water temperatures exceeded coastal water temperatures by at least 2°C. They exhibited rapid and extensive intra- and inter-estuary movements and green sturgeon from all known spawning populations were detected in Willapa Bay. Moser and Lindley (2007) hypothesized that green sturgeon optimize their growth potential in summer by foraging in the relatively warm, saline waters of Willapa Bay.

Information from fisheries-dependent sampling suggests that green sturgeon only occupy large estuaries during the summer and early fall in the northwestern United States. Commercial catches of green sturgeon peak in October in the Columbia River estuary, and records from other estuarine fisheries (Willapa Bay and Grays Harbor, Washington) support the idea that sturgeon are only present in these estuaries from June until October [O. Langness, WDFW, pers. comm. in Moser and Lindley (2007)]. Green sturgeon enter the Columbia River at the end of spring with their numbers increasing through June (B. James, WDFW, pers. comm. 2007 with W. Briner, Portland District). The greatest numbers are caught in the estuary in July through September. The majority of green sturgeon were caught in the lower reaches of the Columbia River based upon harvest information from 1981-2004 (B. James, WDFW, e-mail comm. 2007 with W. Briner, Portland District). There are no known spawning populations in the Columbia River and its tributaries.

Pacific Eulachon. The NMFS listed the southern DPS of Pacific eulachon (smelt) as threatened in March 2010. This DPS consists of populations spawning in rivers south of the Nass River in British Columbia, Canada, to and including the Mad River in California. The Columbia River and its tributaries support the largest known eulachon run. The major and most consistent spawning runs return to the mainstem Columbia River (from just upstream of the estuary at RM 25 to immediately downstream of Bonneville Dam) and in the Cowlitz River. Eulachon typically spend 3-5 years in saltwater before returning to freshwater to spawn from late winter through early summer. Spawning occurs in January, February, and March in the Columbia River. Spawning occurs at temperatures from about 39° to 50°F (4° to 10°C) in the Columbia River and tributaries over sand, coarse gravel, or detrital substrates. Shortly after hatching, the larvae are carried downstream and dispersed by estuarine and ocean currents. After leaving estuarine rearing areas, juvenile eulachon move from shallow nearshore areas to deeper areas over the continental shelf. Larvae and young juveniles become widely distributed in coastal waters and are found mostly at depths up to about 49 feet.

Steller Sea Lion. Steller sea lions breed along the West Coast from California's Channel Islands to the Kurile Islands and the Okhotsk Sea in the western North Pacific Ocean. They are year-long residents along the Oregon Coast. A major haul-out area for Steller sea lions occurs at the head of South Jetty, where the monthly averages between 1995 and 2004 ranged from about 168 to 1106 animals at the South Jetty. Steller sea lions are most abundant in the vicinity during the winter months and tend to disperse elsewhere to rookeries during breeding season between May and July (Corps 2007).

Marine Whales. The whale species listed in Table 1 are all federally endangered and occur as migrants off the Oregon Coast in waters typically much farther from shore than the nearshore MCR area. Blue whales occur off the coast in May and June, as well as in August through October. Blue whales typically occur offshore as individuals or in small groups and winter well south of Oregon. Fin whales also winter far south of Oregon and range off the coast during summer. Sei whales winter south of Oregon and probably occur in southward migration off the Oregon Coast in late summer and early fall. Sperm whales occur as migrants and some may summer off the coast; they forage in waters much deeper than those in the nearshore area. Humpback whales primarily occur off the Oregon Coast from April to October with peak numbers from June through August. Humpback whales are particularly concentrated in Oregon along the southern edge of Heceta Bank and are found primarily on the continental shelf and slope. North Pacific right whales may occur off the coast during winter and summer in cool waters north of 50 degrees north latitude.

According to the NMFS (2008), the southern resident killer whale population consists of three pods, designated J, K, and L pods, that reside from late spring to fall in the inland waterways of Washington State and British Columbia. During winter, pods have moved into Pacific coastal waters and are known to travel as far south as central California. Winter and early spring movements and distribution are largely unknown for the population. Recent sightings of members of K and L pods in Oregon (L pod at Depoe Bay in April 1999 and Yaquina Bay in March 2000, unidentified Southern Residents at Depoe Bay in April 2000, and members of K and L pods off of the Columbia River) and in California (17 members of L pod and four members of K pod at Monterey Bay in 2000; L pod members at Monterey Bay in March 2003; L pod members near the Farallon Islands in February 2005 and again off Pt. Reyes in January 2006) have considerably extended the southern limit of their known range (NMFS 2008). Sightings of southern resident killer whales off the coast of Washington, Oregon, and California indicate that they are utilizing resources in the California Current ecosystem in contrast to other North Pacific resident pods that exclusively use resources in the Alaskan Gyre system (NMFS 2008).

Marine Turtles. The loggerhead sea turtle, green sea turtle, leatherback sea turtle, and olive Ridley sea turtle are all federally listed species and have been recorded from strandings along the Oregon and Washington coasts. The occurrence of sea turtles off the Oregon Coast is associated with the appearance of albacore. Albacore occurrence is strongly associated with the warm waters of the Japanese current. Because these warm waters generally occur 30 to 60+ miles offshore from the Oregon Coast, these sea turtle species do not typically occur in the nearshore MCR area.

In October, 2007, NMFS received a petition from the Center for Biological Diversity, Oceana, and Turtle Island Restoration Network (Petitioners) to revise the leatherback sea turtle critical habitat designation. Current critical habitat consists of terrestrial shoreline approximately in and around Sandy Point Beach, St. Croix, and the U.S. Virgin Islands (see 50 CFR 17.95). In December 2007, NMFS initiated a Notice of Petition finding that there was sufficient merit to initiate further review and requested public information and comment (72 FR 73745). Subsequently, on January 5, 2010, NMFS officials proposed a revised critical habitat designation for the leatherback sea turtle by designating additional locations to include the nearshore area from Cape Flattery, Washington, to Umpqua River (Winchester Bay), Oregon and offshore to the 2,000 meter isobath (75 FR 319).

Leatherbacks forage primarily on cnidarians (jellyfish and siphonophores) and to a lesser extent on tunicates (pyrosomas and salps) (NMFS and USFWS 1998). The nutrient-rich waters of the Columbia River plume tend to aggregate and retain jellyfish in the northern California Current (Shenker 1984). There is some evidence that Leatherbacks feed farther offshore in association with the Columbia River plume and off of Washington in general than they do along the central California coast (PFMC 2006) where they feed in the vicinity of Monterey Bay (NMFS November 2006). Leatherbacks are most frequently sighted in ocean waters off Oregon and Washington from late spring to early fall (Bowlby 1994). From the limited amount of research on jellyfish and leatherbacks in Pacific Northwestern nearshore waters, it appears that there is overlap in time of occurrence of jellyfish and leatherbacks. Knowledge about leatherback abundance in the Columbia River plume, as well as foraging activity, is sparse.

Most species of marine turtles are expected to occur further offshore and would not regularly be in the vicinity of the MCR or a majority of the proposed actions. There may be some occurrence of marine turtles along the potential barge routes, which may overlap with designated critical habitat. Leatherbacks are not known to enter the Columbia River, though they are known to feed offshore and nearer shore on jellyfish.

2.2.2. ESA-listed Species under USFWS Jurisdiction

A Biological Assessment (BA) was prepared and provided to the U.S. Fish and Wildlife Service (USFWS) to evaluate the effects of the proposed action on those fish and wildlife species under USFWS jurisdiction (Table 17).

Table 17. Threatened and Endangered Species under USFWS Jurisdiction

Listing status: 'T' means listed as threatened under the ESA; 'E' means endangered; 'C' means candidate species. FR = Federal Register

Species	Listing Status	Critical Habitat
Birds		
Marbled Murrelet *(Brachyramphus marmoratus)* **T**		
Oregon, Washington, and California Populations	10/01/92; 57 FR 45328; 2/11/09 74 FR 6852	05/24/96; 61 FR 26255; 02/11/09; 74 FR 6852
Western Snowy Plover *(Charadrius alexandrinus nivosus)* **T**	3/05/93; 58 FR 12864	09/29/05; 70 FR 56969
Short-tailed Albatross *(Phoebastria albatrus)* **E**	7/31/00; 65 FR 46643	Not applicable
Northern Spotted Owl *(Strix occidentalis caurina)* **T**	6/26/90; 55 FR 26114	1/15/92; 57 FR 1796; 08/13/08 73 FR 47325
Streaked Horned Lark *(Eremophila alpestris strigata)* **C**	10/30/01 66 FR 54807	Not applicable
Mammals		
Columbian White-tailed Deer *(Odocoileus virginianus leucurus)* **E**		
Columbia River Population	03/11/67; 68 FR 43647	Not applicable
Fish		
Bull Trout *(Salvelinus confluentus)* **T**		
Columbia DPS	06/10/98; 63 FR 31647	10/18/10 75 FR 63897
Invertebrates		
Oregon Silverspot Butterfly *(Speyeria zerene hippolyta)* **T**	07/02/80; 45 FR 44935	07/02/80; 45 FR 44935
Plants		
Nelson's Checker-mallow *(Sidalcea nelsoniana)* **T**	02/12/93; 58 FR 8235	Not applicable

On February 23, 2011 the Corps received a Letter of Concurrence from USFW regarding potential effects to species under their jurisdiction (13420-2011-I-0082). The Corps determined its actions would have no effect on listed species, with the exception of bull trout, marbled murrelets, and snowy plover. The Corps concluded that its actions were not likely to adversely affect these species or their critical habitat. The USFW concurred with the Corps' determination. USFW also included four Conservation Recommendations to protect and improve snowy plover habitat and manage attractant waste derived from construction actions.

Marbled Murrelet. Historical records and observations indicate that marbled murrelets were common and regularly seen along Washington and Oregon coastlines (Gabrielson and Jewett 1940, Jewett 1953, Helm 2009). The marbled murrelet is a near-shore marine bird that is most frequently observed within 1.5 miles of shore (Marshall 1988). Marbled murrelets forage just beyond the breaker-line and along the sides of river mouths where greater upwelling and less turbulence occurs. Murrelets forage within the water column; prey items include invertebrates and small fish such as anchovy, herring, and sand lance (Marshall 1988). Strong and others (1995) recorded less than 10 marbled murrelets on average from boat and shore-based surveys off the MCR in 1992-1993. They reported that murrelets were concentrated within about 0.62 mile of shore in 1992 but broadly scattered within about 3.1 miles of shore in 1993. Marbled murrelets nest in old growth/mature coniferous forests. The low incidence of marbled murrelets at coastal locations is probably related to the loss of old growth coniferous forest from harvest and/or fire (56 FR 28362). Marbled murrelets are expected to occur in the general vicinity of the MCR. The Cape

Disappointment area is located about 1.6 miles northeast of the North Jetty at Benson Beach and contains suitable habitat for marbled murrelet nesting. While nesting has not been documented in this area, birds have been noted in flight during the nesting season.

Western Snowy Plover. Although western snowy plovers historically occurred in the vicinity of Clatsop Spit, no breeding or wintering plovers have been reported from these beaches in recent years (USFWS 2001). In 2012, two snowy plover were sited during surveys at Clatsop Spit, but no nests were observed (Blackstone, 2012). A small population of western snowy plovers occurs on beaches at Leadbetter Point, Washington, which is more than 20 miles north of the project vicinity. The closest Oregon nesting location is far south of the project vicinity at Bayocean Spit in Tillamook County. Though snowy plovers are not currently nesting at the South Jetty, the Oregon Parks and Recreation Department (OPRD) identified the northern-most tip of Clatsop Spit in their 2010 Habitat Conservation Plan (HCP) for western snowy plovers (OPRD 2010). This area is part of Fort Stevens State Park and will be managed for species recovery as OPRD develops its site management plan. In 2011, the Corps entered into a Memorandum of Agreement with federal and state partners including USFWS and Oregon Parks and Recreation Department (OPRD) regarding cooperation in implementing the snowy plover Habitat Conservation Plan (HCP) for the Clatsop Spit.

Short-tailed Albatross. There have been three confirmed sightings of short-tailed albatross off the Oregon Coast. The closest sighting to the project was 20 miles southwest of the MCR (Marshall et al., 2003).

Northern Spotted Owl. Northern spotted owls are nocturnal predators that generally prey primarily on small forest mammals and nest from February to June, with parental care of the juveniles lasting into September (USFWS 2010a). Spotted owls live in forests characterized by dense canopy closure of mature and old-growth trees, abundant logs, standing snags, and live trees with broken tops; they prefer older forest stands with variety multi-layered canopies of several tree species of varying size and age, both standing and fallen dead trees, and open space among the lower branches to allow flight under the canopy (USFWS 2010a). Benson Beach and Clatsop Spit have large areas of land that have accreted since the construction of the MCR jetty system and are not old enough to have evolved these forest characteristics. These habitat conditions do not exist in the immediate vicinity where the majority of the construction activities will occur. Benson Beach and Clatsop Spit are not designated as critical habitat.

Streaked Horned Lark. According to the USFWS (2010b), the streaked horned lark once occurred from British Columbia, Canada, south to northern California and was a common summer resident in larger and smaller valleys on the west side of the Cascade Mountain range, wintering in eastern Washington, Oregon, and Northern California. Streaked horned larks have also been reported on islands in the lower Columbia River. The species is associated with bare ground or sparsely vegetated habitats and are known to nest in grass seed fields, pastures, fallow fields, and wetland mudflats, and can also be found in and along gravel roads and adjacent ditches. Nesting begins in late March and continues into June and consists of a shallow depression built in the open or near a grass clump and lined with fine dead grasses. The streaked horned lark feeds on the ground, and eats mainly weed seeds and insects.

Columbian White-tailed Deer. Columbian white-tailed deer occur on the Oregon and Washington mainland and instream islands primarily from Skamokawa, Washington upstream to Port Westward. Their closest location to the MCR jetties project vicinity is 34 miles upstream at the Julia Butler Hansen National Wildlife Refuge near Cathlamet, WA.

Bull Trout. Bull trout are endemic to western North America and were more widely distributed historically. The Columbia River may have provided important historical rearing and overwintering habitat for bull trout (Buchanan et al., 1997). Currently, the occurrence of bull trout in the Columbia

River downstream of Bonneville Dam appears to be incidental, and their occurrence upstream of Bonneville Dam appears to be limited. However, there are resident populations in rivers and creeks both in and east of the Cascades. Historic records have documented bull trout passing the fish ladder at Bonneville Dam in 1941, 1947, 1982, 1986, and 1994, as well as in the lower Columbia River near Jones Beach. High quality bull trout habitat is characterized by cold water temperatures; abundant cover in the form of large wood, undercut banks, boulders, etc; clean substrate for spawning; interstitial spaces large enough to conceal juvenile bull trout; and stable channels (USFWS 2000). The Columbia River downstream of Bonneville Dam does not typically achieve water temperatures suitable for bull trout.

Oregon Silverspot Butterfly. This butterfly occupies coastal headlands or Coast Range peaks that provide specific habitat features, primarily because of the presence of its host plant, the early blue violet (*Viola adunca*). The closest populations of this butterfly to the project area occur at Camp Riles in Clatsop County, Oregon to the south and at Long Beach, Washington to the north. Suitable viola habitat was not observed during the plant community surveys on Clatsop Spit, and the only community where it could occur is in the tufted hairgrass community (Tetra Tech 2007b).

Nelson's Checker-mallow. This perennial herb has tall, lavender to deep pink flowers. Flowering occurs as early as mid-May and extends into September although Coast Range populations generally flower later and produce seed earlier (USFWS 2010c). Nelson's checker-mallow most frequently occurs in Oregon ash swales and meadows with wet depressions, or along streams, and species also grow in wetlands within remnant prairie grasslands or along roadsides at stream crossings where non-native plants, such as reed canary grass, blackberry, and Queen Anne's lace, are also present (USFWS 2010c). Nelson's checker-mallow primarily occurs in open areas with little or no shade and will not tolerate encroachment of woody species (USFWS 2010c). Critical habitat has not been designated.

2.3. Cultural and Historic Resources

There are no recorded historic properties within the immediate jetty areas. The pilings that remain from the South Jetty trestle structure are historic. The jetties themselves are over 50 years old and may be eligible for listing under National Register criteria (a): "associated with events that have made a significant contribution to the broad patterns of our history." The MCR and nearshore areas to the north and south are littered with shipwrecks (Figure 9). Well over 200 major shipwrecks have occurred near the mouth – known for a century as "The Graveyard of the Pacific" (Astoria and Warrenton Area Chamber of Commerce, http://www.oldoregon.com/about/entry/about-the-astoria-warrenton-area/). The Columbia River bar is one of the most difficult crossings of any river in the world. These shipwrecks date to the early 1800s, although there is circumstantial evidence of shipwrecks before that. Spanish ships may have wrecked in the early 1700s, probably driven ashore in storms.

Figure 9. Shipwrecks at the MCR

Sources: Columbia River Maritime Museum at www.crmm.org: Overview-Shipwrecks. http://neochronography.com/shipwrecks/index.html; and National Oceanic and Atmospheric Administration

2.4. Socio-economic Resources

2.4.1. Communities near the MCR

The following socioeconomic information was taken from the draft community profiles prepared by the NMFS (2006). The North Jetty and Jetty A are located in Pacific County, Washington, near the communities of Ilwaco and Long Beach on the Long Beach Peninsula. The South Jetty is located in Clatsop County, Oregon, near the communities of Warrenton and Astoria.

2.4.1.1. Ilwaco, Washington

According to the 2000 Census, Ilwaco had a total population of 950 people. The median age of the population was 43, which was higher than the national median of 35.3 years. In 2000, 81.5% of Ilwaco's population lived in family households. The racial composition was 92.8% white, 5.3% Hispanic or Latino, 1.4% American Indian and Alaska native, 0.4% Asian, 1.5% Black or African American, and 0.1% Native Hawaiian or other Pacific Islander. Health care and social assistance was the top occupational field for the employed population 16 years and over (12.5%), followed by retail trade with 11.8%, and educational services with 10.8%. The agriculture, forestry, fishing and hunting occupations represented 3.7% of the employed population. Approximately 27.8% of the labor force was employed by local, state, or federal governments, and 3.8% was employed by the armed forces. Ilwaco's per capita income was $16,138, compared to the national average of $21,587. The median household income was $29,632, lower than the national average of $41,944. About 16.3% of the city's population was living below the poverty level, which was higher than the national average of 12.4%.

In 2000, Ilwaco residents owned 21 vessels that participated in commercial fisheries. Of the 338 commercial vessels that delivered landings in 2000 to Ilwaco, the landings were in the following fisheries (data shown represents landings in metric tons/value of said landings/number of vessels landing; NA = not available): coastal pelagic fish (NA/NA/2), crab (861.9 t/$3,864,427/104), groundfish (2350.7 t/$634,261/35), highly migratory fish species (1907.1 t/$3,595,659/119), salmon (187.4 t/$468,717/98), shrimp (NA/NA/2), and other species (47.5 t/$183,071/81). In 2000, approximately 14 charter-fishing operators serviced sport anglers and tourists. In 2003, there were 1,580 sport fishing license transactions valuing $24,978. In Catch Area 1 (Ilwaco-Ocean) and Area 1A (Ilwaco-Buoy 10), the 2000 sport salmon catch was 27,889 and 16,335 respectively. This data includes (1/1A): (1,630/2,972) Chinook and (26,259/13,363) coho, based on creel survey estimates. In 2000, there were about 16,243/42,061 (1/1A) marine angler trips in the sport salmon fishery for a total of 58,304 across both Ilwaco areas. A total of 106 steelhead were caught by anglers in Area 1, Columbia River to Leadbetter Point. The coastal bottom fish catch for Area 1, Ilwaco/Ilwaco Jetty, was 8,388/631, respectively, and the Pacific halibut catch for Areas 1-2 (Ilwaco-Westport-Ocean Shores) was 2,341 fish.

Cape Disappointment State Park (formerly Fort Canby State Park) is situated just outside of Ilwaco. This 1,882-acre, year-round park is a popular recreation area has several miles of ocean beaches that offer water-sport activities such as surfing, kayaking, and kite boarding, as well as beach activities such as clam digging, hiking, and running. The park has a campground, a boat launch, two lighthouses (Cape Disappointment and North Head), and hiking trails.

2.4.1.2. Long Beach, Washington

According to the 2000 Census, Long Beach had a total population of 1,283 people. The median age was 47.4, which was higher than the national median of 35.3 years. In 2000, 66.6% of Long Beach's population lived in family households. The racial composition was 89.9% white, 4.8% Hispanic or Latino, 1.1% American Indian and Alaska native, 1.4% Asian, and 0.1% Black or African American. Accommodations and food services were the top occupational field, employing 21.1% of the employed population 16 years and older. This was followed by health care and social assistance with 20.3% and retail trade with 9.5%. The agriculture, forestry, fishing and hunting occupations represented 4.8% of the employed population. Approximately 17.7% of the labor force was employed by either local, state, or federal governments and 1.1% was employed by the armed forces. Long Beach's per capita income was $21,266, compared to the national average of $21,587. The median household income was $23,611, lower than the national average of $41,944. About 18.7% of the population was living below the poverty level, which was higher than the national average of 12.4%.

In 2000, no commercial vessels delivered landings to Long Beach. Residents owned 21 vessels that participated in West Coast fisheries. Recorded data shows the number of vessels that participated in each fishery by state (WA/OR/CA; NA = not available) was: coastal pelagic (0/1/0), crab (9/4/0), groundfish (1/0/NA), highly migratory species (NA/0/NA), salmon (4/7/1), shellfish (NA/0/NA), shrimp (NA/3/0), and other species (6/0/0). In 2003, there were 5,044 sport fishing license transactions in Long Beach valued at $70,171. In 2000, one salmon charter fishing operator serviced sport anglers and tourists.

2.4.1.3. Warrenton, Oregon

According to the 2000 Census, the population of Warrenton was 4,096. The median age of the population was 36.6 years, slightly above the national average of 35.3. A total of 82.4% of the population lived in family households in 2000. The racial composition was 92.5% white, 3% Hispanic or Latino, 1.8% Asian, and 1.3% American Indian/Alaska Native. In 2000, the main occupational fields were education, health, and social services (19.3%) and retail (18.6%). The agriculture, forestry, fishing and hunting occupations represented 3.4% of the employed population, and 14.2% of the labor force was employed by local, state, or federal governments. Warrenton's per capita income was $16,874, compared to the national average of $21,587. The median household income was $33,472, which was lower than the national average of $41,944. About 14.2% of the population was living below the poverty level, which was higher than the national average of 12.4%.

In 2000, Warrenton residents owned 52 vessels that participated in commercial fisheries. A total of 334 commercial vessels delivered landings to the Astoria-Warrenton port complex in 2000. These fishery landings included (data shown represents landings in metric tons/value of said landings/number of vessels landing): coastal pelagic fish (5907 t/$794,612/29), crab (1399 t/$6,530,137/92), groundfish (45,284 t/$12,980,569/151), highly migratory fish species (1682 t/$3,273,354/112), other fish species (178 t/$633,751/84), salmon (52 t/$138,537/82), and shrimp (3947 t/$3,816,430/48).

In 2000, there were at least four seafood processors operating in Warrenton with about 168 employees. Approximately 39,523,763 pounds of fish were processed at a value of $22,361,265. In 2000, the top three processed products in the community, in terms of pounds landed and revenue earned, were Dungeness crab, flounder, and shrimp. In 2003, at least two outfitter guide businesses and two licensed charter vessel businesses were based in Warrenton. For the Astoria-Warrenton port complex, in 2000 the recreational salmonid catch in the Ocean Boat Fishery was 766 Chinook and 13,712 coho salmon. The recreational non-salmonid catch totaled 1,533 fish, the majority being black rockfish (*Sebastes melanops*).

Fort Stevens State Park is situated just outside of Warrenton. This 3,700-acre, year-round park is a very popular recreation area and offers camping, freshwater lake swimming, 9 miles of bicycle trails, 6 miles of hiking trails, wildlife viewing, an historic shipwreck, and an historic military area. Several miles of ocean beaches offer water-sport activities such as surfing, kayaking, windsurfing, and kite boarding, as well as beach activities such as clam digging, kite flying, hiking, Frisbee, running, and dog exercise.

2.4.1.4. Astoria, Oregon

According to the 2000 Census, the population of Astoria was 9,813. The median age of the population was 38.3 years, slightly higher than the national average of 35.3. The racial composition was 91.1% white, 6% Hispanic or Latino, 2% Asian, 1.2% American Indian/Alaska Native, and 0.5% Black or African American. While the fishing industry has long formed the economic foundation of Astoria, the largest employers in 2003 were the U.S. Coast Guard, the Astoria School District, the Columbia Memorial Hospital, Clatsop County, and the Clatsop Community College. Other main industries in Astoria in 2000 were education, health and social services, retail trade, recreation, and accommodation and food services. According the 2000 Census 17.1% of the surveyed population worked for the local, state, or federal government and 2.5% were in the armed forces. Astoria's per capita income was $18,759, compared to the national average of $21,587. The median household income was $33,011, which was lower than the national average of $41,944. About 15.9% of the population was living below the poverty level, which was higher than the national average of 12.4%.

In 2000, Astoria residents owned 184 vessels that participated in commercial fisheries. For information about commercial fishery landings in Astoria, see Section 2.4.3. There were at least four seafood processors operating in Astoria in 2000. About 154 employees were employed by these processors and about 10,119,325 pounds of fish were processed at an estimated value of $16,870,071. The top three processed products, in terms of pounds and revenue earned, were flounders, Dungeness crab, and shrimp. Astoria had at least six outfitter guide businesses in 2003, and six licensed charter vessel businesses were located in the community. For the Astoria-Warrenton port group, in 2000 the recreational salmonid catch in the Ocean Boat Fishery was 766 Chinook and 13,712 coho salmon. The recreational non-salmonid catch was 1533 fish, consisting primarily of black rockfish.

2.4.2. Commercial Navigation

The MCR is the gateway to the Columbia-Snake River system, accommodating commercial traffic with an approximate annual value of $20 billion dollars a year. The Columbia/Snake River navigation system from the Pacific Ocean to Lewiston, Idaho is a vital transportation link for the states of Oregon, Washington, Idaho, and Montana, as well as for the Nation as a whole. The Columbia/Snake navigation system flows through Idaho and Washington and forms the southern border of Washington and the northern border of Oregon, serving multiple ports along the way. The Corps maintains the navigation channels and operates navigation locks at eight federal hydropower projects on the Columbia/Snake River system. The navigation channels and locks provide access to markets for producers throughout the United States, and are part of a just-in-time delivery system for this major international trade gateway. The elements of the Columbia/Snake navigation system include the deep-draft navigation channel, the inland navigation channel, and the jetties, anchorages, turning basins, and upriver locks necessary to accommodate increasingly larger ships and growing inland barge movements.

The inland navigation channel runs about 365 miles upstream from Portland/Vancouver to Lewiston, Idaho. The Waterborne Trade Atlas indicates that about 10 million tons of cargo is barged annually, with an estimated value of $1.5 to $2 billion. The deep-draft navigation channel runs 110 miles downstream of Portland/Vancouver to the MCR. The Waterborne Trade Atlas indicates that the deep-draft channel carries about 40 million tons of cargo annually, with an estimated value of $20 billion. Also, about 40,000 local jobs are dependent on this trade.

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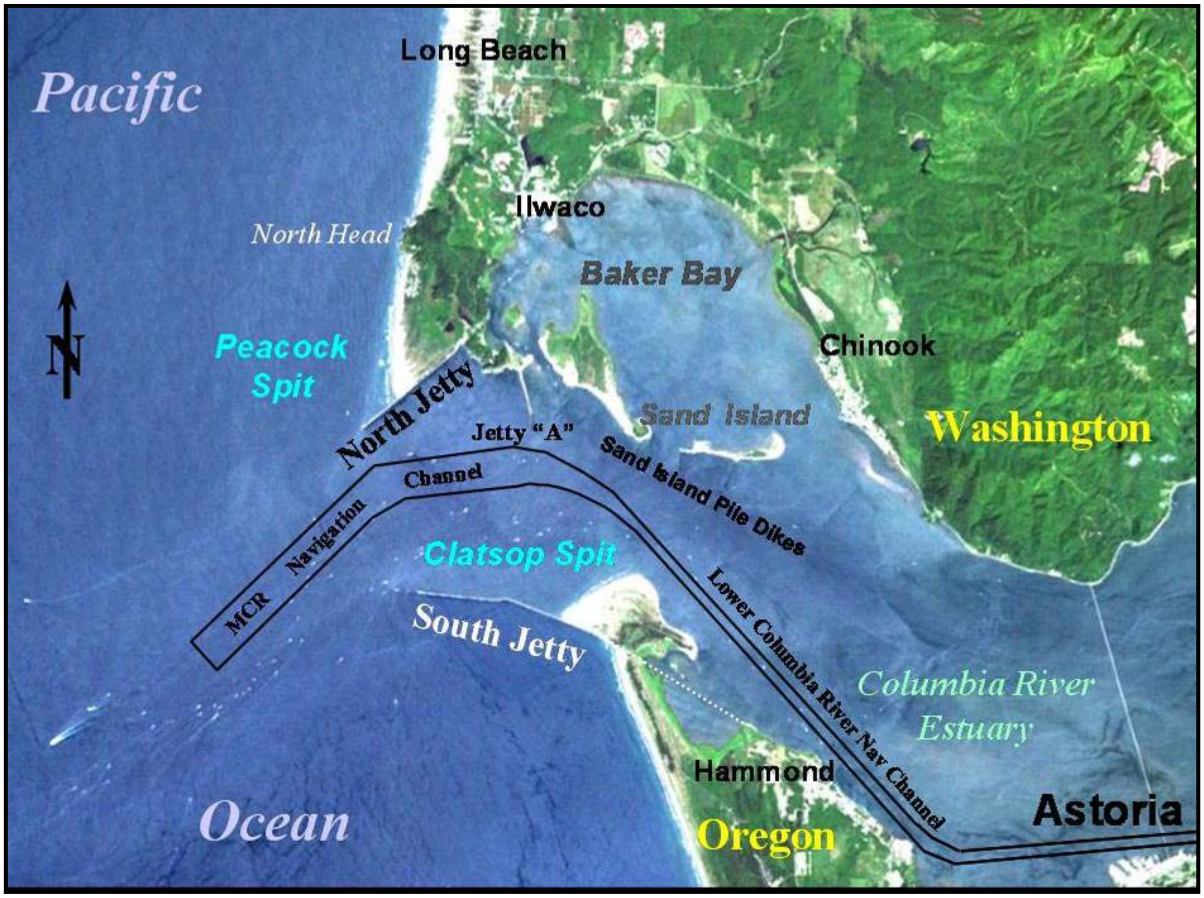
3. NO-ACTION ALTERNATIVE AND MODELING BASE CONDITION FOR THE MCR JETTIES

Each MCR jetty consists of three parts. The head is the seaward terminus and is exposed to the most severe wave action. The trunk forms the connection from jetty head to the subtidal beach, retains subtidal shoals, and confines circulation within the inlet. The root forms the connection from the jetty trunk to the shore and prevents accreted landforms from migrating into the inlet. The jetty system at the MCR and adjacent beaches and bays are illustrated below (Figure 10).

Figure 10. Jetty System at the MCR



The following discussions mention station numbers on each jetty. These stations indicate linear distance along the jetty relative to a fixed reference point near the jetty root. Numbering begins at the reference point (0+00) and increases seaward such that each station number represents that distance in feet, multiplied by 100, plus the additional number of feet indicated after the station number. For instance, station 100+17 would be 10,017 feet seaward from the reference point. The reference point (0+00) is located at the landward-most point on the jetty root.

The No Action alternative under NEPA is distinct from the Base Condition also described here. Both scenarios were used as a comparative template in the alternatives modeling. During modeling and alternatives evaluations predictions about the occurrence of different events under the both the Base Condition and the No Action alternative were generated. The number of necessary repair events, location of repairs, possible breaches, dredging needs (dredging and breach events were only considered under fix-as-fails alternatives), etc. were predicted both for the No Action alternative and the Base Condition, as well as for the additional alternatives that were identified for further evaluation and comparison. Further discussion of modeling used to generate and evaluate these predictions is discussed in Section 4.1.2 *Evaluation of Engineering Features*, and Section 4.2 *Range of Alternatives Considered*.

Notably, this revised final EA reflects updates to circumstances assumed under the Base Condition used for modeling predictions to help identify the Preferred Alternative. This is the result of input from an Independent External Peer Review (IEPR) process, refinement in model assumptions, and modification of the assumed regular jetty maintenance and monitoring strategy implemented in the future. The No Action Alternative remains essentially the same, except that South Jetty foredune augmentation has been evaluated here as an alternative rather than assumed as a previously completed action (as it is under the Base Condition).

No Action:
For the No Action Alternative, no planned large-scale action (such as head-capping or spur groin construction) would be taken to slow down the large, physical processes (larger waves, increased storm activity, and others) that are negatively impacting the structural stability the MCR jetty system. Those larger physical processes include landward recession of the jetty head, shrinking of the ebb tidal shoal, foundation erosion, and adjacent shoreline erosion. The lengths of each jetty would continue to recede landward with the expected response of the surrounding morphology including continued shrinking of adjacent underwater shoals and the overall shrinking of the ebb tidal shoal. Much of the material eroded from the inlets' shrinking shoals would be transported into the MCR inlet, thereby adding to requirements for regular maintenance dredging. The underwater sand shoals upon which the jetties are built would continue to erode, leaving deeper water depths along the jetties. The deeper water (over the eroded shoals) would allow larger waves to attack the jetties resulting in greater jetty deterioration and greater foundation erosion. Wave and current action within the MCR inlet would increase.

However, on a smaller scale more immediate actions may be taken to address specific jetty sections and localized processes via an intermittent or fix-as-fails repair strategy. The No Action alternative could be somewhat characterized as a fix-as-fails approach. In this scenario, South Jetty maintenance is deferred for a given segment until the upper cross-sectional area falls below about 30% of its standard template profile. At the North Jetty and Jetty A, the repair strategy is triggered at a lower threshold when at a given segment the upper cross-sectional area falls below about 40% of its standard template profile. Because of the greater potential navigational impacts from a failure at the North Jetty and the length and exposure of making repairs difficult at the South Jetty, this results in relatively more frequent repair actions under the repair strategy for the North Jetty compared to fix-as-fails at the South Jetty. Depending on the condition and rate of damage to the jetty cross-section for either repair strategy, maintenance actions may be conducted as a normally planned operation, in an expedited fashion, or on an emergency basis.

A fix-as-fails approach involving minimal, site-specific emergency repairs is how the jetties have been maintained historically. This approach represents the No-Action alternative.

Base Condition (for Corps Planning and Modeling Purposes):
Interim repairs have a different repair threshold trigger than fix-as-fails such that action is taken when less of the prism is gone (~30-40%- remaining for interim) relative to fix-as-fail (under fix-as-fails, ~30% remaining on the South Jetty standard template profile, ~30-40% remaining of the standard template profile for North Jetty and Jetty A). Because of the greater potential navigational impacts from a failure at the North Jetty and because of the length and exposure of making repairs difficult at the South Jetty,

this results in relatively more frequent repair actions under the interim repair strategy for the North Jetty compared to at the South Jetty. Interim repairs are a more proactive approach. For the purposes of modeling, interim repair strategies were part of the suite of alternatives evaluated for the jetties under the Base Condition alternative.

The Base Condition is a Corps-specific plan/scenario against which all other alternative plans are measured in the Corps' planning process. When predicting a Base Condition, the most reasonable operations and maintenance (O&M) strategy must be forecasted and used to compare against various project alternatives. The following considerations were determined to develop the Base Condition: operating trends, current and projected reliability of all critical components, and planned maintenance on the project. Unlike the No-Action alternative, Base Condition additional repair actions and activities must be considered and may be implemented to keep the jetties functional, and as such may extend beyond those localized, minimal actions undertaken as reactive, fix-as-fails maintenance. Consequently, while the MCR Base Condition allows the jetty heads to recede, interim repairs on the jetty trunk are implemented to prevent costly emergency repairs. Base Condition maintenance is beyond that which might be exercised under No Action per NEPA. The Base Condition requires the Corps to take all measures short of major repairs and rehabilitation to keep the jetty system functional.

A rubble-mound structure can incur a certain level of damage before the whole cross section fails resulting in a functional impact; however, a complete breach through the above water portion of the structure can result in rapid deterioration. Due to the level of construction and the high mobilization costs, the Base Condition does not include any jetty head re-construction. Only the trunk and the root of the jetty are maintained via interim repairs, and the jetty is allowed to recede landward. Maintenance of trunk and root of the jetty is minimized by deferring repair activities into the future for as long as possible. Jetty repairs are initiated only when an unacceptable failure of the upper portion of the jetty cross section seems to be progressing. The Base Condition is identified as an interim repair approach because the upper portion of the cross section is allowed to be damaged to approximately 40% remaining prior to repair actions being taken. In this way, the jetty is maintained close to the margin of functional loss.

Depending on the percentage of lost cross section and rate of damage which results from the deferred action, maintenance actions may need to be conducted as a normally planned operation or on an expedited basis. In all cases, the repair occurs before the complete failure of the upper part of the cross section. The interim repair approach carries an elevated risk for incurring added costs through expediting repairs (to prevent functional loss of a jetty). Consequently, there is an elevated likelihood that jetty repairs may be more expensive (cost/ton of repair stone placed) when they do occur.

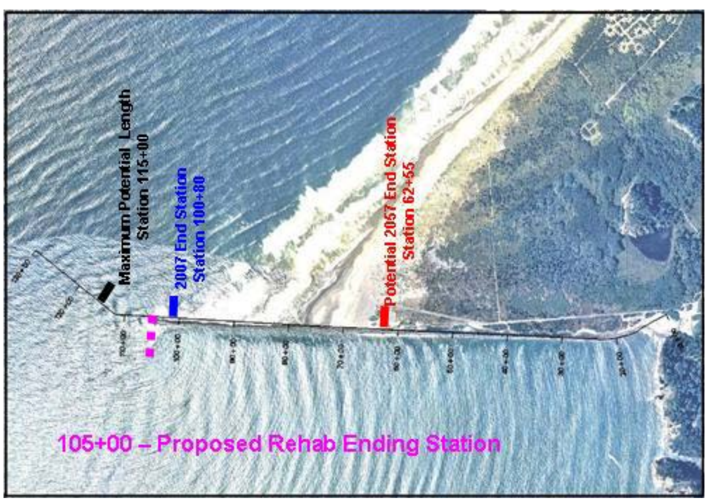
It is also noteworthy that for modeling purposes only augmentation of the foredune at the South Jetty is considered part of the base-condition, but it is NOT part of the No Action alternative. Similarly, limited repair actions (stations 86-99) and lagoon fill at the North Jetty are also included as part of the base condition for modeling, but are NOT part of No-Action. This is due to the fact that North Jetty repairs, North Jetty lagoon fill, and augmentation of the South Jetty foredune would all be implemented as maintenance actions regardless of whether or not the additional major rehabilitation and repairs are completed in order to avoid a breach. They have been identified as priority actions that are required as a basis for all subsequent actions. Therefore, limited North Jetty repairs, lagoon fill, and foredune augmentation at the South Jetty are assumed components when the base conditions are discussed. These actions will likely be a separately funded maintenance projects and were further described and evaluated for their effects in the 2011 EA and FONSI. They have yet to be implemented and are closely associated with the other components of the proposed action. They would occur early in relationship to the overall rehabilitation and repair schedule.

The following sections provide a detailed discussion of the BOTH the No-Action and the modeling Base Condition evaluated here for each MCR jetty.

3.1. North Jetty No Action and Base Condition

No Action:

The North Jetty has receded approximately 2,100 feet in length since original construction in 1916. Under the No Action and Base Condition, the head of the jetty would continue to deteriorate at a rate of about 20-50 feet per year. In 50 years, it is expected to reach approximately station 91 (or about 1,000 feet of additional loss from its current position; see figure below). Peacock Spit and Benson Beach are expected to continue to erode shoreward at a similar rate to the jetty length deterioration. Much of the sediment loss associated with shoreline retreat would migrate into the federal navigation channel and possibly contribute to the overall operations and maintenance (O&M) dredging requirement at the MCR. Maintenance dredging of the entrance could increase over time. The volume of additional maintenance dredging associated with the continued landward recession of Peacock Spit was estimated to be 25% of the O&M dredging at MCR (or 0.5 to 1 million cubic yards (mcy) per year). The resulting head loss would have moderate adverse effects on wave climate and navigability. Erosion of the surrounding shoal would expose more vulnerable areas of the jetty to increased damage. Continued loss of jetty length (and Peacock Spit) could potentially expose the seaward half of the South Jetty to higher wave conditions.



The jetty trunk is expected to degrade by three distinct processes: direct wave impact, wave overtopping (affecting the above-water-portion of the jetty), and scour at the jetty base (affecting the below-water-portion until it fails and destabilizes the above water portion).

During the 50-year project life under the No Action scenario, modeling predicted that the North Jetty would breach, destabilizing more of the jetty and allowing large amounts of sand to move through it. Breaching typically occurs during severe winter storm attack. Modeling suggests that during the 50-year project life, breaching would occur between 3 and 5 times at multiple locations along the North Jetty resulting in emergency repairs. If a segment breaches, it is predicted that adjacent segments have a high probability of also breaching.

For the worst-case breach event, it is predicted that approximately 2-3 mcy of material would move from Peacock Spit and Benson Beach into the navigation channel. A shoal within the navigation channel would begin to form. In the absence of emergency dredging, it is expected that the depth of the navigation channel would be reduced from -55 feet to -40 feet in about 2 to 4 months. In order to maintain navigability of the navigation channel, the Corps would likely perform emergency repairs on the breach and attempt to mobilize sufficient dredges to maintain the authorized channel depth. During the 50-year project life, modeling predicts approximately 1 to 4 repairs would be expected to occur along the North Jetty.

Base Condition for Modeling:
In the 2011 EA, the base condition included the potential for breaching and emergency dredging. However, as described above, the interim maintenance approach triggers action prior to either a breach or emergency dredging event. Under the revised alternative, more aggressive and intensive monitoring would ensure breaches do not occur and help to further inform necessary actions at the North Jetty. Under Base Conditions, during the 50 years of project life, modeling predicted that the North Jetty would experience 5 unit repairs, each at an approximate representative length of 3,100 ft and volume of 130,000 tons (81,250 cy).

North Jetty Lagoon – No Action:
Scouring has taken place on the north side of the North Jetty resulting in formation of a backwater area (lagoon) that is often inundated by tidal waters that come through the jetty and by fresh water that drains through the accreted land to the north. This accelerates the deterioration of the jetty because it is no longer securely tied to the land mass and its foundations and root can be undermined by water on both rather than one side of the jetty.

North Jetty Lagoon – Base Condition
The approximately 16-acre wedge of land between the North Jetty and Jetty Road would be filled in order to stabilize the foundation of the root (stations 20 to 60). Fill areas would include uplands, the lagoon, and three wetland areas (area of wetlands and waters of the United States is approximately 8.86 acres). This maintenance action is considered part of the model's Base Condition. As also mentioned, interim maintenance repairs between stations 86-99 on the North Jetty are also part of the modeling Base-Condition, but NOT the No Action alternative.

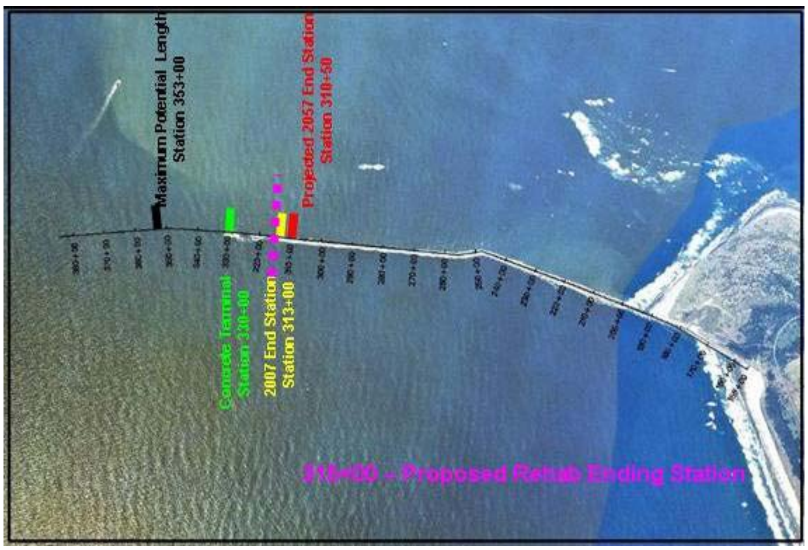
These actions have not been implemented and are associated with the project as the first phase in the rehabilitation plans. They have been identified as priority measures.

3.2. South Jetty No Action and Base Condition

No Action:
The South Jetty has receded approximately 6,200 feet in length since original construction in 1885-1913. Under the No Action and Base Condition, the head of the jetty would continue to deteriorate at a rate of 5 to 20 feet per year until the concrete monolith at the terminal collapses (see below), at which time the head is projected to deteriorate more rapidly. In 50 years, it is expected to reach about station 292 (or about 2,100 feet lost). Continued loss of the jetty length (and Clatsop Spit) would expose the seaward half of the South Jetty to higher wave conditions. Loss of jetty length would contribute to continued loss of the underwater shoal, exposing the jetty to increasing wave action and the shoreline at the root of the jetty to higher wave

forces. The shoreline would continue to erode and recede, resulting in a shoreline breach into Trestle Bay in about 8 to 16 years.

Based on the present condition of the concrete monolith at the terminal, it is expected to slump into the ocean and basically become non-existent within 12 to 20 years, contributing additional deteriorating forces to the seaward half of the jetty. The remaining rubble mound portion of the jetty would then begin to deteriorate in an accelerated way.



The jetty trunk is expected to degrade by the same three distinct processes discussed for the North Jetty.

Modeling suggests that during the 50-year project life under the No Action scenario, breaching would occur between 3 and 6 times along the South Jetty. Unlike the North Jetty, emergency dredging would likely not be needed because the material is not anticipated to affect the federal navigation channel in the short term. Increased dredging would likely occur during the summer maintenance months. The breach would not be repaired by emergency actions; rather, repairs would be performed during the following summer.

<u>Base Condition for Modeling</u>:
As with the North Jetty, the Base Condition in the 2011 EA included the potential for breaching and emergency dredging. However, as described above, the interim maintenance approach triggers action prior to either a breach or emergency dredging event. Under the revised Base Conditions, more aggressive and intensive monitoring would ensure breaches do not occur and help to further inform necessary actions at the jetties. Under the revised base condition, modeling suggests that during the 50-year project life, the South Jetty would require 8 unit repairs, each at a representative length of approximately 5,000 ft and volume of about 220,000 tons (137,500 cy).

<u>South Jetty Root Erosion – No Action:</u>
The shore area along the South Jetty root has experienced profound changes since the time of jetty construction. Before construction, the nearshore area immediately south of the jetty was dominated by a broad shallow ebb tidal shoal, exhibiting relatively shallow water depth. Construction of the South Jetty dissipated this shoal, resulting in a rapid trend of increasing water depth through time. As the water depth along the south side of the jetty increased, wave action along the jetty root and adjacent shore area increased. The increased wave environment motivated rapid deterioration of the entire South Jetty and culminated with the notable breaching event along the South Jetty root in the late 1920s. During the 1930s, extensive efforts were undertaken to rebuild the South Jetty and re-establish the shore land interface along the south-side root of the jetty. The effort was successful; however, the result has been subjected to an increasingly harsh environment of wave action and related circulation since the 1930s.

Currently, the coastal shore interface along the South Jetty is in a condition of advanced deterioration. The foredune separating the ocean from the backshore is almost breached (Figure 11). The backshore is a narrow strip of a low-elevation, accretion area that separates Trestle Bay from the ocean by hundreds of yards. The offshore area along the South Jetty (and to the south) continues to erode, promoting larger wave action to affect the shoreline along the South Jetty root. The back-dune of Trestle Bay has continued to advance westward due to increased circulation in the bay, seasonal wave chop, and hydraulic surcharging.

Without foredune augmentation, the shoreline at the root of the South Jetty would continue to erode and recede, resulting in a possible shoreline breach into Trestle Bay in about 8-16 years. If this sand spit breach occurs, the result would be catastrophic. The MCR inlet would establish a secondary flow way from the estuary to the ocean along this area (south of the South Jetty). This condition would profoundly disrupt navigation at the MCR and bring lasting changes to the physical nature of the inlet.

Figure 11. Clatsop Spit and South Jetty Root Erosion

Base Condition for Modeling:
Under the Base Condition alternative, foredune augmentation adjacent to the South Jetty Root would be implemented in order to begin addressing erosion concerns. However, as mentioned, this is NOT considered part of the No Action alternative.

3.2.1. Concrete Monolith

During rehabilitation of the South Jetty in the 1930s, a concrete cap 500 feet long was constructed to secure the jetty head at station 330. The seaward most 200 feet of the concrete cap was composed of a solid core monolith. This cap has served well since 1940 (or about 80 years); however, the entire cap has been severely damaged due to the harsh wave climate that exists 3 miles offshore and is progressively failing. This cap serves as an anchor to secure and protect the un-reinforced area of the South Jetty immediately inshore of the cap. When the cap fails completely (i.e., falls off of the jetty crest), the land area adjacent to the cap will rapidly deteriorate due to relentless wave action. Based on the present condition of the concrete monolith, it is expected to slump into the ocean and basically become non-existent within 12 to 20 years, which would add additional deteriorating forces to the seaward half of the jetty. The remaining rubble mound portion of the South Jetty would then begin to deteriorate in an accelerated way.

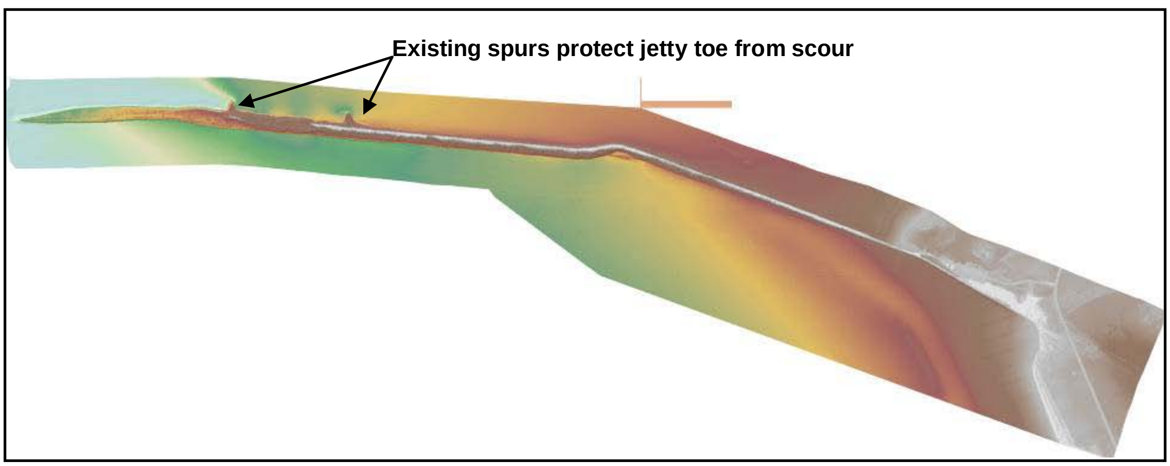
3.2.2. South Jetty Existing Spur Groins

Historical records show that six spur groins (#1-4, #6-7) were constructed along the channel side of the South Jetty (Table 18). Four of the groins were buried by accreted shoreline or sand shoal. The two visible, most seaward spur groins (at ~stations 309 and 333) clearly show an influence on the surrounding underwater contours. The 100-foot spur groins push the more extreme tidal velocities channel-ward, so that the shoal material at the base of the jetty is stabilized. Figure 7 illustrates the important effect these spur groins have on stabilizing the underwater shoal and protecting the South Jetty. These small structural features help with the long-term structural stability of the South Jetty by: (1) promoting sediment deposition along the jetty foundation; and (2) inhibiting the shoreline erosion occurring at the root of the jetty.

Table 18. Additional Structures at the MCR South Jetty

Additional Structures	Year Completed	Station Location	Length (feet)
Spur Groin #1	1893	228+00	500
Spur Groin #2	1893	156+00	600
Spur Groin #3	1895	88+00	1000
Spur Groin #4	1895	52+00	1000
Shore Revetment	1896	25+80	3955
Spur Groin #6	1913	309+33	~110
Spur Groin #7	1913	333+46	~90

Figure 12. Existing Spur Groins at the MCR South Jetty

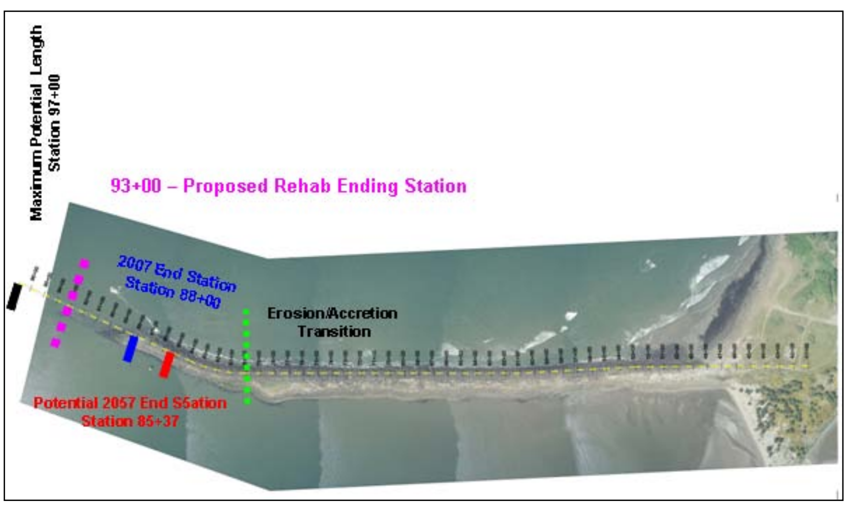


3.3. Jetty A No Action and Base Condition

No Action:
The main purpose of Jetty A is to direct river currents away from the North Jetty. Jetty A has receded approximately 900 feet in length since original construction in 1939. Under both No Action and the Base Condition, the jetty is expected to continue to deteriorate at a rate of about 5 to 20 feet per year. In 50 years, it is predicted to reach approximately stations 83 (or about 500 feet lost).

The jetty trunk is expected to degrade by the same three distinct processes discussed for the North Jetty. Under the No Action scenario, increases in dredging would be expected as Jetty A receded. Clatsop Spit would move northward toward the navigation channel. The bathymetry in front of Sand Island would be cut back, mobilizing additional material. The shallower area between Jetty A and the North Jetty is also predicted to be impacted allowing movement of that material toward the channel. The deepening expected to happen in the vicinity of the North Jetty would further destabilize the jetty's foundation and impact its long-term reliability. It is expected that a one-time increase in dredging would occur on the order of 800,000 to 1.6 mcy followed by incremental increases in dredging that would depend on changes in channel shoaling patterns and spit movement.

During the 50-year project life, it is predicted that Jetty A would breach, destabilizing more of the jetty and allowing significant amounts of sand to move through it. Modeling suggests that during the 50-year project life, breaching would occur between 2 and 4 times along Jetty A. If a segment breaches, adjacent segments have a high probability of also breaching. It is estimated that 2 to 3 repairs would occur along Jetty A. Unlike the North Jetty, emergency dredging would not be needed because the material is not expected to affect the navigation channel in the short term. Increased dredging would occur during the summer maintenance months. Also, repairs to the breach would occur the following summer.



Base Condition for Modeling:
As previously discussed for the other two jetties, the revised Base Condition no longer includes the possibility of emergency dredging or breaching scenarios. During the 50-year project life, modeling predicts Jetty A would require 4 unit repairs, each at a representative length of about 1,900 ft and volume of about 55,000 tons (34,375 cy).

4. ALTERNATIVES AND DESIGN OPTIONS

4.1. General Alternatives Analysis Categories and Features

Neither the alternatives in this EA nor the previously Preferred Alternatives for the MCR jetties discussed in the 2006 and 2010 draft EAs or May 2011 EA include rebuilding the three jetties to their originally authorized lengths, nor to the lengths proposed in the first Draft EA released in 2006. Evaluations of the alternatives now consider the ends of the jetties at their current locations or receding, which is short of both the originally authorized and the 2006 recommended lengths. In addition, this EA updates the alternative plans considered and includes a revised Preferred Alternative at the North Jetty, South Jetty, and Jetty A. The current changes to the Preferred Alternative for the North Jetty, South Jetty, and Jetty A would further avoid and minimize some of the previously identified environmental impacts by reducing the final structure and construction footprints necessary to achieve a resilient jetty system at the MCR.

The major changes from the 2011 EA are the additional alternatives considered and the assumptions in the Base Condition such that the jetties are managed and maintained in order to not allow them to breach. The model takes a simplified approach to managing the risk of degradation trigger points and assessing life-cycle costs of different cross-sections and timing of actions. All alternatives are compared to the No Action alternative and also to this revised Base Condition.

Alternatives and design options were evaluated by comparing reliability of the system, average annual costs, potential environmental effects, and anticipated repair frequencies for each alternative. Repair and rehabilitation options comprise the general categories of alternatives considered and evaluated for the MCR jetty system, as described below.

Repair Alternatives. The programmed scheduled repair strategy monitors each 100-ft jetty segment for its current cross section and degradation rates. When a threshold occurs (usually about four-years before failure), this triggers a repair action. Generally, they are triggered when the upper profile of the cross-sectional area falls below 30-50% of its standard template profile (or, 50-70% of the previously existing prism is gone). Repair alternatives usually involve adding limited amounts of stone to trunk and root features in order to restore the affected cross-section back to a standard repair template. Under repair options, stone placement generally is limited to above-water sections and remains within the existing jetty and relic stone structures. Repair alternatives also considered differing degrees of repair varying by volume, frequency, and size of the restored prism. Repair alternatives are also varied in their implementation strategy, which could occur on the basis of a scheduled, predetermined time and place, or on an interim repair basis (as the base condition) for which a stochastic model predicted jetty repair scenarios. For the North and South Jetties and Jetty A, the repair alternative included repair combined with and without engineering features (head capping, spur groins, etc.).

Scheduled repairs occur even sooner than interim repairs, as they are initiated when even less of the jetty prism has been degraded. Interim repairs (Base Condition) allow a greater level of degradation to occur prior to triggering action relative to levels acceptable under the scheduled repair scenario. However, this interim repair strategy also entails more aggressive and intensive monitoring such that interim repairs avoid both breaching and resulting dredging scenarios. Both are more proactive than fix-as-fails under the No Action alternative.

Rehabilitation Alternatives. Rehabilitation alternatives generally incorporate engineering components which may extend beyond the current footprint of jetty and relic stone structures and could entail both above and below-water fill. Certain engineering features were evaluated and incorporated as common components present in many of the rehabilitation alternatives considered. Engineering features included capping jetty heads, constructing additional spur groins, and filling the North Jetty lagoon area. However, fill at the North Jetty lagoon, certain North Jetty repairs from stations 86-99, and augmentation of the South Jetty foredune are engineering features but are also considered separate maintenance actions that are implemented under the Base Condition; they are NOT part of the No Action alternative. Rehabilitation strategies were evaluated as both immediate and scheduled. *Immediate rehabilitation* begins at one end of the jetty and continues in succession along adjacent section of the jetties without prioritizing a reach based on its condition. *Scheduled rehabilitation* constructs at specific locations along the jetty at specific time periods in order to prioritize areas where conditions warrant sooner attention.

4.1.1. Common Engineering Features Considered as Part of Rehabilitation Alternatives

4.1.1.1. Spur Groins

Historically, spur groins were constructed along the trunk of the jetties and were a design component considered in the current alternatives analyses related to this rehabilitation. A spur groin is a relatively short structure (in comparison to jetty length) usually extending perpendicular from the main axis of a jetty. Spur groins are constructed: (1) on the ocean or beach side of a jetty to deflect the longshore (rip) current and related littoral sediment away from the jetty and prevent littoral sediment from entering the navigation channel; and (2) on the channel side of a jetty to divert the tidal or river current away from the channel side toe of the jetty. Spur groins also act to reduce the scour affecting the foundation while increasing the current in the navigation channel, thus reducing the deposition in the channel. In areas where foundation scour threatens the overall stability of the MCR jetties, spur groins constructed perpendicular to the structure facilitate stabilization by the accumulation of sediment along the jetty's foundation.

4.1.1.2. Jetty Length and Head

All three MCR jetties have receded measurably from their original authorized length, and without the proposed action this is expected to continue. As described previously, all three jetties have essentially lost their functional heads, resulting in further unraveling and deterioration of their remaining trunk and root structures. Due to the interaction of wave patterns and currents with the jetties configuration, shorter jetty lengths can increase underwater shoal erosion and influence shoreline position adjacent to the jetties. Jetty head design is much larger (wider prism, with larger-sized armor stone) than a typical jetty trunk section due to its increased exposure to wave attack and its critical protective function for the rest of the structure. It was important to determine how much to rebuild the original jetty structures and where the newly located (shortened, compared to the authorized length) jetty lengths should be stabilized. Parameters evaluated in addressing jetty lengths included possible impacts on tidal velocities and salinity, protection of the navigation entrance from waves, impacts on adjacent shorelines and ebb tidal shoal erosion, and impacts on dredged material disposal activities. The location of the relic stone base left from past construction efforts also played a role in determining the head stabilization location. Head capping is one method of head stabilization that was evaluated in more detail as described further below. However, there are various methods and degrees of head and length stabilization which could include capping or some other form of armoring.

4.1.1.3. Cross-section Design

The cross-section design for the MCR jetties was guided by the following considerations:

- The repair template must be cost effective in terms of construction materials.

- The repair template must be easily constructed.
- The minimum modification to the jetty footprint is most desirable in order to limit potential impacts to the surrounding environment.
- The jetty repair should be structurally consistent with the current jetty configuration and future repair scenarios.
- Each action taken should be directed toward improving the long-term reliability of the jetty system and its function to protect the navigation channel.

Because of the variability in wave climates between the jetties, the jetties' individual reach sections, and their individual repair histories, the cross-section design options vary for the jetties. Jetty cross-section options examined crest elevation, crest width, and side-slope adjustments. For jetty reaches where foundation stability was a concern, special designs were developed for the toe berm area of the cross section for the long-term stabilization of the upper portion of the section. Above and below water adjustments also were made to address both the variability in design climate and the accuracy and expected method of construction. Two-dimensional physical modeling was used to assess and fine-tune the cross-section designs for each jetty. There are four general categories of cross-section descriptions:

Minimum. This cross section generally fits within the existing footprint of the current jetty structure or relic stone and involves rock placement above the water.

Small. This cross section generally fits mostly within the existing footprint of the current jetty structure or relic stone, but may extend slightly beyond it. It generally involves rock placement above the water.

Moderate. This cross section fits somewhat within the existing footprint of the current jetty structure or relic stone, but may extend beyond it. It generally involves rock placement both above and below the water. Much of the cross section is encased in armor stone, and below-water instabilities are addressed.

Large. This cross section generally extends beyond the existing footprint of the current jetty structure or relic stone. It involves rock placement both above and below the water. Much of the cross section is encased in two layers of armor stone, and below-water instabilities are addressed. Slopes are generally flatter and include a larger toe structure.

Composite. When referring to a composite cross-section, this could entail any combination of the above cross-section types tailored to address structure concerns along specific jetty reach sections.

4.1.2. Evaluation of Engineering Features

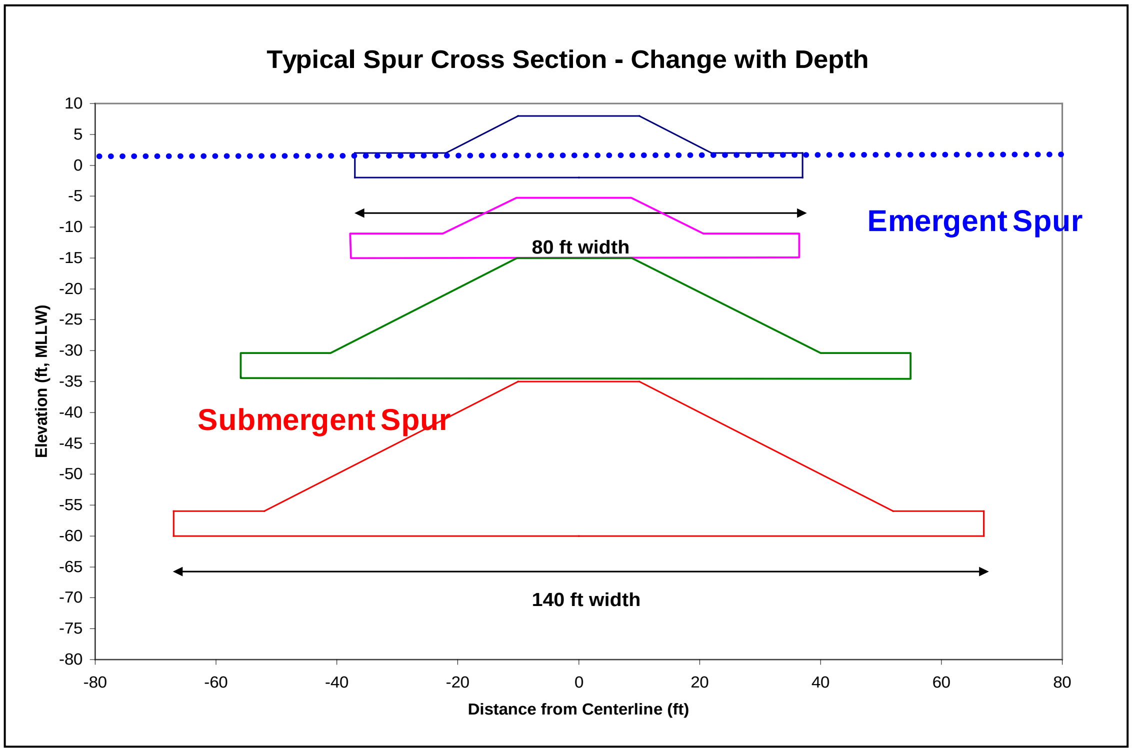
4.1.2.1. Spur Groin Location and Number (ERDC Model)

The Corps' Engineering Research and Development Center (ERDC) in Vicksburg, Mississippi analyzed the hydrodynamics and circulation patterns in the MCR entrance, as well as the potential impacts and effectiveness of placing spur groins on the jetties. This analysis was conducted with the coastal modeling system and other models to select the type, depth, and length of spur groins necessary to protect the each jetty from the processes causing increased scour (e.g., rip currents, eddies).

Though spur groins were evaluated based on the following assumptions detailed below, further subsequent modeling by the Portland District Corp no longer justifies the need for spur groins at any of the jetties. It is currently assumed that a stable jetty system can be maintained without spur groins. Real-time monitoring will be conducted yearly to confirm assumptions that the jetties remain stable without these features and that there is no risk of breaching. Therefore, these features are no longer being carried forward for inclusion as part of the proposed actions under the Preferred Alternative. If monitoring demonstrates that the assumptions were incorrect, then spur groins will be re-evaluated for implementation. For the sake of completeness in this EA, the original evaluation assumptions are retained here to enhance understanding of the effects considered and how they pertain to the rest of the discussions.

Previously, it was assumed that each spur groin would have a crest width of about 20 feet and would be constructed using a bedding layer (mixture of gravel and rock) that would be covered with large stone sized for the location and exposure. Submergent spur groins located at a greater depth typically have wider bases than shallower, emergent groins. This is illustrated in the typical cross-section in Figure 13.

Figure 13. Typical Spur Cross Section - Change with Depth



Two potential construction methods were considered that could have been used for spur groins, either land-based or marine-based depending on location. Barges or similar equipment could be used to dump the bedding layer rock into place and a clamshell would be used to place larger stone on top of the bedding rock layer in locations with sufficient water depth. Material could also be placed using land-based equipment from on top of the jetty. Land-based construction would have required a wide turnout crane placement with over-excavation down to grade as the crane walks back onto the main jetty axis. In addition, the emergent spur groins could have been used as turnouts for construction equipment. The land-based construction method could have been used for all but the deepest spur groins. However, to reiterate as noted, spur groins were evaluated and originally included as part of the suite of proposed actions under the preferred alternative but are no longer incorporated under the current proposed action.

For the North Jetty, as the jetty length recedes so does the adjacent beach. It is assumed that if the North Jetty is stabilized at the existing location, Benson Beach would become more stable. Stabilization in conjunction with filling the lagoon area (another alternative described below) produces a fairly stable jetty tied to a landmass. It is anticipated that spur groins would not be required in the near-term. Monitoring would be conducted to validate these assumptions.

4.1.2.2. Jetty Length (USGS Model)

The U.S. Geological Society (USGS) assisted the Corps with evaluating potential improvements and impacts of rebuilding the lengths of the MCR jetties. The USGS efforts focused on using the Delft-3D model to identify potential changes in circulation, salinity and sediment transport that could result from the offshore re-build of the three jetties. Increased jetty lengths were investigated to determine if they could provide a more sustainable jetty system over the long term. An initial assessment of options for jetty rebuild limited the considerations to partial jetty rebuild rather than considering rebuild to fully authorized lengths. The South Jetty length rebuild was investigated out to station 353 or 4,000 feet seaward of its current location; the North Jetty out to station 115 or 1,500 feet seaward; and Jetty A out to station 97 or 900 feet seaward. The model results for the jetty length rebuilds showed only small changes on the overall patterns of salinity flow, waves, and sediment transport at the MCR inlet.

However, due to the severe ocean conditions at the MCR, tremendous costs would be required to rebuild the jetties and to re-establish a resilient jetty head section at the originally authorized lengths or to those proposed in the earlier 2006 EA. It was recommended that all three jetty lengths remain the same as the current jetty head locations. However, a project plan that does not stabilize the jetty heads would likely have a negative impact on both Clatsop and Peacock Spits, as well as the shoreline areas adjacent to both the North and South jetties. Stabilizing the jetty heads at the proposed current locations would reduce the migration of littoral sediment from Peacock Spit into the navigation channel. This current proposal is anticipated to provide an adequate level of protection for the jetty system and adjacent landforms and habitats, while rebuilding to the authorized or previously proposed lengths would add considerable cost increases without an anticipated equivalent or sufficient corresponding benefit in additional protection or reliability. Part of the exponential increase in cost for achieving the authorized lengths is derived from the volume of rock placement needed for structure fill at current depths characteristic of the locations where the heads were originally authorized.

4.1.2.3. Cross-section Design (Physical Model)

The ERDC was contracted to conduct a two-dimensional physical model of the jetty cross-section design. The range of structural repair types addressed in the model included crest elevation and crest widths variations, side-slope variations, underwater berms, armor stone, and concrete armor unit options. The purpose for the two-dimensional physical model was three-fold:

1. Assist in defining damage initiation and progression relationships (damage function) for existing condition and proposed alternatives to feed into a reliability analysis of the three structures.
2. Conduct qualitative screening of a wide range of alternatives that will bracket potential structural and material-type options that could be applied on the three structures.
3. Assist in cross-section optimization and material-type design for the alternatives to be assessed.

Both the North and South jetties were tested under low and high water conditions. Incident wave heights up to 35 feet were applied to the jetty cross sections. Armor units tested included quarry stone and dolos concrete armor units. An additional concrete armor unit was tested called a c-roc. The c-roc armor unit more closely resembles a large rock with interlocking members. Due to its rock-like configuration, it is expected to be less fragile than concrete armor units which have thinner flange-like elements. Existing condition and potential design alternative cross sections were modeled. The physical model testing of the jetty cross section resulted in a range of graduated design options that achieve varying levels of structure reliability that were carried forward into the life-cycle analysis model of the jetty system.

Physical modeling results showed that the primary failure modes for the North and South jetties were high water level wave attack and overtopping. The jetties can be reliably designed using attainable rock (quarry stone). The seaward head of jetty may require advanced design. Dolos concrete armor units did not hold up well in the tests. Very flat slopes would be needed to make this armor unit viable. C-roc appeared to hold up well during preliminary testing (concerns regarding c-roc include reliability of one-layer system, not field-tested, elaborate construction control requirements, and uncertainty about interlocking with relic base). The results were used to determine cross-section design options for the jetties that achieve varying levels of structure reliability.

4.2. Range of Options and Alternatives Considered

The options under consideration for the MCR jetties ranged from the reactive fix-as-fails interim repairs of the No Action alternative, to the more aggressive interim repairs under the Base Condition, to increasingly higher levels of repair or rehabilitation action to prevent cumulative jetty damage and impacts to project function. Not all of the options addressed the full range of structure and project degradation and each had varying levels of risk, as well as need for repair and emergency action readiness associated with it. The options considered for the jetties included No Action, Base Condition, scheduled repair, immediate rehabilitation, and scheduled rehabilitation as shown below.

To reiterate, South Jetty dune augmentation, North Jetty interim repairs from Stations 86-99, and North Jetty Lagoon fill (Stations 20-60) were considered part of the model's base condition, *but were not* part of the No Action alternative. They are considered as priority maintenance actions.

No Action Alternative

- Fix-as-fails; Allows jetty to recede (North Jetty, Jetty A and South Jetty). Emergency or expedited repairs to occur as needed.

Base Condition

- ***Interim Repair; Allow jetty to recede*** (North Jetty, Jetty A and ***South Jetty***)
- Interim Repairs; Hold jetty at current location (North Jetty, Jetty A and South Jetty)
- South Jetty foredune augmentation
- North Jetty critical repairs (STA 86-99)
- North Jetty lagoon fill (STA 20-60)

Scheduled Repair Alternative

- ***Scheduled Repair without engineering features*** (***North*** and South ***Jetties***, ***Jetty A***)
- Scheduled Repair with engineering features (North and South jetties)
- Scheduled Repair both ***holding the jetty end station*** and allowing it to recede (***North Jetty***, ***Jetty A*** and South Jetty)

Immediate Rehabilitation Alternative

- Using minimum cross section (North and South jetties)
- Using small cross section (South Jetty and Jetty A)
- Using moderate cross section (North and South jetties)
- Using large cross section (North and South jetties)
- Using composite cross section (North and South jetties)

- Both holding the jetty end station and allowing it to recede (North Jetty, South Jetty, and Jetty A)

Scheduled Rehabilitation Alternative

- Using minimum cross section (North and South jetties)
- Using small cross section (Jetty A)
- Using composite cross section (North and South jetties)

The scheduled repair alternatives evaluated use a minimum cross-section repair template that addresses only above-water jetty structural degradation processes.

The full rehabilitation alternatives evaluated may include all engineering features for structure stability or variations of components. The intent of full rehabilitation of the MCR jetties is three-fold: (1) to improve the stability of the foundation (toe) of each jetty affected by scour; (2) to improve the side-slope stability (above and below water) of each jetty; and (3) to improve the stability of each jetty to withstand wave impact. Two different methods were used to apply the full rehabilitation alternatives, immediate rehabilitation and scheduled rehabilitation. Under immediate rehabilitation, actions would begin at a given year and continue annually until the entire jetty is completed. Under a scheduled approach, the timing of the rehabilitation would be staged by applying the rehabilitation only to a portion of the jetty when it was needed. The sheer size of the MCR jetties along with the limited construction window available at the project requires that any rehabilitation effort would result in scheduling the construction over a number of years. Construction at the North and South jetties is projected to take from 5 to 20 years, depending on the alternative.

Rehabilitation efforts were also distinguished by their cross-section design. In the following discussions, it is notable that the small cross section is not mentioned as alternatives considered for the North Jetty. Because of the contemporary depths of the channel side toe of this structure, the amount and placement of stone necessary to attain a stable slope and base would automatically exceed descriptive thresholds of the small cross-section category at the North Jetty.

The characteristics of the list of alternatives considered for the MCR jetties are discussed in the following subsections.

4.2.1. No Action Alternative

The No Action Alternative is described in Section 3. For this analysis, the No Action alternative (fix-as-fails or interim repairs approach) jetty repairs are deferred for as long as reasonably possible. The interim and fix-as-fails repair maintenance strategies carry higher risk for implementing expedited or emergency actions in response to an imminent or actual breach action. However, the Corps may take additional measures beyond those described in the No Action Alternative depending on future conditions, monitoring results, and funding. This alternative was included in the analysis as part of the NEPA process requirements. The No Action alternative has the lowest functional reliability. The following recap characterizes the No Action alternative at each of the jetties.

North Jetty. Modeling suggests that in 50 years, the North Jetty could breach between three and six times at multiple locations, destabilizing more of the jetty and allowing sand to move through the jetty. The jetty head would continue to recede back at a rate of 20-50 feet per year. Modeling suggests that for a worst-case breach event, about 2-3 mcy of sand could move from Peacock Spit and the Benson Beach area into the federal navigation channel. In the absence of emergency dredging, it is expected that the federal channel could fill with up to 15 feet of sand in about 2-4 months. In order to maintain navigability of the federal channel, emergency repairs would be needed on the breach and dredges mobilized to maintain the authorized channel depth. To perform emergency repairs to a breached area, a contractor would truck in readily available stone from existing quarries to the jetty needing repair, build a haul road on top of the jetty, and place jetty stone into the breached area with an excavator or similar equipment to stop sand from migrating into the navigation channel. These actions may not be as feasible during inclement weather common in the winter months.

In order to maintain navigability of the federal channel, emergency repairs would be performed on the breach and/or emergency dredging of the channel would occur. A breach would likely happen during winter (October-March) in response to a storm wave event (wave action at the MCR during winter can be intense). If a jetty breaches, adjacent segments would have a high probability of also breaching. However, due to the inclement weather and dangerous conditions at MCR, emergency repairs and dredging may not be immediately feasible during the winter months. Emergency dredging and repairs are more likely for breaches at the North Jetty, as hydraulic conditions at Jetty A and the South Jetty are less likely to cause rapid channel encroachment and immediate navigation interference. Post jetty breach responses at the South Jetty or Jetty A would occur the following summer (within 7 months of a breach). In this case, the breach response would be expedited in nature.

The Columbia River Bar can only be maintained with the use of a hopper dredge. These types of dredges have two drag arms that extend to the river bottom and hydraulically remove material. The material is temporarily stored within the ship in a hopper, and then transported to a disposal location. Once at the proper location, doors on the bottom of the ship open or the hull of the ship opens and the material falls from the hopper through the water column to the disposal site. To perform emergency dredging, one or two dredges would be mobilized. Production rates for the dredges would be approximately 20% to 30% of normal due to weather conditions and storm events. The dredges would rely on weather windows and favorable sea conditions to remove as much of the shoal as possible with a goal of maintaining navigation. Due to the physical limitation of the dredges, it is unlikely they could achieve the -55 feet of depth of the outbound lane with swells of larger than 10 feet.

This course of action would present high risks to the dredges and their crew. Given the winter wave conditions, it is highly likely that damage would occur to the drag arm of the dredge while working. Environmental concerns regarding loss of hydraulic fluid or oil spills may result if the dredges are damaged. Dredged material would be disposed of at an approved in-water disposal site. Because it is predicted that up to 3 mcy of material would enter the navigation channel (for a worst case north jetty breach scenario), the dredges are not expected to be able to remove all of the material from the channel; therefore, the following dredging year could require up to three dredges to work the entrance to remove twice the amount of material than in a normal maintenance year. During the last 23 years, there were about 7 years when the wave climate would have been too severe to do emergency dredging. Under those circumstances, there would be more risk of not being able to do emergency dredging with the potential impacts to navigation.

Because there were no capping or stabilization measures to protect the head, jetty recession was predicted to continue throughout the life of the project, ultimately reaching Benson Beach. Furthermore, multiple breaches were anticipated throughout the length of the jetty, and one to four major repairs were expected to occur along the jetty within the 50-year life span. These were not qualities that would ensure the purposes of maintaining a functional MCR jetty system or deep-draft navigation.

South Jetty. Modeling suggests that during the 50-year project life, the South Jetty could breach between 3 and 6 times at multiple locations, destabilizing more of the jetty and allowing sand to move through the jetty. The jetty head would continue to recede back at a rate of 5 to 20 feet per year. Unlike the North Jetty, emergency dredging may not be needed because in the short term, since the sand is not anticipated to affect the federal navigation channel. Dredging could occur during maintenance during the following summer.

Because there were no capping or stabilization measures to protect the head, jetty recession was predicted to continue throughout the life of the project, ultimately reaching about station 295. Furthermore, multiple breaches were anticipated throughout the inner 2/3 of the length of the jetty, and three to six major repairs were expected to occur along the jetty within the 50-year life span. These were not qualities that would ensure the purposes of maintaining a functional MCR jetty system or deep-draft navigation.

Jetty A. During the 50-year project life, modeling predicts Jetty A could breach between two and five times, destabilizing more of the jetty and allowing sand to move through the jetty. The jetty head would continue to recede back at a rate of 5-20 feet per year. Like the South Jetty, emergency dredging may not be needed because in the short term, since the sand is not anticipated to affect the federal navigation channel. Dredging would occur during maintenance during the following summer.

Because there were no capping or stabilization measures to protect the head, jetty recession was predicted to continue throughout the life of the project, ultimately losing around 500 feet of jetty length from present position. Furthermore, numerous breaches were anticipated throughout the length of the jetty, and two or three major repairs were expected to occur along the jetty within the 50-year life span. These were not qualities that would ensure the purposes of maintaining a functional MCR jetty system or deep-draft navigation.

Given the relatively larger anticipated number of repairs and probable increase in maintenance dredging needs, the No Action alternative for the North Jetty, South Jetty, and Jetty A likely would lead to higher frequencies of human disturbance to the natural environment via repairs and dredging in the MCR due to the vicinity of these man-made features to both fish and wildlife and their habitats. The actual footprint of the No Action Alternatives is smaller compared to the other alternatives and there would be fewer storage and staging needs. However, with the No-Action Alternative there could be jetty recession which at the North Jetty would result in additional loss of beach front and intertidal sand habitat as a result of littoral drift into the navigation channel, and this alternative is at greater risk for this process than the other alternatives. The morphology at the MCR would also be at a higher risk of accelerated alteration as wave, current, and erosional forces would continue to influence the potential migration of the channel mouth. For these reasons, the No Action alternatives at the North and South Jetties and Jetty A could have some of the greatest impacts to the human environment.

4.2.2. Base Condition Alternative for Modeling

North Jetty. During the 50 years of project life, modeling predicted that the North Jetty would experience 5 unit repairs, each at an approximate representative length of 3,100 ft and volume of 130,000 tons (81,250 cy). As mentioned, South Jetty foredune augmentation, interim maintenance repairs between stations 86-99 on the North Jetty and lagoon fill (Stations 20 to 60) are also part of the Base-Condition alternative.

This alternative was included as a result of the IEPR comments in order to meet Corps planning requirements. However, the Base Condition alternative is not considered as the preferred alternative for the North Jetty because it had low functional reliability. Interim repairs without measures to protect or stabilize the head allowed jetty recession that was predicted to continue throughout the life of the project, ultimately reaching Benson Beach. These were not qualities that would ensure the purposes of maintaining a functional MCR jetty system to support deep-draft navigation.

South Jetty. Modeling suggests that during the 50-year project life, the South Jetty would require 8 unit repairs, each at a representative length of approximately 5,000 ft and volume of about 220,000 tons (137,500 cy). The jetty head would continue to recede back at a rate of 5 to 20 feet per year. Unlike the North Jetty, emergency dredging may not be needed because in the short term, the sand is not anticipated to affect the federal navigation channel. Dredging could occur during maintenance during the following summer.

The Preferred Alternative for the South Jetty is the Base Condition — continuing the interim repairs, allowing head recession, and including foredune augmentation near the jetty root. However, when conditions are appropriate (i.e., repairs of the South Jetty allow for a haul road to be established to the end of the jetty), head stabilization would be re-evaluated — using parameters such as least cost, environmental acceptability and engineering feasibility — during the development of the detailed design report (DDR). Because the concrete monolith at the head is predicted to last for another 12-20 years, it is expected that the optimal head location would be determined before the monolith is lost and accelerated recession occurs.

Additionally, South Jetty foredune stabilization provides lower risk of breaching through Trestle Bay, and there is less risk to the navigation channel in the event of a breach along the South Jetty trunk relative to the North Jetty. An interim repair approach allows the upper portion of the cross section to be damaged until approximately 40 percent remaining prior to repair actions being taken. However, a rubble-mound structure can incur a certain level of damage before the whole cross section fails resulting in a functional impact. In this way, the jetty is maintained close to the margin of functional loss without breaching. For the South Jetty, the Base Condition is the least-cost alternative and is expected to provide adequate function to meet the project's purpose and need.

Base condition with the foredune stabilization at the jetty root is the least-cost plan for the South Jetty and is expected to meet the purposes of providing a resilient and functional jetty system in support of deep draft navigation.

Jetty A. During the 50-year project life, modeling predicts Jetty A would require 4 unit repairs, each at a representative length of about 1,900 ft and volume of about 55,000 tons (34,375 cy). The jetty would continue to recede back at a rate of 5-20 feet per year. Like the South Jetty, emergency dredging may not be needed because in the short term, since the sand is not anticipated to affect the federal navigation channel. Dredging would occur during maintenance during the following summer.

This alternative was included as a result of the IEPR comments in order to meet Corps planning requirements. However, Base Condition alternative is not considered as the preferred alternative for Jetty A because it had low functional reliability. Because there were no stabilization measures to protect the head, jetty recession was predicted to continue throughout the life of the project, ultimately losing around 500 feet of jetty length from present position. These were not qualities that would ensure the purposes of maintaining a functional MCR jetty system to support deep-draft navigation.

4.2.3. Options Addressing Erosional Areas

4.2.3.1. North Jetty Lagoon Fill

Scouring has taken place on the north side of the North Jetty resulting in formation of a backwater area (lagoon) that is often inundated by tidal waters that come through the jetty and by fresh water that drains through the accreted land to the north. The approximately 16-acre wedge of land between the North Jetty and Jetty Road would be filled in order to stabilize the foundation of the root. Fill areas would include uplands, the lagoon, and three wetland areas (area of CWA 404 wetlands and waters of the United States is approximately 8.86 acres). This fill alternative was considered in combination with other repair and rehabilitation alternatives. Ultimately, it was considered part of the Preferred Alternative and is described in more detail below.

4.2.3.2. South Jetty Root Erosion

As described under No Action for the South Jetty, the offshore area along the South Jetty (and to the south) continues to erode, promoting larger wave action to affect the shoreline along the South Jetty root. The back dune of Trestle Bay has continued to advance westward due to increased circulation in the bay, seasonal wave chop, and hydraulic surcharging. To address this, two options for South Jetty foredune augmentation were evaluated based on potential variation of the implementation strategy to stabilize the foredune within the erosion embayment adjacent to the South Jetty. To adequately protect the foredune during storm conditions, the template for both options requires that the top of fill (crest) extend vertically to 25 feet North American Vertical Datum (NAVD) and have an alongshore application length of approximately 1,100 feet extending southward from the South Jetty root. The constructed template crest would be approximately 10 to 15 feet above the current beach grade and have a 1 vertical to 10 horizontal slope aspect from crest to existing grade.

Sand Berm Foredune Augmentation

Augmenting the South Jetty foredune using a sand fill template was one option considered but ultimately not recommended as the Preferred Alternative. It would have required placement of approximately 225,000 cy of sand. Maximum crest width of the sand fill template was estimated to extend 400 feet seaward from the seaward base of the present foredune. Construction of the sand berm augmentation would have required 4-8 weeks. The gradation of the sand fill material would have varied from fine sand to coarse sand depending upon the source of the material.

Two options were also considered for placing the sand fill material. Sand procured from upland sources would be placed using haul trucks and dozers; in this case, the sand is more likely to be medium to course sand. Upland source sand would have been transported on surface roads and through Fort Stevens State Park to a beach access point at the project site. The sand fill material was also considered for procurement from the MCR or lower Columbia River navigation channel during maintenance dredging. The dredged material (clean sand of variable gradation) would have been pumped ashore to the jetty root using a “pump-ashore” method. A hopper dredge possibly located in the interior area of Clatsop Spit near Trestle Bay (RM 6) would likely have pumped-off sand from the dredge located near the proposed jetty stone marine delivery area, across the neck of Clatsop Spit, to the augmentation area. Depending on bathymetry and final staging location, additional dredging would likely have been required to position the hopper dredge. Ultimately, relative to use of upland sources, this sand pump-ashore method was likely to cause a greater range of geographic and aquatic resources disturbance via additional dredging in shallow-water habitat for the dredge vessel, and in-water and overland placement of the pipeline dredge through sensitive wetlands and wildlife viewing areas.

Cobble Berm Foredune Augmentation

The other stabilization option that was evaluated and ultimately included as the Preferred Alternative involves using a cobble rather than sand substrate. Augmenting the South Jetty foredune using a cobble fill template would require placement of approximately 60,000 cy of cobble material. Maximum crest width of the cobble fill template is estimated to extend 70 feet seaward from the seaward base of the present foredune. Construction of the cobble berm augmentation would require 2 to 6 weeks. Cobble fill material would be procured from upland sources and placed using haul trucks and dozers. The cobble material would be transported on surface roads and through Fort Stevens State Park to a beach access point at the project site.

Advantages of the cobble berm are that it would require less material than a sand berm, exhibit more resiliency (to wave action), and have a smaller construction footprint. One disadvantage is that the unit cost for cobble material may be higher than that for sand. Over time, the slope of the cobble berm would be flattened to perhaps 1 vertical to 20 horizontal. The areal configuration of the cobble berm should minimize alongshore displacement. Although offshore transport of the cobble material is expected to be much less than for sand, over a period of time the cobble berm would lose material. The cobble berm would emulate the foreshore conditions similar to those at Seaside, Oregon, 18 miles south of the South Jetty. If repairs to the South Jetty are not completed, the cobble berm may require maintenance every 4-10 years (assume 40% replacement volume).

Due to the costs and potential environmental impacts from dredging and sand placement entailed in the implementation of the sand foredune alternative, the cobble option is included as the Preferred Alternative. The cobble alternative is also expected to demonstrate superior engineering performance regarding stabilization and resilience compared to the sand augmentation option, and for these reasons is also favored. Impacts from these activities would be above MHHW outside 404 water of the US and are anticipated to be insubstantial. As a result shoreline area would be preserved. This option uses small cobble to fortify the toe of the western, South Jetty foredune to resist wave-induced erosion/recession. A layer of sand may be placed over this berm or natural accretion may facilitate sand recruitment in the area. Further design details are discussed under the South Jetty Proposed Action. This alternative was considered in combination with other repair and rehabilitation alternatives. Ultimately, it was considered part of the Preferred Alternative and is described in more detail below.

Cobble Augmentation in Trestle Bay

This option is no longer being proposed under this action. Cobble or sand augmentation to the Trestle Bay side of Clatsop Spit was an additional alternative considered in the design to stabilize the Spit area. Shoreline of approximately 1,800-ft along-shore (centered on relic South Jetty) and 900-ft cross-shore from (mean tidal low) MTL to +4 MHHW (mean higher high water) of the Trestle Bay was evaluated for stabilization actions. Enhanced vegetation was considered for addition to the intertidal area from MTL to MHHW. Extratidal stabilization from MHHW to +4 MHHW via placement of approximately 50,000 cy of coarser material was also evaluated. It is notable that neither cobble nor sand augmentation to the east side of Clatsop Spit in Trestle Bay is proposed as part of the Preferred Alternative.

Consideration would also be given to development of appropriate revegetation plans which incorporate native dune grasses to supplement foredune stabilization in the augmentation area. This bioengineering component could help restore habitat and take advantage of natural plant rooting functions that provide greater protection from erosive forces.

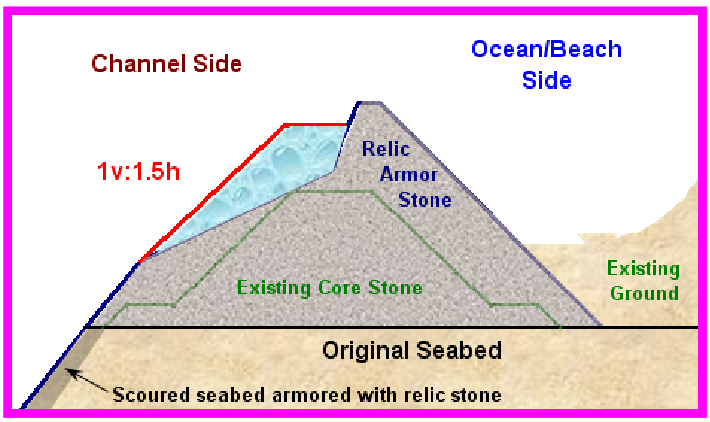
4.2.4. Scheduled Repair without Engineering Features

This option was evaluated for all three jetties and consists of conducting scheduled repairs that only address above-waterline instability. This option is slightly more proactive than the No Action alternative, but like the No Action alternative, it would not include any engineering features (there would be no spur groins or capping performed on any jetty) but would include actions to improve the South Jetty shore area near the root (foredune augmentation) and some repair of the North Jetty and lagoon fill, because they are implemented in the base condition. This type of repair strategy would continue for the entire project life, with increases to the reliability of the structures. Ongoing monitoring of the structures would be necessary in order to prevent loss of function to the project.

4.2.5. Scheduled Repair with Engineering Features

This option was evaluated only for the North and South Jetties and consists of conducting scheduled repairs that only address above-waterline instability. This option is more proactive than the No Action alternative and would include actions to improve the South Jetty shore area near the root and lagoon fill (base condition), and also includes spur groins and jetty head capping. This type of repair strategy would continue for the entire project life. Ongoing monitoring of the structures would be necessary to prevent loss of function to the project. Construction efforts to implement these plans are estimated to extend from 2 to 5 years.

4.2.6. Immediate Rehabilitation using Minimum Cross Section



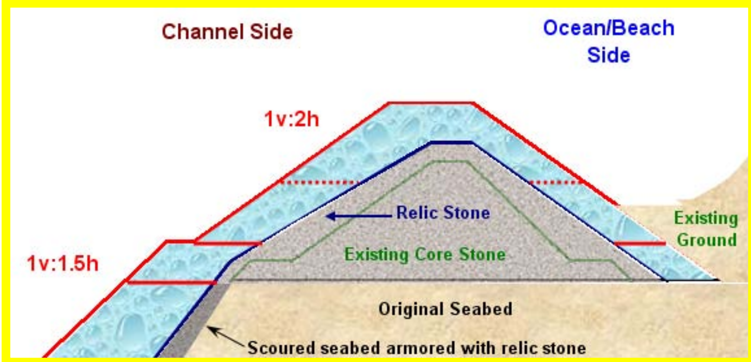
This option would rehabilitate the North and South jetties along their full length using the minimum cross section (see cross-section example at right, new rock shown in blue), which basically repairs the cross section above the waterline and within the existing footprint, and includes spur groins, jetty capping, lagoon fill, and South Jetty shore area near the root (latter two are base conditions). If the minimum cross-section template does not fit within the existing jetty footprint, the crest elevation is lowered until the cross section does fit. It was estimated that it would take a minimum of 5 years to complete all the jetties, assuming that work would be conducted on the jetties concurrently. If concurrent construction could occur, then completion could take up to one-and-a-half to two times as long.

4.2.7. Immediate Rehabilitation using Small Cross Section

This option would rehabilitate the South Jetty and Jetty A along their full length using the small cross section which basically repairs the cross section above the waterline, and includes spur groins, jetty capping, lagoon fill, and South Jetty shore area near the root (latter two are base conditions). Although this cross-section template is relatively small, it is not constrained to fit within the footprint of the existing structure. It is estimated that it would take a minimum of 5 years to complete the jetties, assuming that work could be conducted on the jetties concurrently. If concurrent construction could not occur, then completion could take up to one-and-a-half to two times as long.

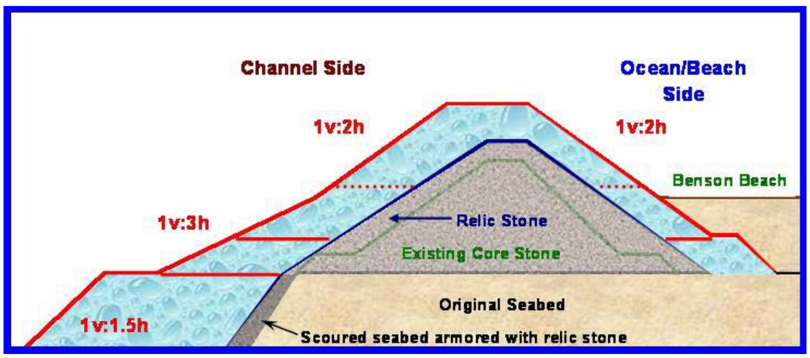
4.2.8. Immediate Rehabilitation using Moderate Cross Section

This option would rehabilitate the North and South jetties along their full length using a moderate cross section (see cross-section example at right, new rock shown in blue), which encases the existing jetty cross section. It would repair the cross sections both above and below the waterline, and include spur groins, jetty capping, lagoon fill, and the South Jetty shore area near the root (latter two are base conditions). It is estimated that it would take a minimum of 9 years to complete all the jetties, assuming that work could be conducted on the jetties concurrently. If concurrent construction cannot occur, then completion of the jetties could take up to one-and-a-half to two times as long.



4.2.9. Immediate Rehabilitation using Large Cross Section

This option would rehabilitate the North and South jetties along their full length using a large cross section (see cross-section example at right, new rock shown in blue), which encases the existing jetty cross section and which also places a stabilizing toe berm along key reaches of each structure. It would repair the cross sections both above and below the waterline, and include spur groins, jetty capping, lagoon fill, and the South Jetty shore area near the root (latter two are base conditions). It is estimated that it would take a minimum of 9 years to complete the jetties, assuming that work could be conducted on the jetties concurrently. If concurrent construction cannot occur, then completion of the jetties could take up to one-and-a-half to two times as long.



4.2.10. Immediate Rehabilitation using Composite Cross Section

This option was evaluated for the North and South Jetties. For scheduling, immediate rehabilitation begins at one end of the jetty and occurs continuously in succession without alternating to different reaches based on conditions. It essentially applies a combination of the cross sections described above, with the size of the cross-section determined by specific conditions within each jetty section. For appropriate cross section sizing, areas could receive a different treatment, from minimum through large templates, based on the sections' specific needs and benefits that were predicted by the model. Immediate rehabilitation would address the jetties along their full length using a plan suited to deterioration processes by jetty station, repair the cross section above and below the waterline where needed, address foundation instability issues where needed, and include jetty capping, spur groins, lagoon fill, and South Jetty dune augmentation (because these would be implemented under the base condition). It is estimated that it would take a minimum of 8 years to complete the jetties, assuming that work could be conducted on the jetties concurrently. If concurrent construction does not occur, then completion of the jetties could take up to one-and-a-half to two times as long. Five separate immediate composite plans were evaluated for the South Jetty and one immediate composite plan for the North Jetty.

4.2.11. Scheduled Rehabilitation using Minimum or Composite Cross Section

Scheduled rehabilitation options were evaluated for the North and South Jetties. Due to the sheer size of the MCR jetties and the limited construction window, any rehabilitation work on the MCR structures will need to occur over a number of years. Scheduled rehabilitation takes the scheduling a step further to implement the rehabilitation of specific reaches of each jetty at designated times to address the most vulnerable reaches first; includes adding spur groins on the jetties to promote structure stability, capping the head of both the North and South jetties to stop deterioration, lagoon fill at the North Jetty to stop erosion at the jetty root, and South jetty foredune augmentation near the root (again, already part of the base condition). Rehabilitation is not conducted until conditions indicate that there is a need for rehabilitation of specific portions of the jetty. The reliability and the cost of the scheduled alternatives were evaluated for the minimum and composite templates. Conducting the rehabilitation when needed instead of continuously, as in the immediate rehabilitation alternative increases the length of time construction occurs to 15 years but construction actually occurs only 11 years out of that total. This is expected because construction is not expected to occur on all jetties at the same time.

The following figures further illustrate the described design options that were evaluated during this review. Though 3-dimensional examples are not available for all of the alternatives or selected plans, the concepts are well displayed and remain applicable for describing scheduled repair templates.

The minimum template with a smaller version of head stabilization relative to capping will most closely resemble the proposed scheduled repair actions.

Figure 14. 3-D Examples of Rehabilitation and Template Options at All Jetties

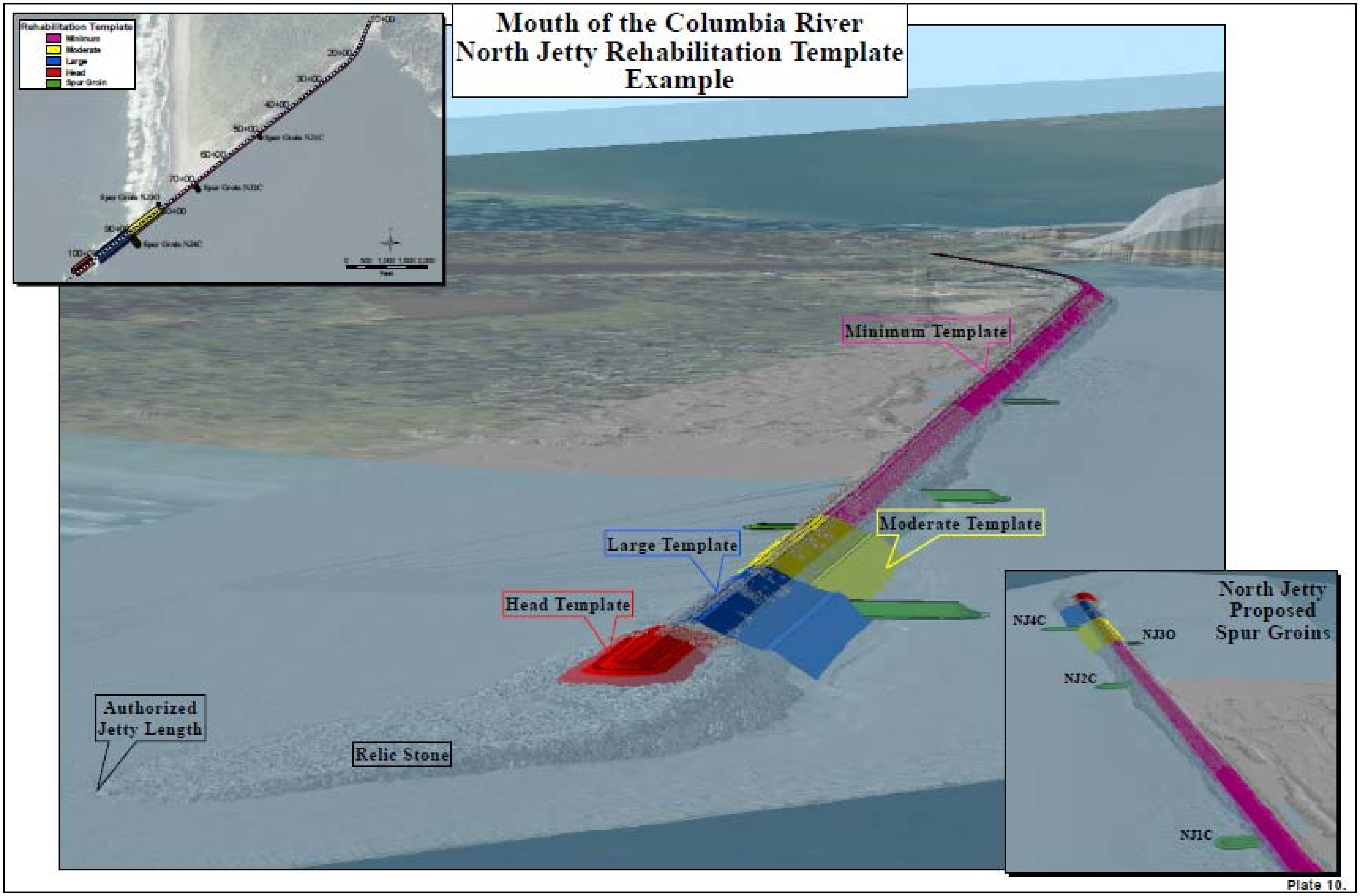
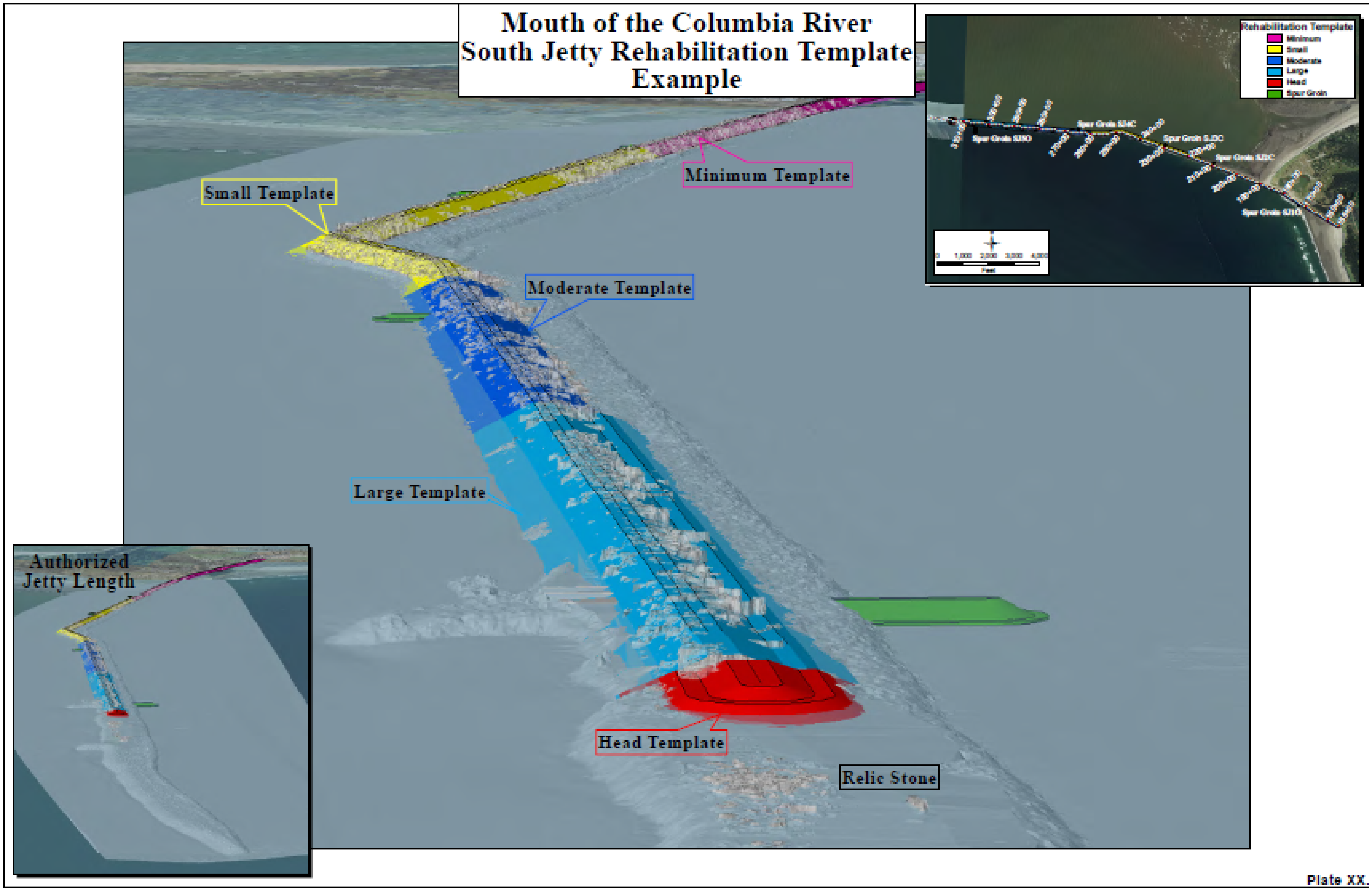


Figure 14 (continued)



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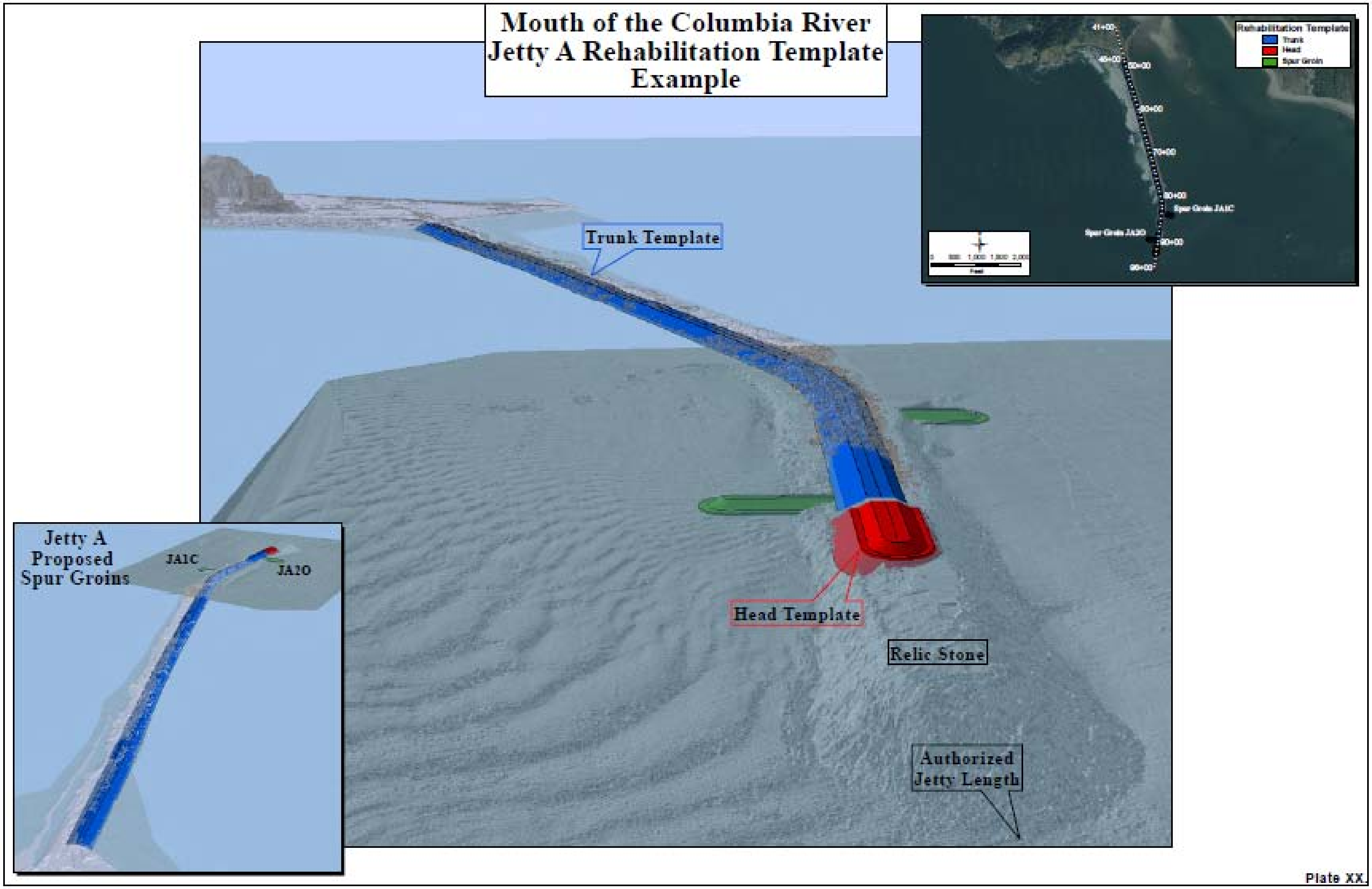

4.3. Comparison of Design Options and Alternatives

An analysis and optimization of the design options was performed using a stochastic (probability), risk-based life-cycle model developed for the MCR jetties. Each jetty was analyzed separately. The model application was initiated by simulating the structures' previous life cycle history and producing a calibrated model of structure performance. This calibrated model was used to project the existing condition into the future. Future life-cycle simulations were performed for the range of repair and rehabilitation alternatives described in Section 4.2. The model used a series of storms and waves that attacked the jetties. Damage to the jetties was calculated when certain trigger points were reached. The model would then simulate repair of the appropriate portion of the jetty according to the particular alternative approach (interim base condition, scheduled, or immediate repair or rehabilitation cross-sections) and then continue assessing the structure and actions over a 50-year timeframe. The model was used to produce life-cycle costs for damages to the structure, repair volumes required, and changes in annual dredging volumes. Then, costs were further developed.

A common set of life-cycle metrics was used to assess the performance for each jetty within a historical and future context. Metrics used to assess historical performance included jetty repair aspects (timing, frequency, location), life-cycle repair cost, jetty geometry configuration (crest profile, cross-section, jetty head location), and jetty reliability. The metrics used to assess future jetty performance and compare the alternatives included:

1. Average annual cost (AAC), including:
    a. Initial construction cost.
    b. Repair costs and their timing after rehabilitation.
    c. Reliability or the probability of a project feature to perform satisfactorily.
2. Constructability and access costs

Design options were evaluated using three categories predicted to have some degree of environmental impact. These categories included: (1) frequency of required repair and construction activities; (2) potential morphological changes at the inlet from continued jetty recession; and (3) shallow-water habitat loss due to placement of engineering features, specifically offloading facilities and lagoon fill. Category one was evaluated based on minimizing repeated impact to the same area after the area had re-established. Category two evaluated the changes to the jetty foundation, the inlet, and the adjacent beaches as a result of continued recession of jetty length. The current assumptions favored rigidity as a surrogate for resilience, and assumed fewer new environmental impacts by maintaining current habitat locations. Category three reflected the loss of shallow-water habitat by the engineered structures and fill. These categories were rated high, medium, and low depending on the loss of habitat or frequency of repair or change in morphology of the inlet. Maximum effects were assumed to occur with the largest jetty cross section, maximum change in morphology from the largest reduction in jetty length and the highest amount of repairs. Other construction and staging elements also were evaluated to determine the best way to avoid and minimize environmental impacts. Additional common project elements across design options included location of stockpile storage, selection of staging areas, location of barge offloading sites, and construction access.

The options for each jetty are discussed and compared in the following sections.

4.3.1. North Jetty Alternatives

For the North Jetty the following design options in addition to No Action were evaluated:

- Base Condition: Interim repairs with and without head stabilization.
- Scheduled Repair: Six scheduled repair plans were evaluated for the North Jetty: scheduled repair without engineering features and scheduled repair with engineering features (head capping, spur groins); both holding the jetty end station and allowing it to recede.
- Immediate Rehabilitation (Rehab): Eight immediate rehabilitation plans were evaluated for the North to determine which plan to select for further consideration. Various cross-sections were analyzed; both holding the jetty end station and allowing it to recede.
- Scheduled Rehab: Fourteen scheduled rehabilitation plans considered for the North Jetty. Various cross-sections were analyzed; both holding the jetty end station and allowing it to recede.

For this evaluation, the comparison of alternatives was simplified. All actions were initiated when a common physical trigger occurred (a percent degradation of the original jetty cross-section prism). Triggers were similar in nature and consequences but different strategies and timing were applied to reduce the rate of degradation. This changed the length of time between actions. Different maintenance and rehabilitation options have different triggers for enacting repairs, and different durations of time for which the repairs last before additional action would be necessary.

For the North Jetty, the immediate and scheduled rehabilitation options with moderate and large cross sections were screened out due to their high average annual costs. Originally, model results and a comparison of the economic and performance parameters for the best performing North Jetty alternatives were used to determine the selected plan.

When ranked by functional reliability, the composite scheduled rehabilitation options ranks the highest, followed closely by scheduled repair with engineering features. When ranked by costs of repair after rehabilitation, the immediate and scheduled rehabilitation options have the lowest costs because they address jetty damage processes at the beginning of the life cycle and provide more resilient jetty maintenance plans. The scheduled rehabilitation options with composite cross section addresses existing and ongoing damage and provides less likelihood of breaching than the smaller cross-section options (scheduled repair and base condition). However, comparing the immediate and scheduled rehabilitation options to scheduled repair with engineering features shows that the scheduled repair options provides high functional reliability at the lowest average annual cost and highest benefit-to-cost ratio. The scheduled repair options had less risk of potential for breech events over the base condition and increased functional reliability of the project. The scheduled repair options would stabilize the jetty head to prevent further head recession and potential impacts to the inlet, adjacent shorelines and shoals, and navigation channel. In addition, while construction of spurs provides more resilience to the jetty foundation along its length and helps control erosion of the supporting underwater shoal, they were not recommended at this point. However, a more intensive and aggressive jetty monitoring and inspection schedule would be implemented to address and avoid any potential breach or emergency dredging scenarios. Additional actions would be taken and the addition of spur groins re-considered if current assumptions prove incorrect and the jetty foundation reaches an unacceptable level of deterioration. For these reasons, it was determined that scheduled repair holding the head stable but without additional engineered features would be described as the Preferred Alternative at the North Jetty.

Therefore, the Preferred Alternative includes Scheduled Repair and holding the end station at or around its current location, which is the least cost plan for the North Jetty.

4.3.2. South Jetty Alternatives

For the South Jetty the following options in addition to No Action alternative were evaluated:

- Base Condition: Interim repairs with and without head stabilization.
- Scheduled Repair: Six scheduled repair plans were evaluated for the South Jetty: scheduled repair without engineering features and scheduled repair with engineering features (head capping, spur groins); both holding the jetty end station and allowing it to recede.
- Immediate Rehab: Eighteen immediate rehabilitation plans were evaluated for the South Jetty to determine which plan to select for further consideration. Various cross-sections were analyzed; both holding the jetty end station and allowing it to recede.
- Scheduled Rehab: Four scheduled rehabilitation plans considered for the South Jetty. Various cross-sections were analyzed; both holding the jetty end station and allowing it to recede.

For the South Jetty, the immediate and scheduled rehabilitation options with moderate, large, and composite cross sections were screened out due to their high average annual costs. Model results and a comparison of the economic and performance parameters for the best performing South Jetty alternatives were used to determine the preferred plan. One feature common to several of the option brought forward for the South Jetty is inclusion of engineering features – jetty head capping and spur groins. While previous analysis showed that these engineering features were necessary for the long-term stability of the MCR jetty system, the jetty roots, and the navigation function, they were not recommended at this point. However, a more intensive and aggressive jetty monitoring and inspection schedule would be implemented to address and avoid any potential breach or emergency dredging scenarios. Additional actions would be taken and the implementation of spur groins re-considered if current assumptions prove incorrect and the jetty foundation reaches an unacceptable level of deterioration.

If the South Jetty head recedes further, it is likely to impact Clatsop Spit and the adjacent shorelines. Continued head recession could negatively affect the wave climate and navigability of the inlet and could expose other elements of the jetty system to higher wave conditions. However, South Jetty foredune stabilization provides lower risk of breaching through Trestle Bay, and there is less risk to the navigation channel in the event of a breach along the South Jetty trunk relative to the North Jetty. It is anticipated that the jetty head would be allowed to recede during the next 8 years of construction, but in the future may be rebuilt to or at its current location. Monitoring and ongoing assessment during Detailed Design Review (DDR) would help assess the optimal jetty length. Continued monitoring would further refine and determine the optimal timing and location of the stabilization features.

Comparing immediate and scheduled rehabilitation to scheduled repair with engineering features shows that scheduled repair provides higher functional reliability at a demonstrably lower average annual cost. Scheduled repair almost cuts in half the potential for breech events over the base condition and increases functional reliability of the project. Scheduled repair would stabilize the jetty head to prevent further head recession and potential impacts to the inlet and adjacent shorelines and shoals. In addition, while the construction of spurs would provide more resilience to the jetty foundation along its length and help control the erosion of the supporting underwater shoal, they were not recommended at this point. However, a more intensive and aggressive jetty monitoring and inspection schedule would be implemented to address and avoid any potential breach or emergency dredging scenarios. Additional actions would be taken and the addition of spur groins re-considered if current assumptions prove incorrect and the jetty foundation reaches an unacceptable level of deterioration. In comparing South Jetty alternatives, key criteria were the considerable cost to repair the structure and the relatively low threat to navigation immediately after a failure. For these reasons, it was determined that the Base

Condition (interim repairs) alternative without engineering features would be the best alternative for the South Jetty.

An interim repair approach allows the upper portion of the cross section to be damaged until approximately 40 percent remaining prior to repair actions being taken. However, a rubble-mound structure can incur a certain level of damage before the whole cross section fails resulting in a functional impact. In this way, the jetty is maintained close to the margin of functional loss without breaching. For the South Jetty, the Base Condition is the least-cost option and is expected to provide adequate function to meet the project's purpose and need.

Base condition with the foredune stabilization at the jetty root is the least-cost plan for the South Jetty and is expected to meet the purposes of providing a resilient and functional jetty system in support of deep draft navigation. This is described as part of the Preferred Alternative for the South Jetty, which is the Base Condition at this location where the jetty head would eventually be stabilized after some degree of recession. This will be accompanied by a more intensive and aggressive jetty monitoring and inspection schedule to address and avoid any potential breach or emergency dredging scenario.

4.3.3. Jetty A Alternatives

For Jetty A the following options were evaluated in addition to No Action:

- Base Condition: Interim repairs with and without head stabilization.
- Scheduled Repair: Two scheduled repair plans were developed and evaluated for Jetty A: scheduled repair allowing head recession and scheduled repair holding the end station.
- Immediate Rehab: Four immediate rehabilitation plans were developed and evaluated for Jetty A: immediate rehabilitation with two types of small templates; allowing head recession and holding the jetty end state.

Model results and a comparison of the economic and performance parameters were also used for analyses of the Jetty A options. The immediate rehabilitation option with small cross section offers greater reliability at a lower average annual cost (and higher benefit-to-cost ratio) than scheduled repair without engineering features, and would require a continuous and aggressive maintenance strategy to prevent negative impacts to navigation.

Though previous analyses recommended immediate rehabilitation, subsequent modeling demonstrated that a resilient jetty system could be achieved at a lower cost. This was demonstrated by a more simplified modeling approach to manage risk associated with degradation so that repair needs were addressed by implementing them sooner or by implementing them with a larger cross section.

The Scheduled Repair, holding the end current station, is part of the Preferred Alternative at Jetty A and is the least cost plan for Jetty A. As with the other two jetties, this would be accompanied by a more intensive and aggressive jetty monitoring and inspection schedule to address and avoid any potential breach or emergency dredging scenario.

In summary, the proposed action (Preferred Alternative) for the MCR jetty system consists of the following features:

- **North Jetty** – scheduled repair with head stabilization (to a lesser extent relative to previously proposed capping), along with Base Condition interim maintenance repairs to stations 86-99 and lagoon fill to stop erosion of the jetty root.
- **South Jetty** – Base Condition without current head stabilization and including foredune augmentation near the jetty root.
- **Jetty A** – scheduled repair and head stabilization at a reduced scale relative to capping.

Section 5 of this EA provides a detailed description of the Preferred Alternative for the MCR jetty system.

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5. PREFERRED ALTERNATIVE

5.1. Overview

The Preferred Alternative (Proposed Action) is generally composed of four categories applicable to each jetty: (1) engineered designs elements and features of the physical structures; (2) construction measures and implementation activities; (3) proposed Clean Water Act (CWA) 404 mitigation actions for impacts to wetlands and waters of the US, and (4) proposed establishment of and coordination with an Adaptive Management Team (AMT) composed of representatives from the Corps and appropriate federal and state agencies.

After additional feedback and comments from an Independent External Peer Review (IEPR) process, the current Preferred Alternative includes actions at each jetty, which have been modified from what was described in the previous draft EAs. The Preferred Alternative represents a further reduction in project footprint and schedule while continuing to meet the purpose of maintaining a resilient jetty system and functional navigation channel.

The duration of the construction schedule is about 8 years with a 50-year operational lifetime for the MCR jetty system. Therefore, an inherent level of uncertainty exists regarding dynamic environmental conditions and actual conditions of and at each of the jetties. For this reason, in all cases where areas, weights, and volumes (tons, acres, cubic yards, etc.) or other metrics are indicated, these are best professional estimates and may vary by greater or lesser amounts within a 20% range when final designs are completed. These amounts represent Corps' best professional judgment of what the range of variability could entail as the design is further developed and as on-the-ground conditions evolve over the construction and maintenance schedule. This variability may also apply to the construction schedule as funding streams may not be available at the forecasted times, or additional new information may shift the repair priorities to alternate sections on the jetties. The Corps maintains an active jetty monitoring and surveying program that would further inform the timing and design of the proposed action in order to facilitate efficient completion of the project and whenever possible to avoid emergency repair scenarios. This program would also pursue an even more aggressive level of monitoring, inspection frequency, and reviews in order to ensure detailed evaluation helps maintain a resilient jetty system and responds with appropriate actions. This suite of actions represents the proposed repair and rehabilitation strategy based on the most current information available based on present jetty conditions. Jetty conditions and deterioration may change over time or perform in ways not anticipated in modeling. In this case, additional repair actions or features may be required in the future.

Details regarding the Preferred Alternative are described below. In practice the following would be done to assess actual locations for repair: a biennial monitoring program where photogrammetric surveys of each of jetties would be executed to track cross-sectional degradation and head recession; annual visual inspections; and reporting by the Coast Guard and commercial ship traffic. Consequently, actual jetty repairs may not follow the exact locations identified by the predictive planning model used to develop the seven-year construction sequence on all three jetties.

Furthermore, while earlier modeling indicated the need for spur groins as part of the jetty stabilization measures, refinements and revised forecasts do not currently demonstrate a need for these structures. As noted previously, spur groins were evaluated for their effects in earlier versions of EAs and are maintained in this draft EA as reference material. However, they are no longer included in the suite of proposed actions under the Preferred Alternative.

The same is true for head-capping. While head stabilization remains included in the suite of proposed actions, it is at a level reduced from that which was proposed under the head-capping measures. The stabilization measure would be a reduced version of the earlier versions of head-capping and would occupy a smaller footprint relative to that previous evaluated in earlier EA versions. However, the information from the earlier analysis is retained here for informational purposes. In both cases monitoring would determine if the assumptions and predictions are valid, and appropriate corrective measures would be pursued and spurs and head stabilization would be re-evaluated.

(1.) Design elements and structural features specific to each jetty include the following:

- North Jetty – Scheduled repairs addressing the existing loss of cross section and head stabilization to minimize future cross section instability are proposed. The cross-section repairs are primarily above MLLW, with a majority of stone placement not likely to extend beyond -5 feet below MLLW. To address the structural instability the jetty head (western-most section) would be stabilized with armoring of large stone, but to a lesser extent than capping that was previously proposed. The head stabilization measure at approximately station 101 would be placed on relic and jetty stone that is above MLLW. The shore-side measures that have been identified are culvert replacement and lagoon fill (STA 20-60). These actions are designed to stop the current ongoing erosion of the jetty root and are considered part of the base condition, along with interim repairs between stations 86-99.

- South Jetty – Maintenance of the Base Condition, interim repair strategy that defers head stabilization is proposed. The head may recede somewhat, but the optimal terminal location remains to be determined. The cross-section repairs are primarily above MLLW, with a majority of stone placement not likely to extend beyond -5 feet below MLLW. Augmentation of the dune at the western shoreline extending south from the jetty root has been included in the base condition, but is describe in detail under the selected plan. This action is intended to prevent the degradation of the jetty root and prevent the potential breaching of the foredune.

- Jetty A – Scheduled repairs addressing the existing loss of cross section and head stabilization to minimize future cross section instability are proposed. The cross-section repairs are primarily above MLLW, with a majority of stone placement not likely to extend beyond -5 feet below MLLW. The jetty head (southern most section) would be stabilized at approximately station 87 with large armoring stone placed on relic and jetty stone that is above MLLW.

(2.) Construction measures and implementation activities for all three jetties include the following:

- Storage and staging areas for rock stockpiles and all associated construction and placement activities such as: roadways, parking areas, turn-outs, haul roads, weigh stations, yard area for sorting and staging actions, etc.
- Stone delivery from identified quarries either by barge or by truck. Possible transit routes have been identified. This also includes the construction and use of permanent barge offloading facilities and causeways with installation and removal of associated piles and dolphins.
- Stone placement either from land or water, which includes the construction, repair, and maintenance of a haul road on the jetty itself, crane set-up pads, and turnouts on jetty road. Placement by water could occur via the use of a jack-up barge on South Jetty, but will not occur by other means or on North Jetty to avoid impacts to crab and juvenile salmon migration.
- Regular dredging and disposal of infill at offloading facilities with frequency dependent on a combination of the evolving conditions at the site and expected construction scheduling and delivery. Disposal will occur at existing designated and approved in-water sites.

(3.) In addition, the Corps has identified specific and potential mitigation for impacts to CWA 404 wetlands and waters of the US. Wetland mitigation opportunities have been identified adjacent to the impacted wetlands at the North Jetty. Wetland mitigation for Jetty A would also be implemented at the North Jetty because space is unavailable at Jetty A. Mitigation for wetland impacts at the South Jetty would occur within the State Park but southwest of the impact area in a location south of Trestle Bay. The mitigation for the impacted wetlands would be creation of wetlands of similar type and function. Specific mitigation for impacts to waters other than wetlands has not been determined, but a suite of potential projects and examples has been identified. Depending on further development of both the project and potential mitigation alternatives and commensurate with final impacts, a specific mitigation project or combination of projects would be selected and constructed concurrently. Mitigation would provide environmental benefits to offset impacts as portions of the proposed action are completed over time. This EA has identified and quantified the maximum amount of impacts and mitigation likely under the Preferred Alternative, and further details and selection of specific appropriate mitigation actions for waters other than wetlands would be refined as the project moves forward. Depending on the method of project implementation, commensurate mitigation could also be reduced if impacts are avoided. Generally, possible mitigation measures could include but are not limited to an individual project or a combination of projects and actions such as the following list.

- Excavation and creation of tidal channel and wetlands to restore and improve hydrologic functions including water quality, flood storage, and salmonid refugia.
- Culvert and tide gate replacements or retrofits to restore or improve fish passage and access to important spawning, rearing, and resting habitat.
- Beneficial uses of dredged material from MCR hopper dredge to replenish littoral cells.
- Invasive species removal and control and revegetation of native plants to restore ecological and food web functions that benefit fisheries.

Mitigation meets compliance obligations under the Clean Water Act and would be commensurate with impacts from construction activities. It also complements Corps obligations to protect and restore critical habitat for ESA listed species. More specifics regarding mitigation are described in that section.

(4.) Due to the dynamic conditions at MCR and the long duration of the MCR Jetty Rehabilitation schedule, the Corps proposes formation of a modified interagency Adaptive Management Team (AMT). The Corps suggests annual meetings and more as needed to discuss relevant design and construction challenges and modifications, technical data, new species listings or critical habitat designations, evolving environmental conditions, and adaptive management practices as needed. The primary purpose of the proposed AMT and its implementation is to ensure construction, operation, and maintenance actions have no greater impacts than those described in the Biological Assessments and this Environmental Assessment, and that Corps obligations and terms and conditions are being met. This will also allow confirmation that any necessary construction or design refinements remain within the range and scope of effects described during Consultations and that compliance obligations are being met and efforts are being made to adjust mitigation once final impacts are fully understood. These adjustments could result in a reduction in mitigation based on actual impacts occurring. This forum would provide an opportunity for periodic evaluation as to whether or not the proposed actions, ESA listings, or environmental conditions result in any re-initiation triggers. It would also facilitate continued coordination and updating and allow the Corps to inform agency partners when unforeseen changes arise. Results regarding marine mammal and fish monitoring, mitigation monitoring, as well as water quality monitoring would be made available to the AMT in order to fulfill reporting requirements and to address any unexpected field observations. Results of jetty monitoring surveys would also inform the AMT of the repair schedule and design refinements that may become necessary as the system evolves over time. This venue would provide transparency and allow opportunities for additional agency input. Final selection and design of the mitigation proposal would be determined by the Corps and would be vetted through this forum to facilitate obtaining final environmental clearance documents for this component of the MCR proposed action. Potential principal partners include federal (National Marine Fisheries Service, U.S. Fish and Wildlife Service) and State (Washington and Oregon) resource management agencies.

5.2. Actions for the North Jetty

The proposed action for the North Jetty is Scheduled Repair (including base condition interim repairs between stations 86 and 99), head stabilization, culvert replacement, and lagoon fill to stop erosion of the jetty root (base condition) (Figures 15 and 16). The jetty head and foundation at the most exposed portion of jetty will be stabilized.

5.2.1. North Jetty Trunk and Root

The cross-section design from stations 20+00 to 99+00 would have a crest width of approximately 30 feet and would lie essentially within the existing jetty footprint based on the configuration of the original cross section, previous repair cross sections, and redistribution of jetty rock by wave action. About 221,000 tons (~138,125 cy) of new rock will be placed on relic armor stone, with the majority of stone placement above MLLW. About three repair events were predicted over the next 50 years. Each repair action is expected to cover a length range of up to 1,500 feet and include stone volumes and rework in the range of 53,000 to 103,000 tons (~33,125-64,375 cy) per season.

At the time of repair, it is expected that 50% to 70% of the standard jetty template cross-section has been displaced. Therefore, each repair event would increase the degraded cross-section from 30% to 50% back to 100% of the desired standard cross-section template. This means the overall added rock would essentially triple what exists immediately prior to the time of repair. This could be described as a ~300% increase in rock relative to the existing jetty rock volume. However, this would not increase the jetty prism or footprint beyond the scope and size of the historic structure, and does not include any modification that changes the character, scope, or size of the original structure design.

The following estimates were made previously but remain somewhat within the range of percents placed in each zone and are somewhat representative of the Preferred Alternative. With placement divided into elevation zones per representative repair event, about 21,550 cy of rock would have been placed above MHHW. This represented 58% of the overall stone placement on these portions of the jetty and 376% change from the existing jetty prism. This meant that currently only a small portion of the original profile remained in this zone and over three times as much stone would be placed compared to what presently remained. As described, above, this same concept applied to characterizations about the rest of the zones. About 9,230 cy of rock would have been placed between MHHW and MLLW. This represented 25% of the overall stone placement on these jetty portions and a 192% change from the existing jetty prism. About 6,675 cy of rock would have been placed below MLLW. This represented 18% of the overall stone placement on these jetty portions and a 150% change from the existing jetty prism. The footprint of the trunk and root will remain on relic stone and within its current dimensions.

Figure 15. North Jetty Cross Section for Existing Condition and Scheduled Repair Template

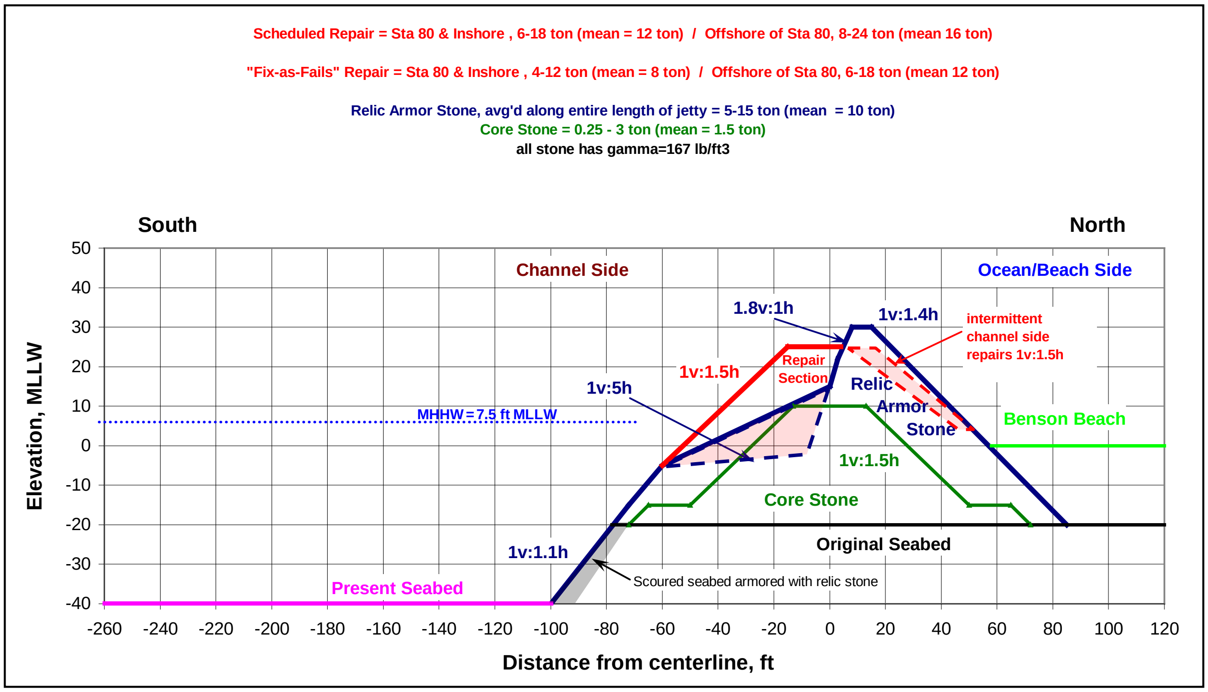
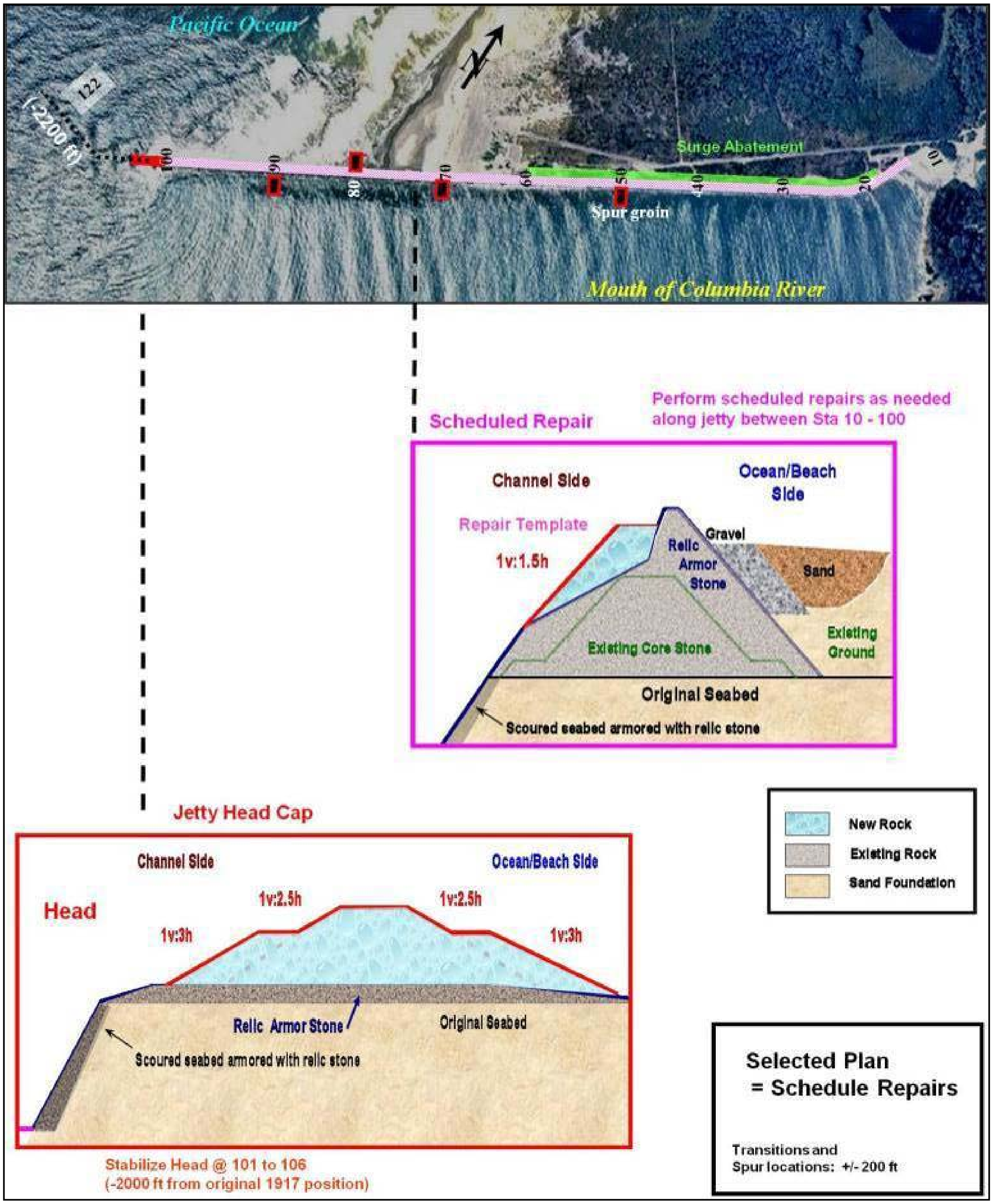


Figure 16. Proposed Action for the North Jetty (Without Spur Groins or Head-Capping)



5.2.2. North Jetty Spur Groins (No Longer Proposed)

Originally, modeling indicated spur groins were necessary to ensure jetty foundation stabilization. Subsequent model refinements have indicated spur groins are not required for maintenance of a resilient jetty system within the Corps standards and operations and maintenance forecasts. More aggressive monitoring and inspection would confirm these assumptions. If unacceptable degradation is observed, then actions that could include spur groins may be implemented in the future and would be re-evaluated accordingly. The following discussion is retained here in order to provide information and disclosure of the previous context in which these structures were evaluated for their effects.

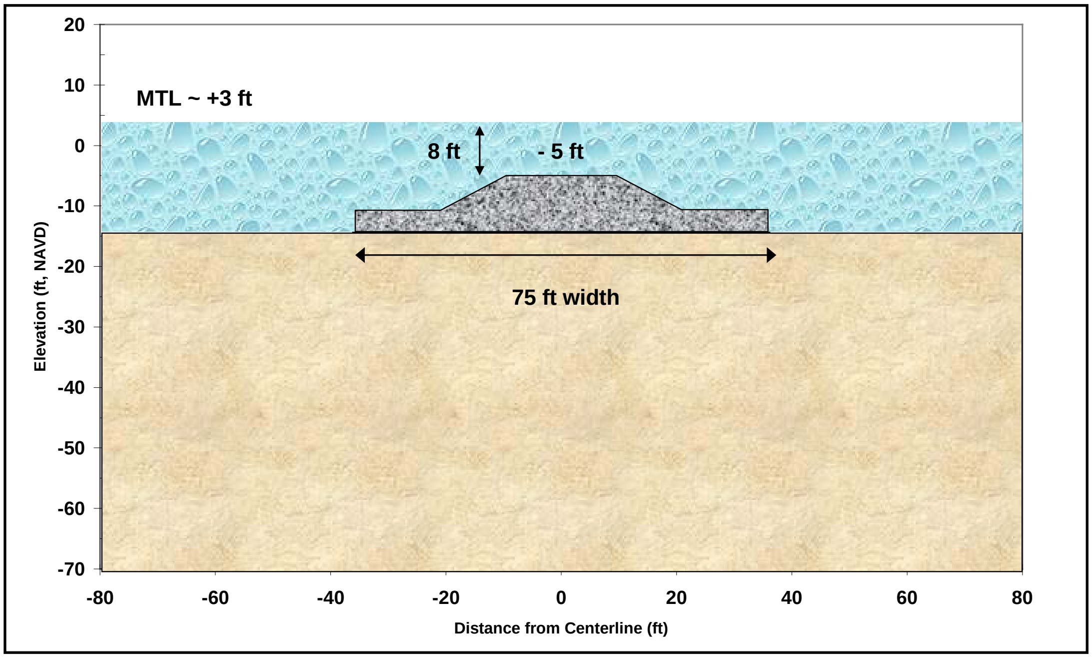
Three submergent spur groins were planned for the channel side (NJ1C, NJ2C, and NJ4C) and one emergent spur groin on the ocean side (NJ3O) of the North Jetty to stabilize the foundation (Figures 17 to 20). The approximate dimensions and other features of the spur groins are shown in Table 19.

Table 19. North Jetty Spur Groin Features (No Longer Proposed)

Spur Groin Features	North Jetty
Number of spurs on channel side	3
Number of spurs on ocean side	1
Approximate total rock volume per spur (± 20%)	NJ1C: 3,350 tons (~2,094 cy) NJ2C: 11,090 tons (~6,931 cy) NJ3O: 2,010 tons (~1,256 cy) NJ4C: 29,250 tons (~18,281 cy)
Approximate total rock volume (all spurs) (± 20%)	53,000 tons (~33,125 cy)
Approximate area affected by each spur	NJ1C: 0.18 acres NJ2C: 0.45 acres NJ3O: 0.11 acres NJ4C: 0.80 acres
Approximate total area affected (all spurs)	1.55 acres
Approximate area of spurs above MLLW	NJ1C: 0% NJ2C: 0% NJ3O: 24% NJ4C: 0%
Approximate area of spurs below -20 MLLW	NJ1C: 0% NJ2C: 88% NJ3O: 0% NJ4C: 100%
Approximate dimension of spurs: length x width x height (feet)	NJ1C: 100 x 80 x 10 NJ2C: 170 x 115 x 19 NJ3O: 60 x 80 x 10 NJ4C: 170 x 115 x 19

Figure 17. North Jetty Spur Groin NJ1C (No Longer Proposed)

Note difference in scale between vertical and horizontal axes.



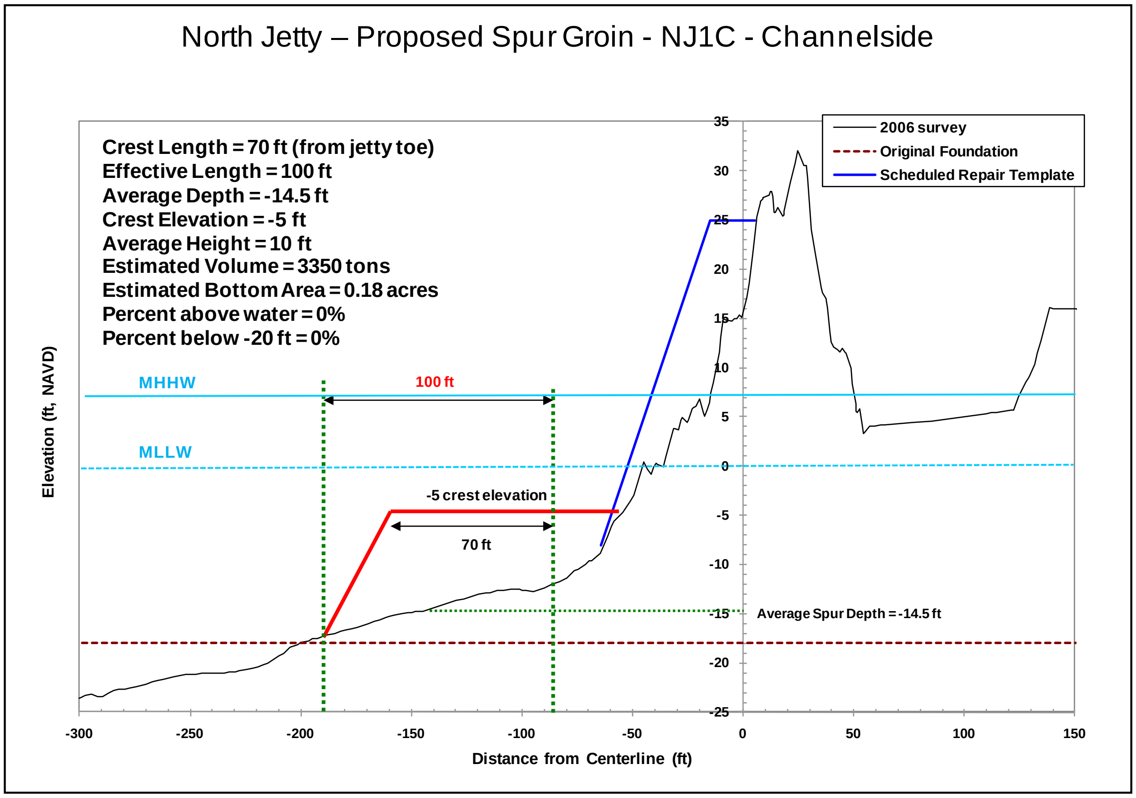
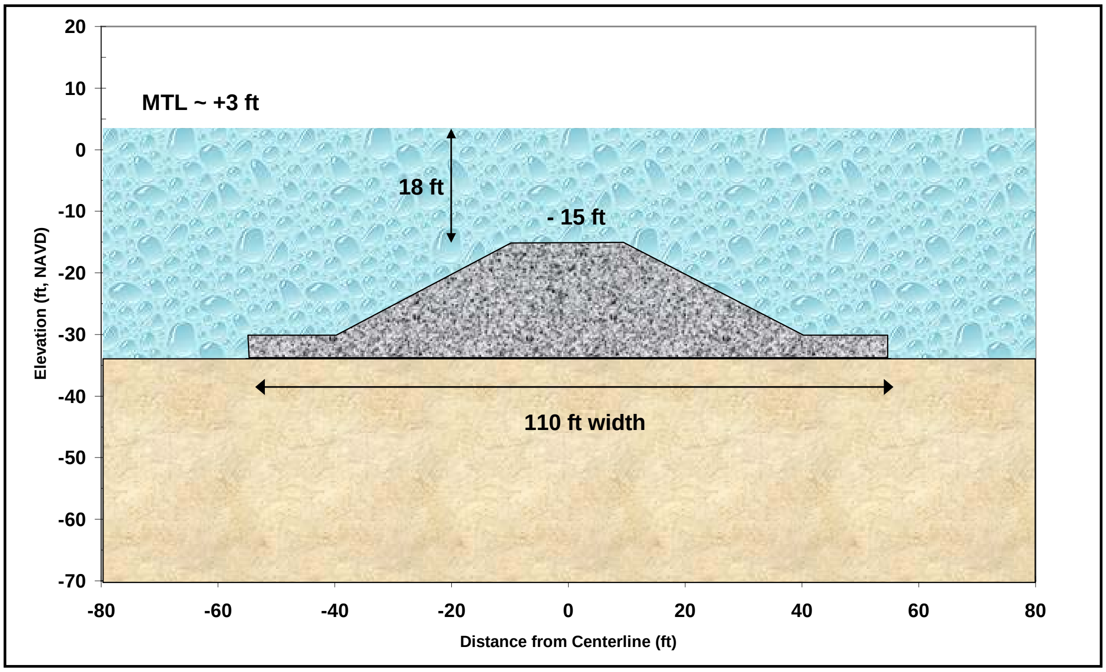


Figure 18. North Jetty Spur Groin NJ2C (No Longer Proposed)

Note difference in scale between vertical and horizontal axes.



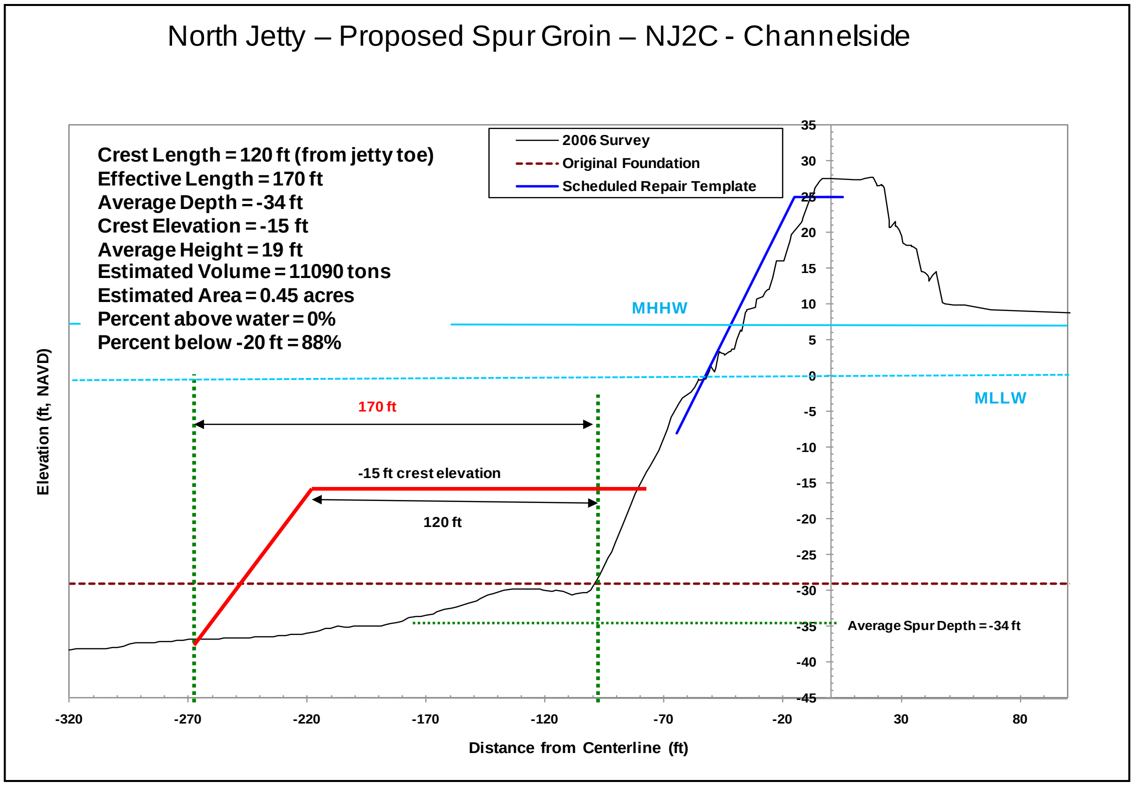
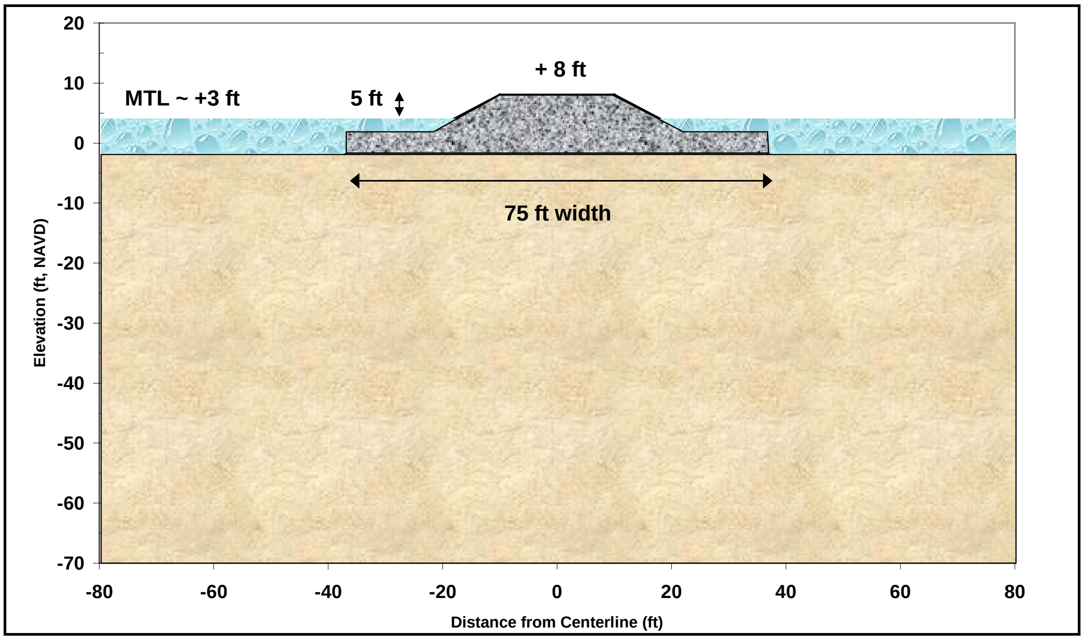


Figure 19. North Jetty Spur Groin NJ3O (No Longer Proposed)

Note difference in scale between vertical and horizontal axes.



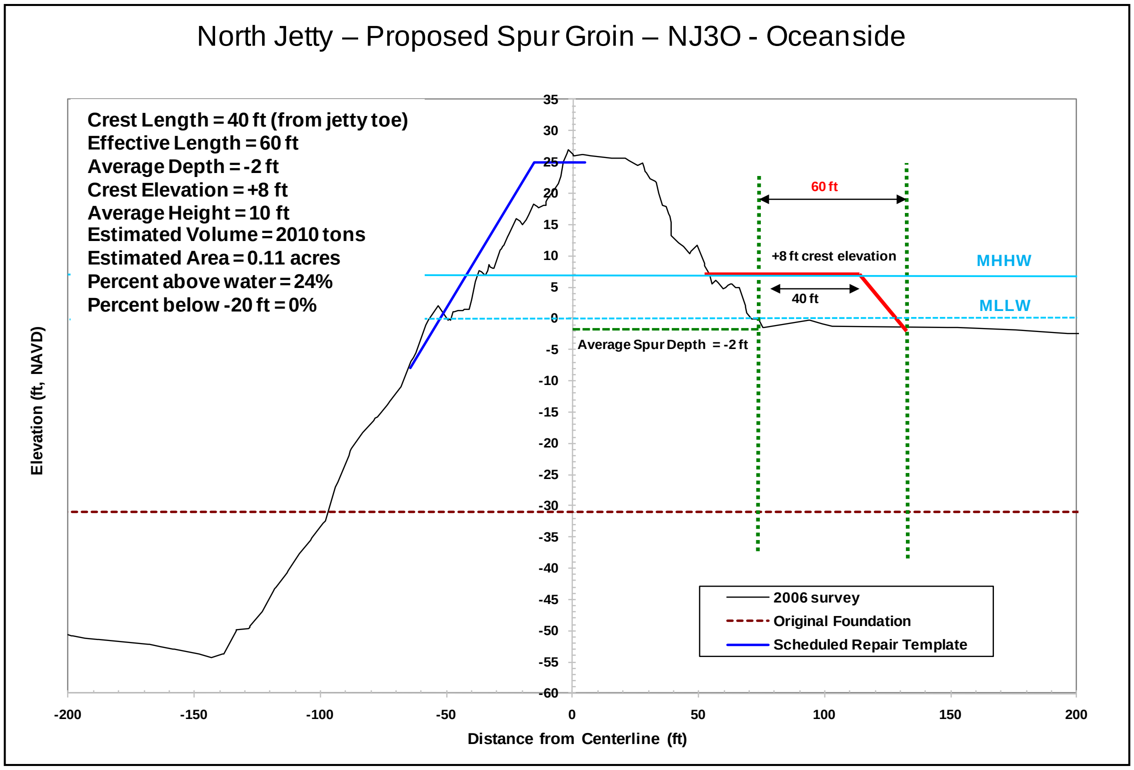
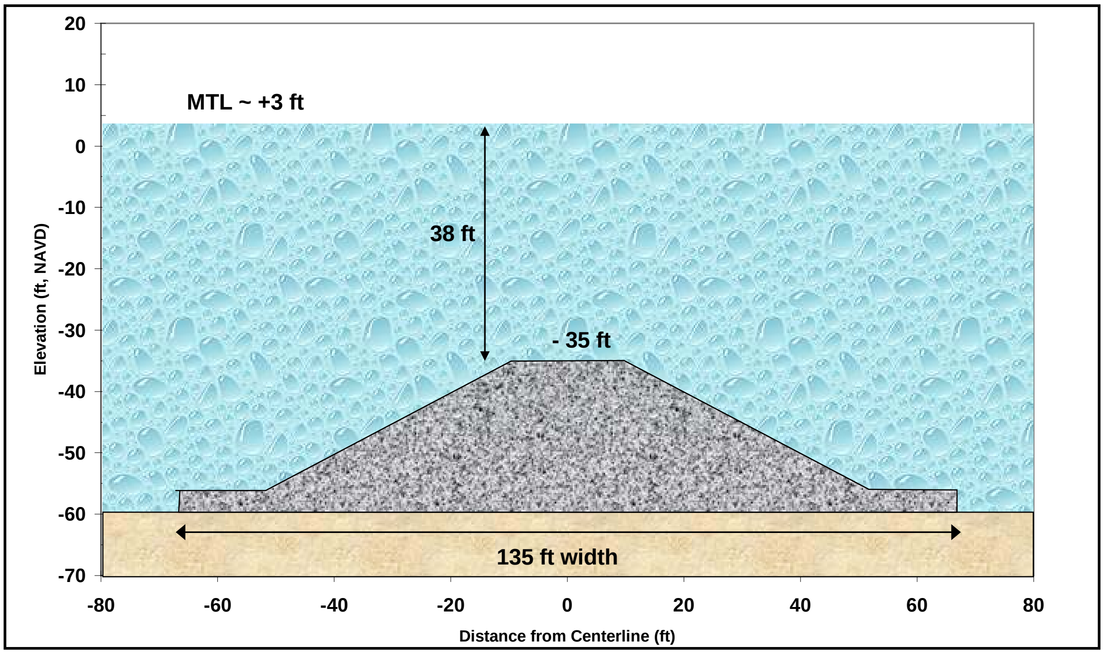
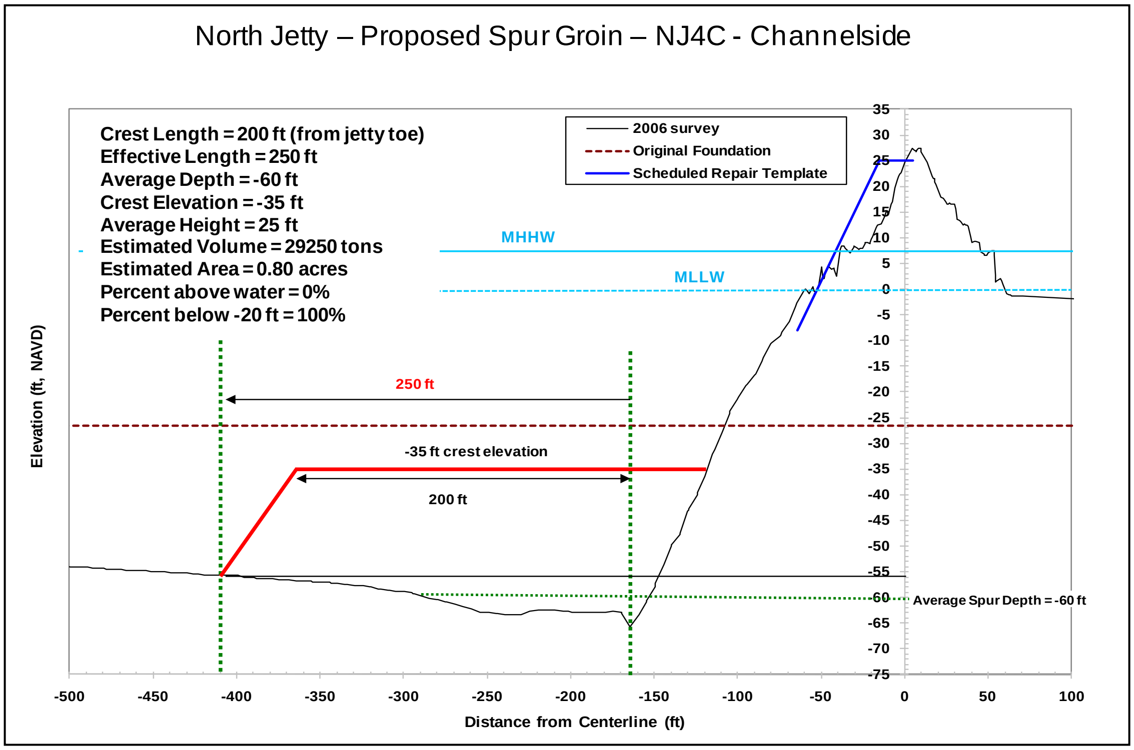


Figure 20. North Jetty Spur Groin NJ4C (No Longer Proposed)

Note difference in scale between vertical and horizontal axes.





Previously, if possible in order to avoid and minimize impacts to aquatic species and habitats, either one of the spur groins located around stations 50 or 70 was planned to serve a dual purpose as an offloading facility for stone delivery. An offloading facility is still anticipated in this vicinity and proposed construction would occur at one of these locations at the contractor's discretion depending on channel current and wave conditions along the jetty trunk. Otherwise, a separate offloading facility would be constructed in the vicinity between these stations to take advantage of calmer waters. Barge offloading structures and dredge activities are discussed in more detail later in this assessment.

For all spurs previously considered on the North Jetty, when placement was divided into elevation zones, about 25 cy of rock would be placed above MHHW. This represented 0.1% of the overall stone placement on these portions of the North Jetty spur groins and there was very little or no existing jetty stone expected to be present within this elevation range. About 1,146 cy of rock would be placed between MHHW and MLLW. This represented 4% of the overall stone placement on these portions of the North Jetty spur groins and there was very little or no existing jetty stone expected to be present within this elevation range. About 27,760 cy of rock would be placed below MLLW. This represented 95.9% of the overall stone placement on these portions of the North Jetty spur groins and there was very little or no existing jetty stone expected to be present within this elevation range. The footprint of the North Jetty spurs would have increased from 0 to 1.55 acres. In the relevant figures, note that the difference in the vertical and horizontal scales causes a slight representational distortion along the axes. However, as noted before, spur groins are no longer included in the Preferred Alternative and therefore avoid the minimal effects previously evaluated.

5.2.3. North Jetty Head Capping (Now Reduced to Stabilization Measure)

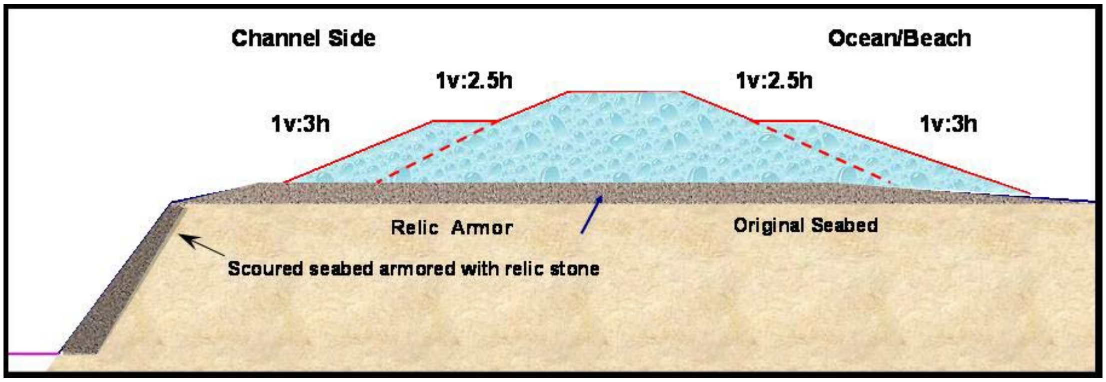
As mentioned earlier, head stabilization would occur, but at a reduced scale relative to the footprint and effects of head capping previously evaluated in earlier versions of the EA. An armor stone cap or concrete armor units were originally considered and proposed for placement on the head of the North Jetty to stop its deterioration (Table 20 and Figure 21). Approximately 38,000 tons (~23,750 cy) of stone or concrete armor units would have been placed on the relic stone to cap the jetty head. Future physical modeling will refine head stabilization features.

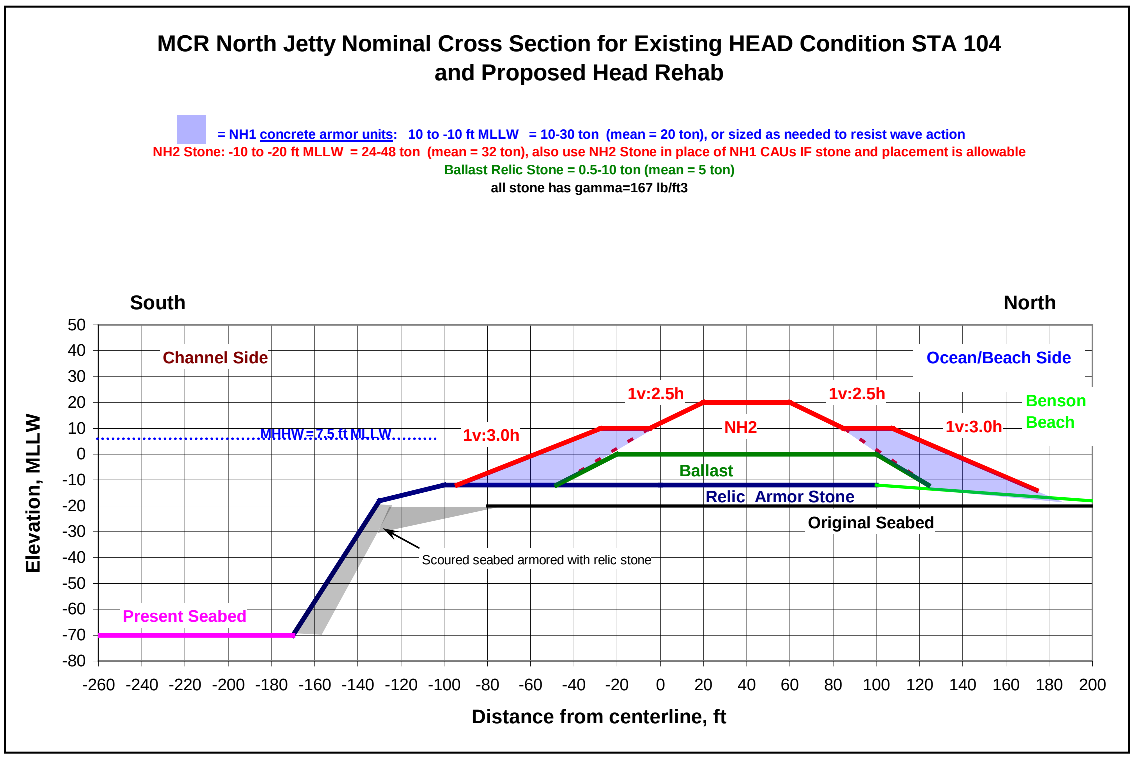
Table 20. North Jetty Head Cap Features (No Longer Proposed; Stabilization Feature Proposed at a Smaller Volume)

Head Cap Features	North Jetty
Location of cap	stations 99 to 101
Timing of construction	2015
Approximate dimensions of cap: length x width x height (feet)	350 x 270 x 45 (2.17 acres)
Stone size	30 to 50 tons
Area affected (outside relic stone)	None
% of cap constructed on relic stone	100%
Construction method	Cranes set on the jetty

For previously proposed head capping, when placement was divided into elevation zones, about 13,425 cy of stone would be placed above MHHW. This represented 49% of the overall stone placement on this portion of the jetty, and there was very little or no existing mounded jetty stone expected to be present within this elevation range. About 6,490 cy of stone would be placed between MHHW and MLLW. This represented 24% of the overall stone placement on this portion of the North Jetty, and there was very little or no existing jetty stone expected to be present within this elevation range. About 7,280 cy of stone would be placed below MLLW. This represented 27% of the overall stone placement on this portion of the North Jetty head, and a 2684% change from the existing jetty prism on this portion, as there was very little or no existing mounded jetty stone expected to be present within this elevation range.

Figure 21. North Jetty Head Cap (No Longer Proposed; Replaced by Smaller Stabilization Feature)





In all zones, previously proposed stone placement would occur on existing base relic stone that formed the original jetty cross-section and was displaced and flattened by wave action, and did not include any modification that changed the character or increased the scope, or size of the original structure design. The terminus of the head was simply closer to shore on a shorter jetty structure. The footprint of the existing jetty mound on the flattened relic stone is approximately 1.37 acres, and the additional capping on the relic stone would have increased the width of the prism approximately 0.80 acres, for a total footprint of 2.17 acres, all of which would remain on the existing relic stone.

5.2.4. North Jetty Lagoon Fill and Culvert Replacement

Approximately 109,000 tons (~68,125 cy) of gravel and sand would be added to the jetty's beach side as lagoon fill to eliminate the tidal flow through the jetty that is destabilizing the foundation. A recent berm repair action now precludes lagoon inundation by tidal nearshore waters. Scouring has taken place on the north side of the North Jetty resulting in formation of a backwater area (lagoon) that was previously inundated both by tidal waters that come through the jetty and by freshwater that drains from the O'Neil Lake-McKenzie Head lagoon and wetland complex area through the accreted land to the north of the jetty and North Jetty Road. This area drains through a culvert under the road and provides some of the freshwater flow to the lagoon. The surrounding lagoon resembles a scoured-out tidal channel and is a non-vegetated (and non-wetland) area of bare sand comprising approximately 8.02 acres. These wetlands and waters would be filled to protect and stabilize the foundation of the North Jetty and to serve as a location for rock stockpiles and construction staging activities. The features of this work are shown in Table 21.

Table 21. North Jetty Lagoon and Wetland Fill Features

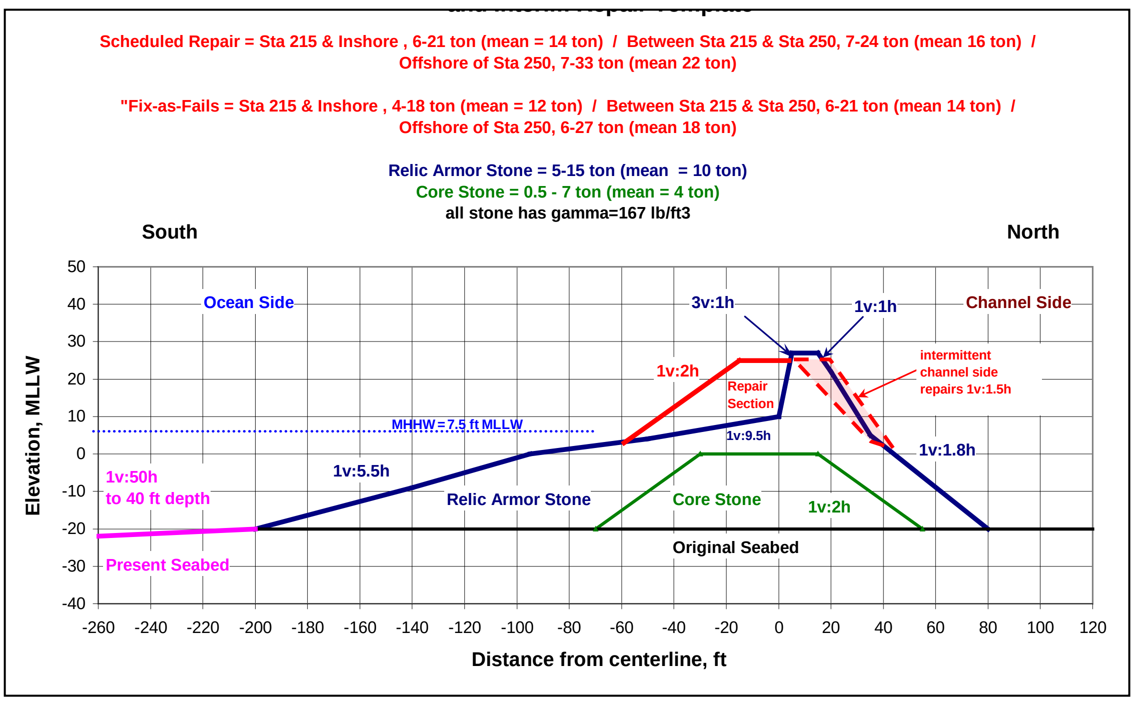
Features	North Jetty
Timing of construction	2014
Material used for fill	Sand, gravel, quarry stone
Short-term and long-term use	Stockpile area, long-term stabilization of root
De-watering	Culvert feeding into area will be replaced
Impact on wetlands	1.14 acres
Impact on Section 404 waters	8.02 acres

The aging culvert draining south from the wetland complex north of the roadway would be replaced, as it provides required drainage under the roadway. The design of the inlet, elevation, and culvert size would be determined so that hydrologic function in the adjacent wetland system is not negatively impacted. The outlet channel downstream of the culvert would not be filled. This area may provide an opportunity for minor stream and bank enhancement which will be evaluated when the culvert design is finalized, but this is uncertain until possible benefits can be further assessed. Under the proposed action, the existing channel would outlet to an engineered sump area comprised of newly placed lagoon fill material. In addition to infiltration through the jetty structure, this small portion of the creek currently connects the wetland to the lagoon and likely also receives some backwater flow from jetty infiltration. The current culvert is perched and the regularly disconnected nature of the lagoon system does not appear to support anadromous fish use. Fish surveys were not completed for the stream inlet leading into this wetland complex and creek. An initial sampling survey would be conducted during peak juvenile salmon outmigration to determine whether or not fish salvage and fish exclusion efforts for ESA-listed species is warranted. The Corps would coordinate with NMFS if listed species are identified. Redesign of this system may provide an opportunity to accommodate improved hydrology to newly created wetlands excavated adjacent to the existing wetland complex, and would be further investigated during the hydraulic/hydrologic design analysis.

5.3. Actions for the South Jetty

The current proposed action for the South Jetty has been revised and includes maintenance of the Base Conditions via interim repairs without stabilization of the jetty head. Previous modeling had indicated a need for scheduled repairs addressing mostly above-MLLW structural instability, five spur groins, head capping, and stopping the erosion near the jetty root (Figure 22). However, refinements in the model now indicate that a resilient jetty system can be maintained to Corps standards without the addition of the features evaluated in earlier analyses. As with the North Jetty, a more aggressive monitoring and inspection approach would be implemented to confirm assumptions. In the event that monitoring indicates an unacceptable level of degradation, spur groins or other engineering features may be reconsidered for installation and would be re-evaulated accordingly regarding potential environmental effects. Under the revised proposed action four interim repair actions over the next 8 years are anticipated at the South Jetty.

Figure 22. South Jetty Cross Section for Existing Condition (and Scheduled Repair, Which is No Longer Proposed)

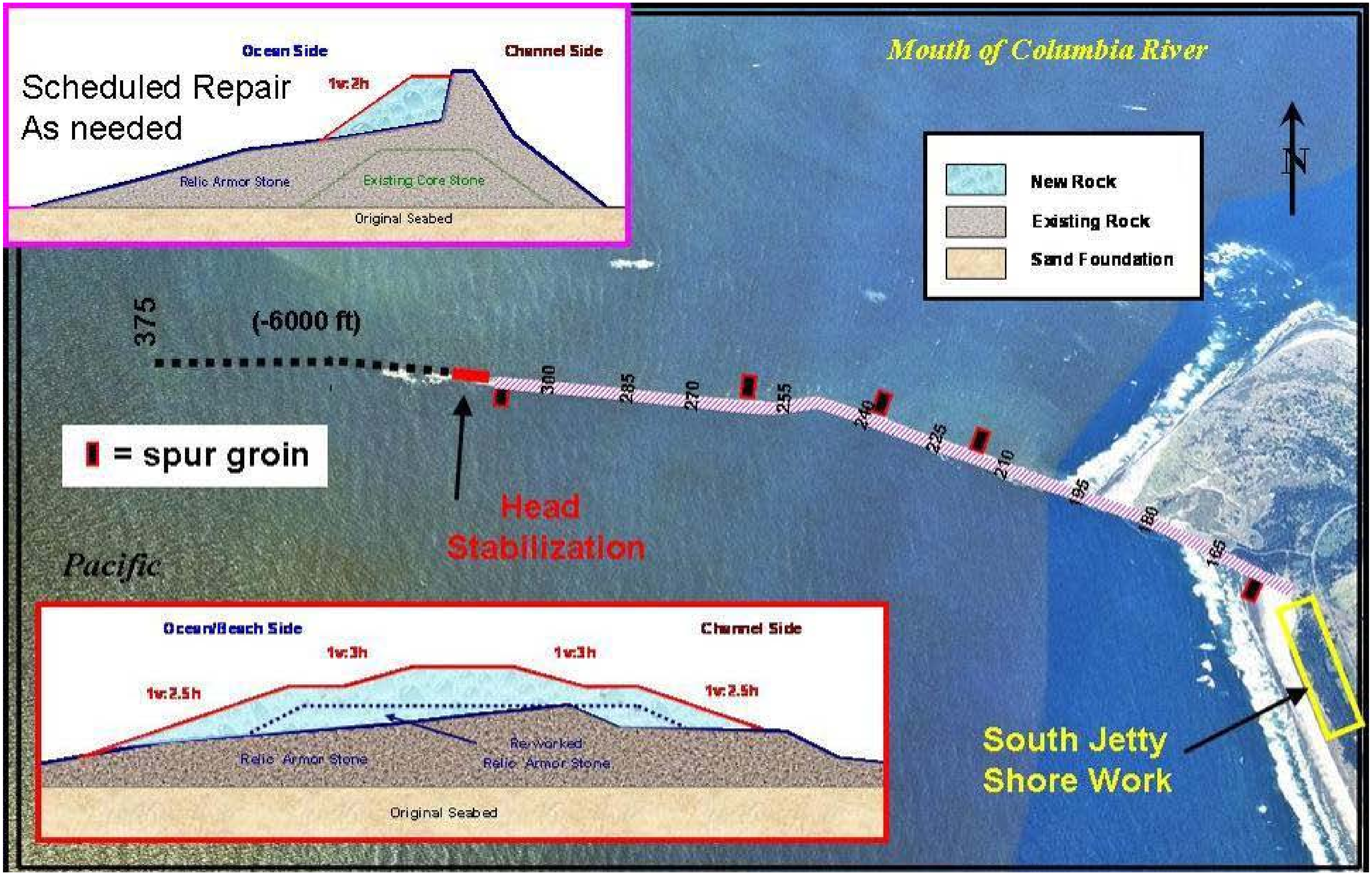


5.3.1. <u>South Jetty Trunk and Root (Preferred Alternative is Now Base Condition)</u>

Under the base condition scenario, the cross-section design from stations 167+00 to 258+00 would have a crest width of approximately 30 feet and would lie essentially within the existing jetty footprint based on the configuration of the original cross section, previous repair cross sections, and redistribution of jetty rock by wave action (Figure 22 & 23). The majority of the stone placement would be conducted above the MLLW. Each repair action is expected to cover a length up to 2,300feet and include stone volumes in the range of 50,261 to 130,353 tons per season (31,329 to 81,471 cy).

Similar to the North Jetty repair action, it was expected that 60% to 70% of the South Jetty's overall standard jetty template cross section had been displaced. Therefore, each repair event would increase the existing degraded cross section from 30% to 40% and back to 100% of the desired standard cross-section template. Overall, this meant that the added rock would essentially triple what existed immediately prior to the time of repair. This could be described as a ~300% increase in rock relative to the existing jetty rock volume. However, this would not result in an increase the jetty prism or footprint beyond the scope and size of the historic structure, and did not include any modification that changes the character, scope, or size of the original structure design.

Figure 23. Proposed Action for the South Jetty Without Spur Groins or Head Cap and With Interim Repair Maintenance Strategy Base Condition



Previously proposed scheduled repairs would have proceeded as described. However, repairs now would occur on an interim basis as described in the Base Condition. Prior, per scheduled repair event, when divided into elevation zones, about 37,640 cy of rock would be placed above MHHW. This represented 68% of the overall stone placement on these portions of the South Jetty and a 1023% change from the existing jetty prism, as very little stone currently remains in the zone and a larger amount of stone must be placed compared to what presently remains. As described above, this same concept applied characterizations about the rest of the zones. About 10,420 cy of rock would be placed between MHHW and MLLW. This represented 19% of the overall stone placement on these portions of the South Jetty and a 225% change from the existing jetty prism. About 6,940 cy of rock would be placed below MLLW. This represented 13% of the overall stone placement on these portions of the South Jetty and a 150% change from the existing jetty cross section. However, in all zones, all proposed stone placement would occur on existing base relic stone that formed the original jetty cross section. The footprint of the trunk and root of the South Jetty would remain within its current jetty dimensions and on relic stone.

5.3.2. South Jetty Spur Groins (No Longer Proposed)

Originally, modeling indicated spur groins were necessary to ensure jetty base stabilization. Subsequent model refinements have indicated spur groins are not required for maintenance of a resilient jetty system within the Corps standards and operations and maintenance forecasts. The following discussion is retained in order to provide information and disclosure of the previous context in which these structures were evaluated for their effects. Monitoring efforts will be implemented to confirm this assumption.

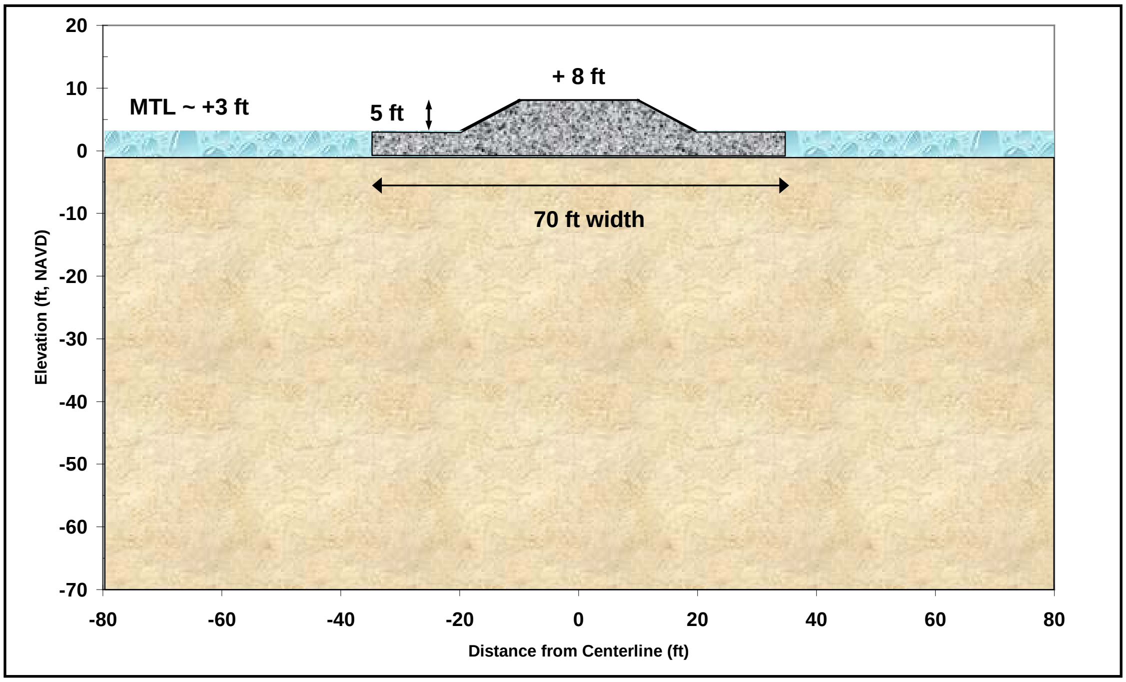
Three emergent and two submergent spur groins were proposed to stabilize the jetty's foundation (Figures 24 to 28). The dimensions and other features of the spur groins are shown in Table 22.

Table 22. South Jetty Spur Groin Features (No Longer Proposed)

Spur Groin Feature	South Jetty
Number of spurs on channel side or downstream	3
Number of spurs on ocean side or upstream	2
Approximate total rock volume per spur (± 20%)	SJ1O: 1,680 tons (~1,050 cy) SJ2C: 2,350 tons (~1,469 cy) SJ3C: 2,350 tons (~1,469 cy) SJ4C: 3,180 tons (~1,988 cy) SJ5O: 18,750 tons (~11,719 cy)
Approximate total rock volume (all spurs) (± 20%)	25,000 tons (~15,625 cy)
Approximate area affected by each spur	SJ1O: 0.11 acres SJ2C: 0.13 acres SJ3C: 0.13 acres SJ4C: 0.19 acres SJ5O: 0.55 acres
Approximate total area affected (all spurs)	1.10 acres
Approximate area of spurs above water	SJ1O: 29% SJ2C: 7% SJ3C: 7% SJ4C: 0% SJ5O: 0%
Approximate area of spurs below -20 MLLW	SJ1O: 0% SJ2C: 0% SJ3C: 0% SJ4C: 0% SJ5O: 92%
Approximate dimension of spurs: length x width x height (feet)	SJ1O: 60 x 80 x 9 SJ2C: 70 x 80 x 10 SJ3C: 70 x 80 x 10 SJ4C: 90 x 90 x 12 SJ5O: 190 x 125 x 22

Figure 24. South Jetty Spur Groin SJ1O (No Longer Proposed)

Note difference in scale between vertical and horizontal axes.



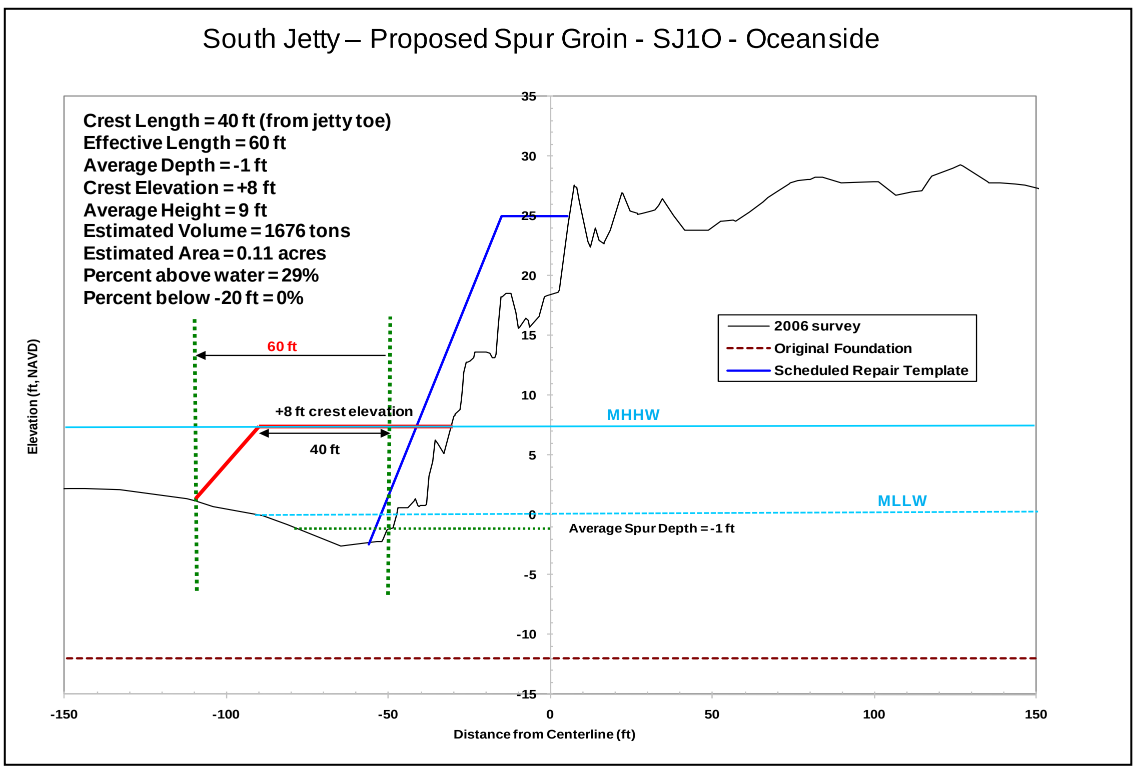
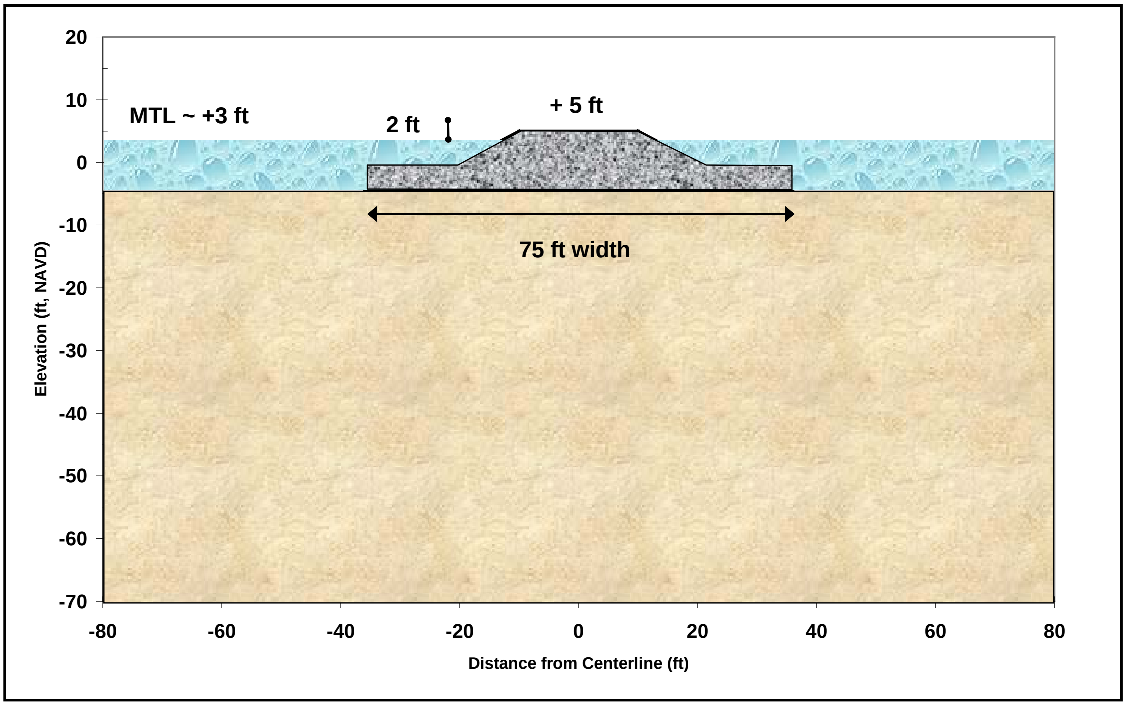


Figure 25. South Jetty Spur Groin SJ2C (No Longer Proposed)

Note difference in scale between vertical and horizontal axes.



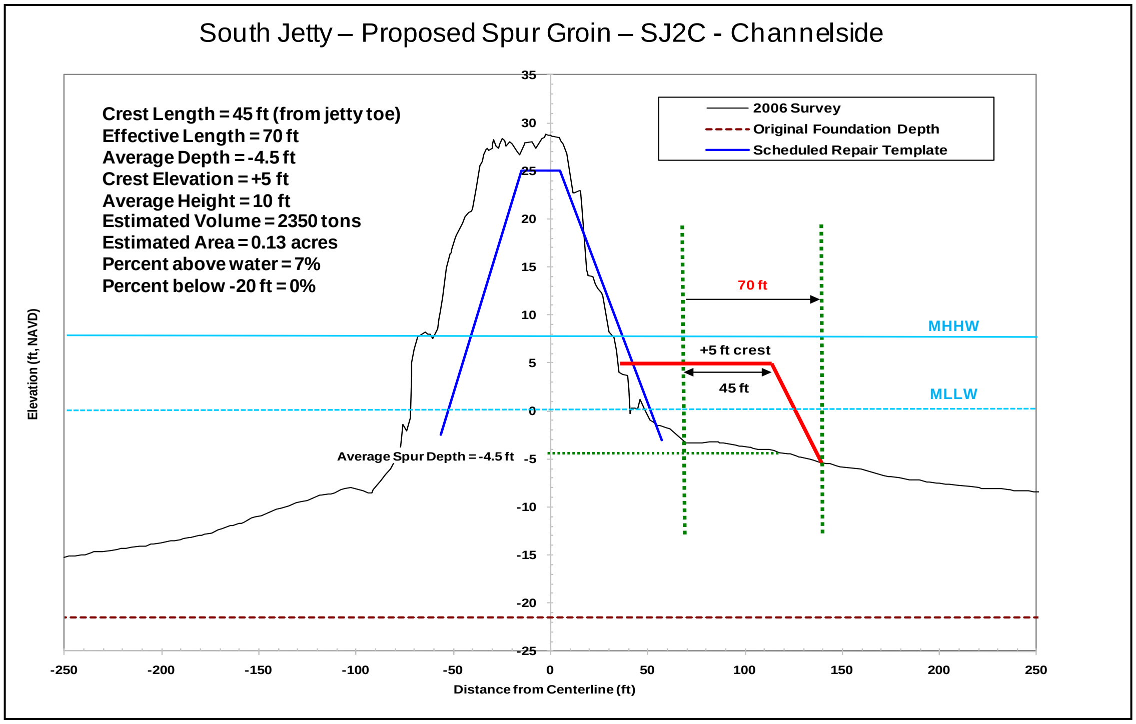
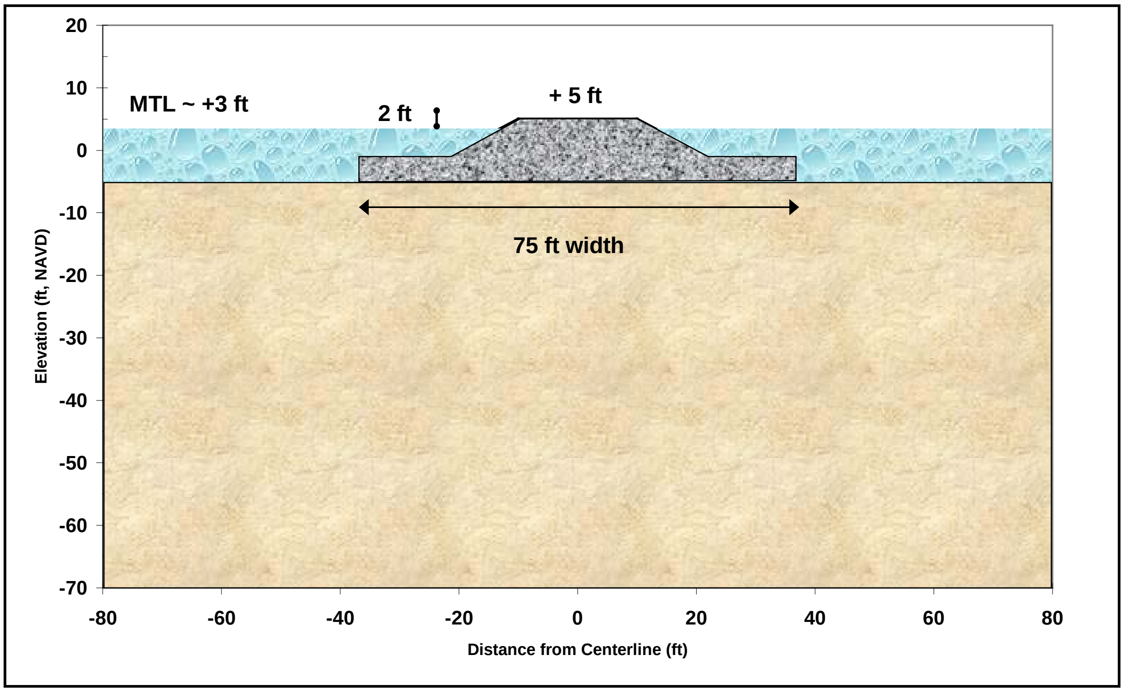


Figure 26. South Jetty Spur Groin SJ3C (No Longer Proposed)

Note difference in scale between vertical and horizontal axes.



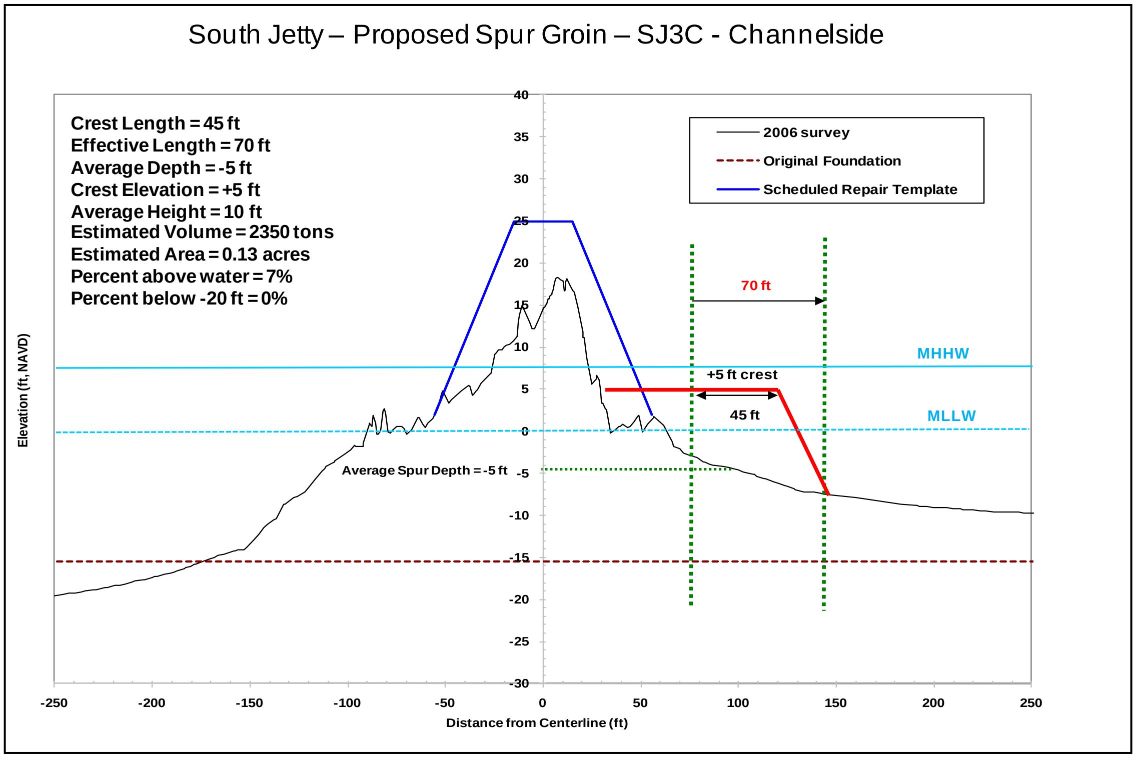
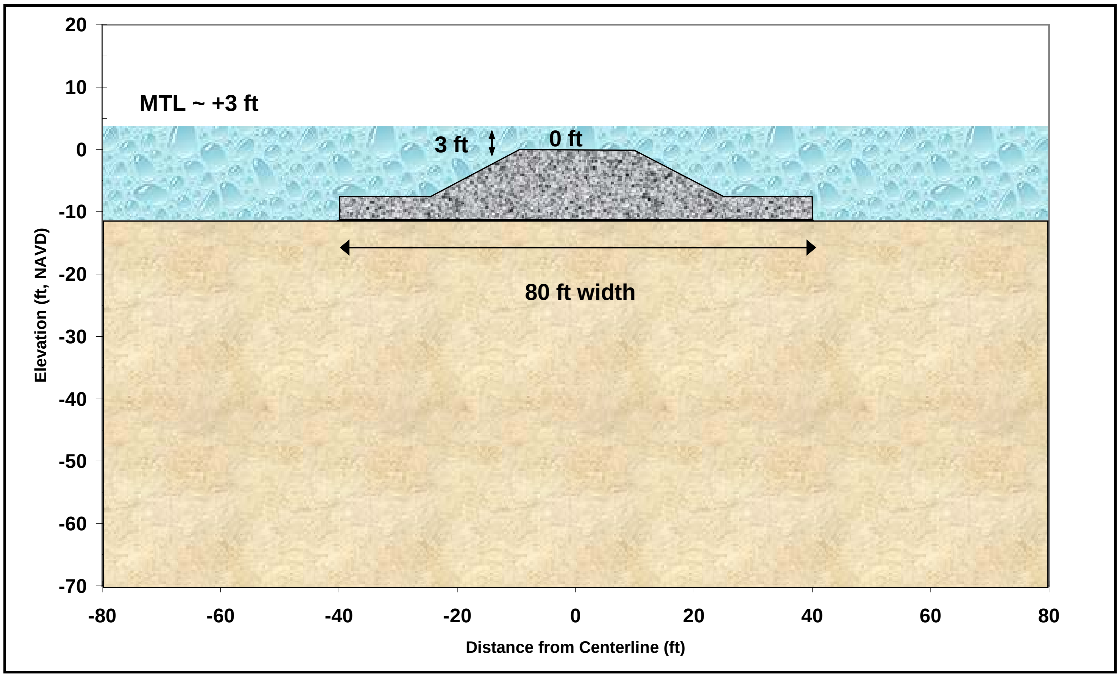


Figure 27. South Jetty Spur Groin SJ4C (No Longer Proposed)

Note difference in scale between vertical and horizontal axes.



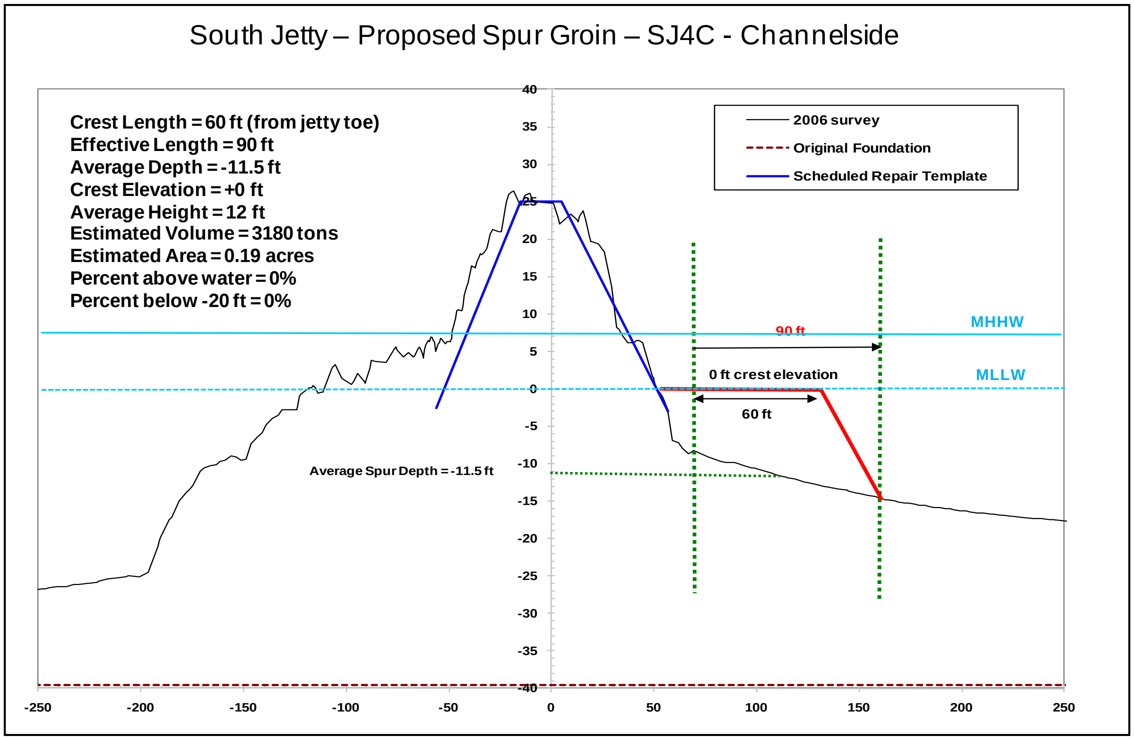
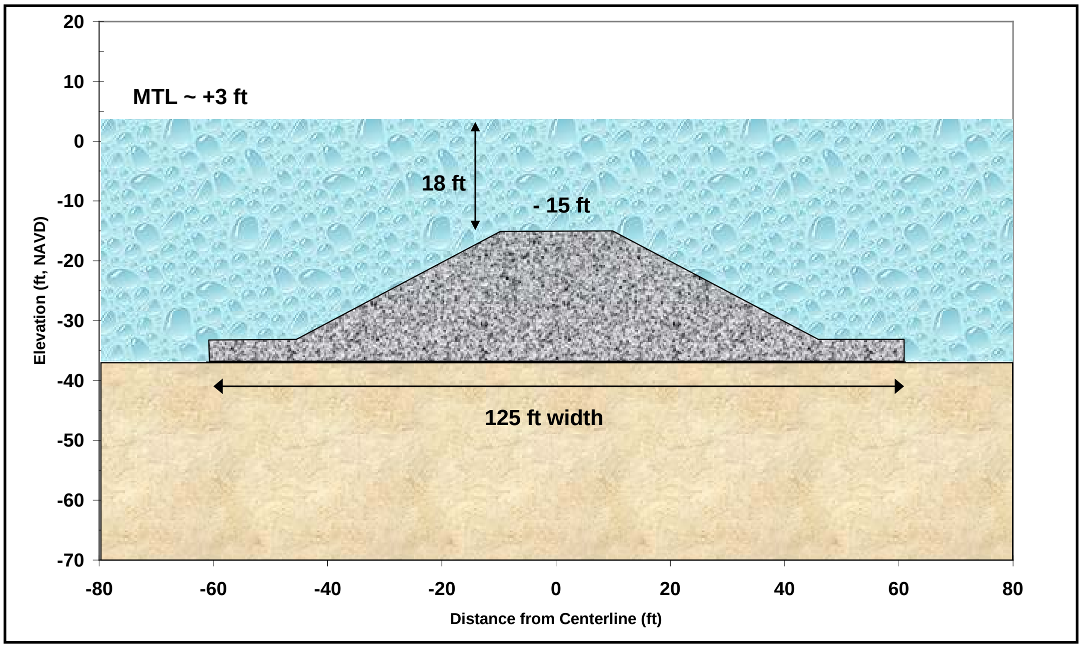
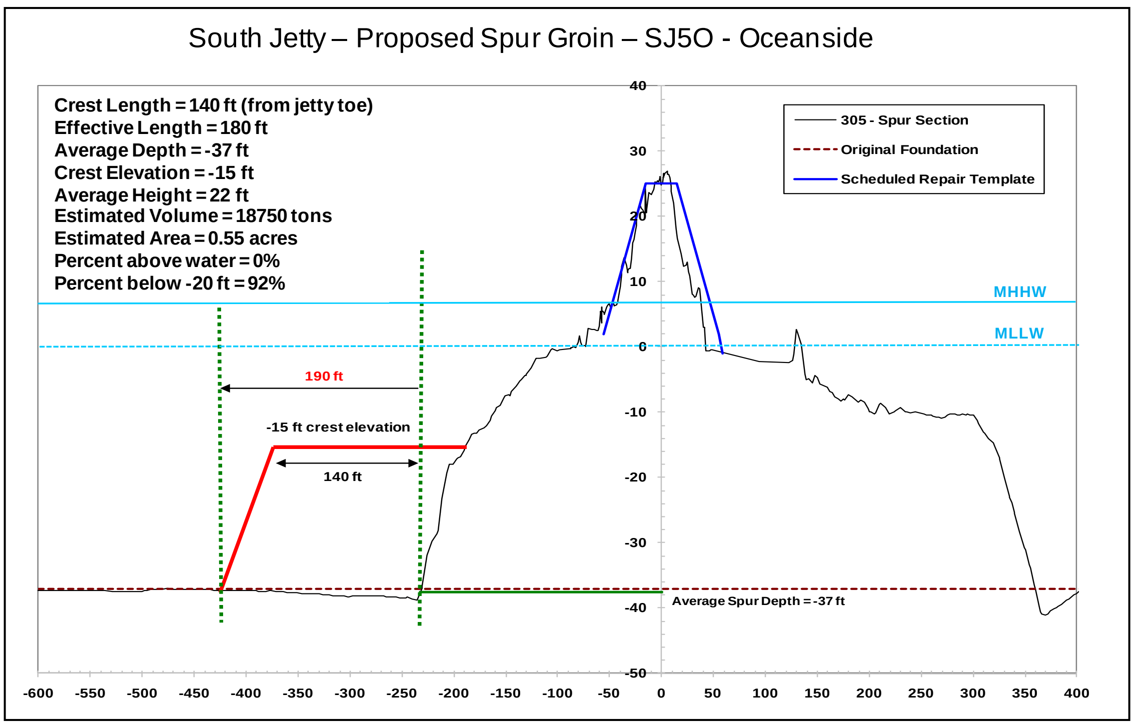


Figure 28. South Jetty Spur Groin SJ5O (No Longer Proposed)

Note difference in scale between vertical and horizontal axes.





For all previously proposed spurs on the South Jetty, when placement was divided into elevation zones, about 21 cy of rock would be placed above MHHW. This represented 0.1% of the overall stone placement on these portions of the South Jetty, and there was very little or no existing jetty stone expected to be present within this elevation range. About 2,190 cy of rock would be placed between MHHW and MLLW. This represented 12.3% of the overall stone placement on these portions of the South Jetty, and there was very little or no existing jetty stone expected to be present within this elevation range. About 15,700 cy of rock would be placed below MLLW. This represented 87.6% of the overall stone placement on these portions of the South Jetty, and there was very little or no existing jetty stone expected to be present within this elevation range. The footprint of the spurs on the South Jetty would have increased from 0 to 1.10 acres. In the relevant figures, note that the difference in the vertical and horizontal scales causes a slight representational distortion.

5.3.3. South Jetty Head Capping (Reduced to a Stabilization Measure)

As mentioned earlier, head capping is no longer considered necessary to achieve a resilient South Jetty, though stabilization measures are proposed. The terminus is likely to remain at or landward of the current station at approximately 311-313. The following discussion is retained for context relative to the information and effects evaluated in earlier versions of the EA. Originally, an armor stone cap with approximately 40,000 to 74,000 tons (~25,000 to 46,250 cy) of stone or concrete armor units was proposed to be placed on the head of the South Jetty to stop its deterioration (Figure 29). The features of this work are shown in Table 23.

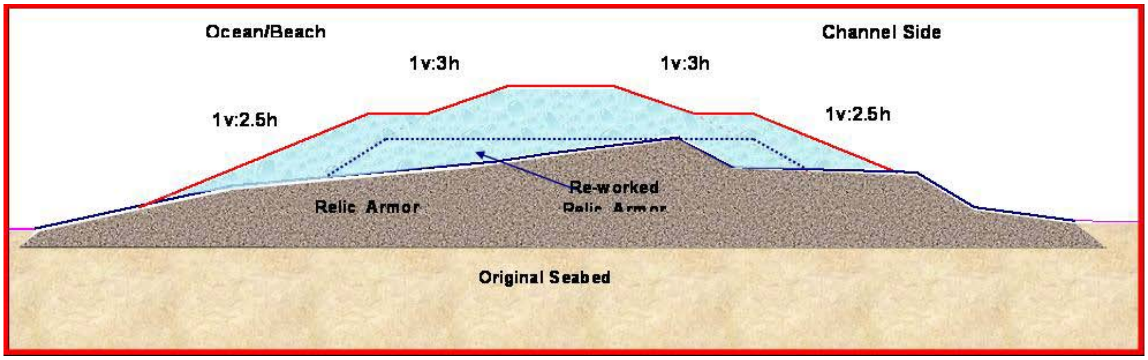
Table 23. South Jetty Head Capping Features (No Longer Proposed)

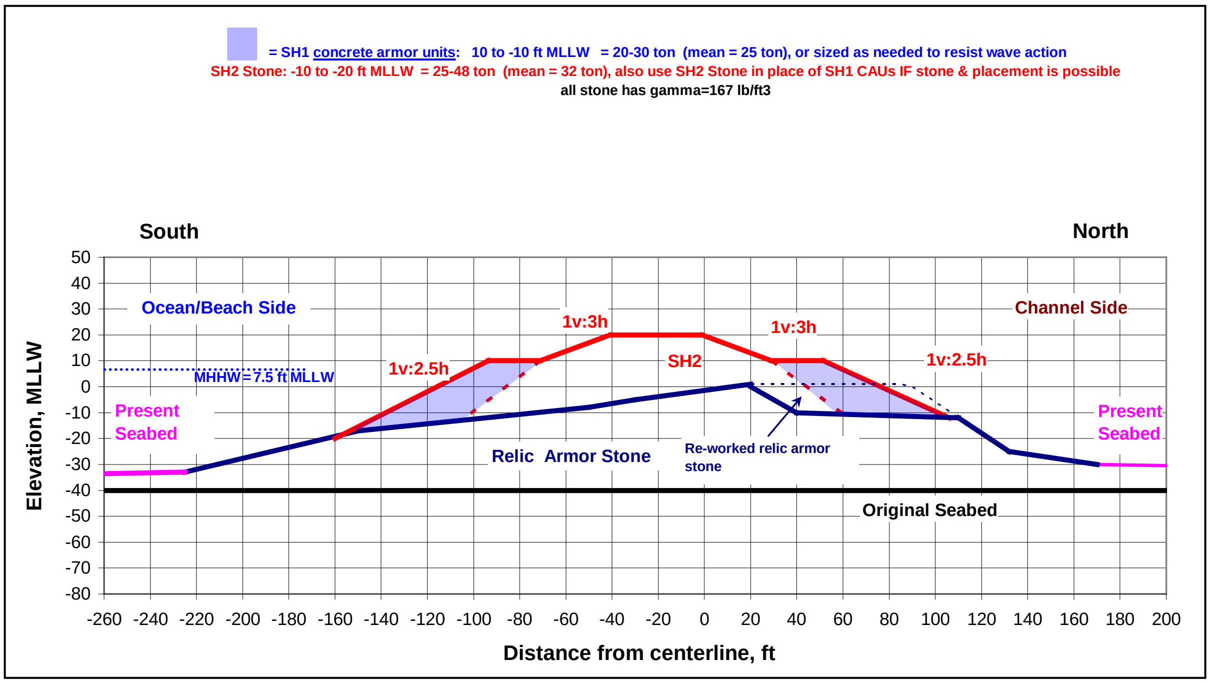
Capping Feature	South Jetty
Location of cap	stations 311 to 313
Timing of construction	2019-2020
Dimensions of cap: length x width x height (ft.)	350 x 290 x 45 (2.33 acres)
Stone size	30 to 50 tons
Area affected (outside relic stone)	None
% of cap constructed on relic stone	100%
Construction method	Land-based cranes or jack-up barge

For head capping, when placement was divided into elevation zones, about 13,425 cy of stone would be placed above MHHW. This represented 52% of the overall stone placement on this portion of the South Jetty and there was very little or no existing jetty stone expected to be present within this elevation range. About 6,490 cy of stone would be placed between MHHW and MLLW. This represented 25% of the overall stone placement on this portion of the South Jetty and there was very little or no existing jetty stone expected to be present within this elevation range. About 6,050 cy of stone would be placed below MLLW. This represented 23% of the overall stone placement on this portion of the South Jetty and 1150% change from the existing base condition as there is very little or no existing mounded jetty stone expected to be present within this elevation range.

In all zones, all proposed stone placement would have occurred on existing base relic stone that formed the original jetty cross section and was displaced and flattened by wave action, and did not include any modification that changed the character or increased the scope or size of the original structure design. The terminus of the head was simply closer to shore on a shorter jetty structure. The footprint of the existing jetty mound on the flattened relic stone is approximately 1.69 acres, and the additional capping on relic stone would have increased the width of the prism approximately 0.64 acres, for a total footprint of 2.33 acres, all of which will occur on existing relic stone.

Figure 29. South Jetty Head Cap (No Longer Proposed)



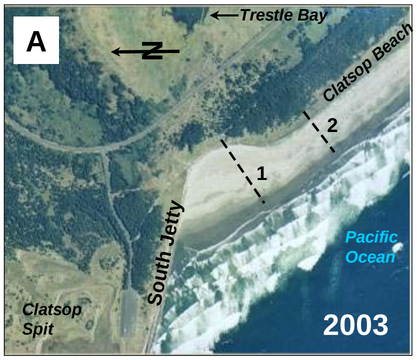


5.3.4. <u>South Jetty Root Erosion and Dune Augmentation</u>

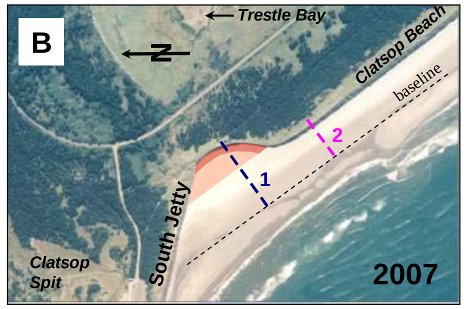
As previously described, the coastal shore interface along the South Jetty is in a condition of advanced deterioration (see Figure 11).

About 40,000 to 70,000 cy of cobble in the shape of angular or rounded graded stone is proposed at the South Jetty root in order to fortify the toe of the foredune and to improve the foreshore fronting to resist wave-induced erosion/recession (Figure 30). Maximum crest width of the template is estimated to extend 70 feet seaward from the seaward base of the present foredune. Construction of the berm augmentation would require 2 to 6 weeks. To adequately protect the foredune during storm conditions, this requires that the top of the stone berm (crest) extend vertically to approximately 25 feet NAVD and have an alongshore application length of approximately 1,100 feet, extending southward from the South Jetty root. This is equivalent to about 3 acres. The constructed template crest would be 10 to 15 feet above the current beach grade and have a 1 vertical to 10 horizontal slope aspects from crest to existing grade. Cobble is not expected to extend below MHHW. A layer of sand may be placed over this berm or natural accretion may facilitate sand recruitment.

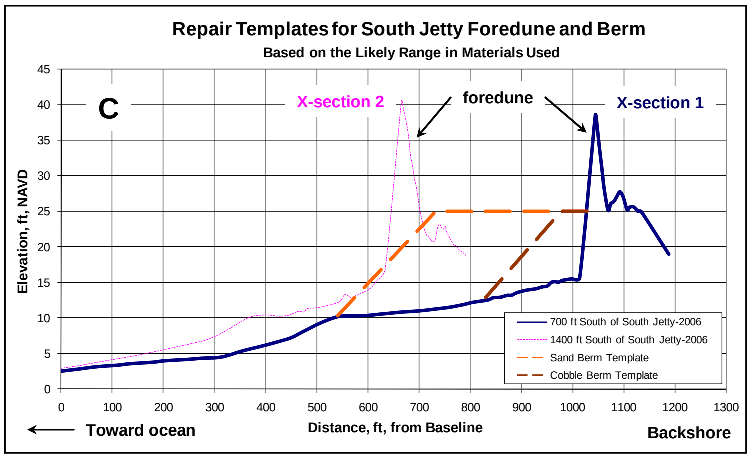
Figure 30. South Jetty Root Shoreline Area



MCR South Jetty root, south side where Clatsop Spit joins with Clatsop Plains/Beach. Panels A and B show the erosion embayment along the south jetty root for 2003 (hIgh tide) and 2007 (low tide). The embayment & adjacent shore have receded 40 ft landward during 2003-2007, reducing the protective foredune along the embayment.



Panel C shows cross-sections 1 and 2 for 2007(shown in panels A & B). Severe erosion in this area had threatened the inlet stability during early 1930s, when jetty rehabilitation and sand augmentation measures were implemented. Erosion has again become chronic since the late 1970s. The foredune protects the backshore (elevation 15-18 ft NAVD) from wave surge action during storms. If the foredune is breached, the backshore will be rapidly eroded. Without erosion abatement, it is estimated that that the Pacific Ocean will establish hydraulic connectivity with Trestle Bay in 10-15 years from 2009, and again threaten inlet stability. Panel C shows two options for protecting the foredune within the erosion embayment: A SAND berm template requires ~225,000 cy of sand placement, and a COBBLE berm template requires ~60,000 cy of cobble placement.



Cobble material would be procured from upland sources and placed using haul trucks and dozers. The material would be transported on existing surface roads and through Fort Stevens State Park to a beach access point at the project site. There is an existing relic access road along the jetty root that would be refurbished and used to transport stone to the dune augmentation area. Though there is an existing razor clam bed adjacent to the vicinity of the proposed dune augmentation, species impacts are not expected because all of the stone placement would occur above MHHW, and haul traffic would be precluded from using Parking Lot B and from driving on the beach during material delivery. Excavator and bulldozer work would be mostly confined to the dry sand areas to further avoid negative species effects.

The dune augmentation may require maintenance every 4 to 10 years (assume 40% replacement volume). Consideration would be given to development of revegetation plans which incorporate native dune grasses to supplement foredune stabilization in the augmentation area. This bioengineering component could help restore vegetated dune habitat and take advantage of natural plant rooting functions that provide greater protection from erosive forces.

5.4. Actions for Jetty A

The proposed action for Jetty A includes scheduled repair and head stabilization at a the level reduced relative to head-capping.

5.4.1. Jetty A Trunk and Root

The cross-section design from stations 48+00 to 84+00 would have a crest width of approximately 40 feet and would lie mostly within the existing jetty footprint based on the configuration of the original cross section, previous repair cross sections, and redistribution of jetty rock by wave action (Figure 31). About 80,375 tons (~50,234 cy) of new rock would be placed on the existing jetty cross section and relic armor stone. Most of the work would occur above MLLW, The proposed action for Jetty A is similar to that shown in Figures 31 and 32 but with a smaller-scaled prism repair.

Figure 31. Jetty A Cross Section for Proposed Action (No Longer Proposed. Cross-section Will Be Similar to that of North Jetty)

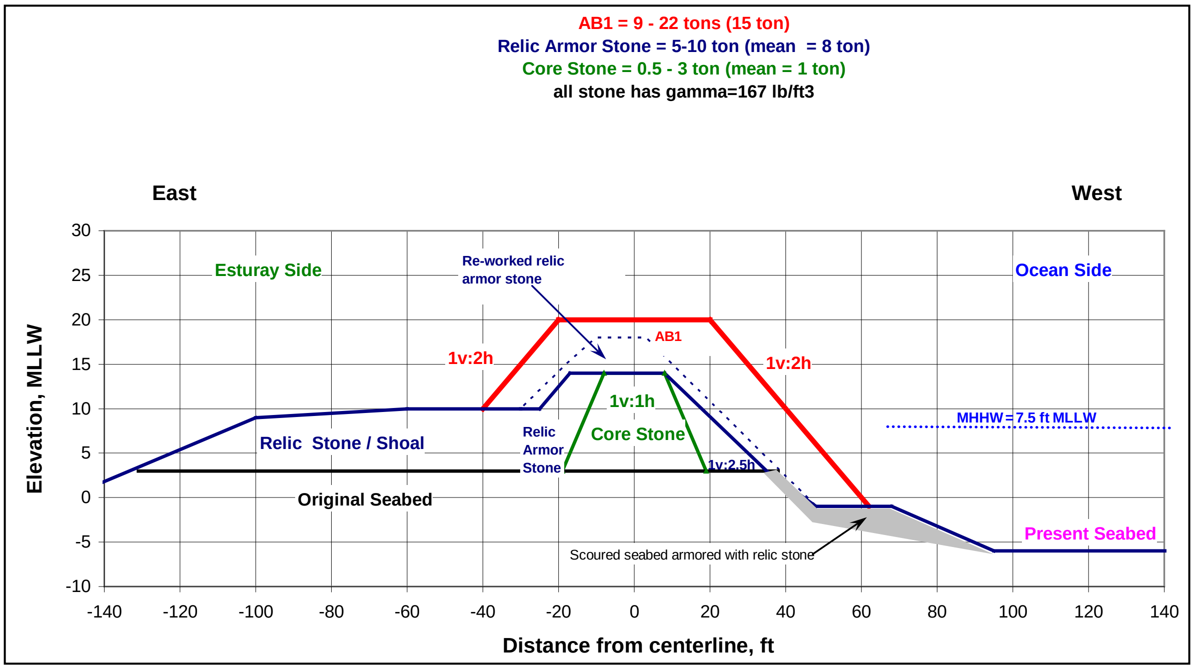
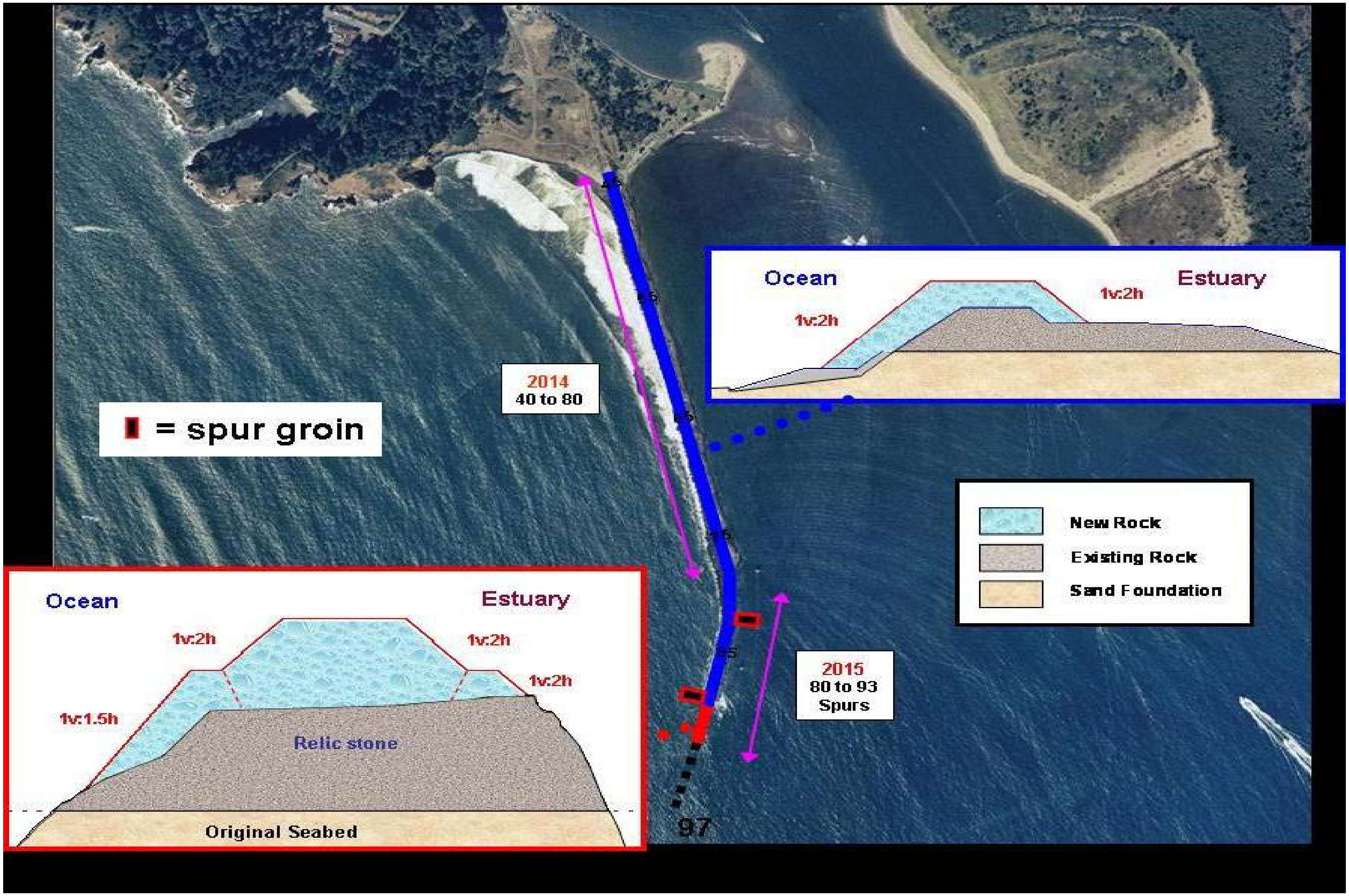


Figure 32. Proposed Action for Jetty A (No Longer Proposed. Scheduled Repair Will Be Similar to that of North Jetty)



The following amounts apply to the previously proposed design option. The new action, which is part of the Preferred Alternative, would have a smaller prism and footprint. Previously, about 63,700 cy of rock would have been placed above MHHW, which represented 63% of the overall stone placement on Jetty A and a 2020% change from the existing jetty prism, as very little stone remains in the zone and a larger amount of stone must be placed. As described for North and South jetties, this same concept applied to characterizations about the rest of the zones. About 28,940 cy of rock would have been placed between MHHW and MLLW, which represented 29% of the overall stone placement on these portions of Jetty A and a 280% change from the jetty prism.

About 8,030 cy of rock would have been placed below MLLW. This represented 8% of the overall rock on these portions of Jetty A and a 233% change from the existing jetty prism. In all zones, most of the stone placement would have occurred on existing base relic stone that formed the original jetty cross-section. However, the footprint of the previously proposed prism could have increase in width as compared to the existing prism by up to 10 feet along the length of the jetty (though it would still be on relic stone). This equaled about 1.2 acres but it was not expected to result in additional habitat conversion because it would have been in a bottom location already comprised of jetty stone, and did not include any modification that changes the character, scope, or size of the original structure design.

5.4.2. Jetty A Spur Groins (No Longer Proposed)

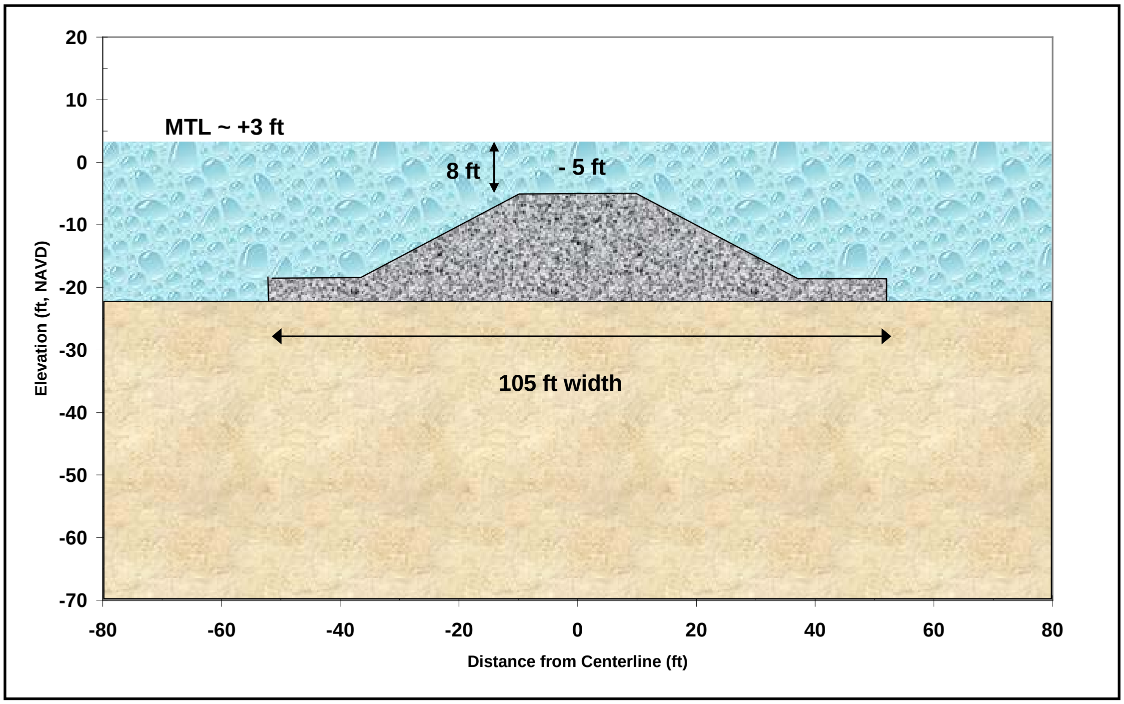
As with previous jetties, spur groins are no longer proposed in the current actions, but the discussions are retained here to provide context regarding what was previously evaluated. Originally, one submergent spur groin would have been placed on the downstream (JA1C) side and one submergent spur would have been placed on upstream (JA2O) side to stabilize the jetty's foundation (Table 24 and Figures 33-34).

Table 24. Jetty A Spur Groin Feature (No Longer Proposed)

Spur Groin Feature	Jetty A
Number of spurs on channel side or downstream for Jetty A	1
Number of spurs on ocean side or upstream for Jetty A	1
Approximate total rock volume per spur (+/- 20%)	JA1C: 9,650 tons (~ 6,031 cy) JA2O: 7,330 tons (~ 4,581 cy)
Approximate total rock volume (all spurs) (+/- 20%)	25,000 tons (~ 15,625 cy)
Approximate area affected by each spur	JA1C: 0.33 acres; JA2O: 0.29 acres
Approximate total area affected (all spurs)	0.61 acres
Approximate area of spurs above water	JA1C: 0%; JA2O: 0%
Approximate area of spurs below -20 MLLW	JA1C: 1%; JA2O: 0%
Approximate dimension of spurs: length x width x height (ft)	JA1C: 135 x 105 x 18 JA2O: 125 x 100 x 15

Figure 33. Jetty A Spur Groin JA1C (No Longer Proposed)

Note difference in scale between vertical and horizontal axes.



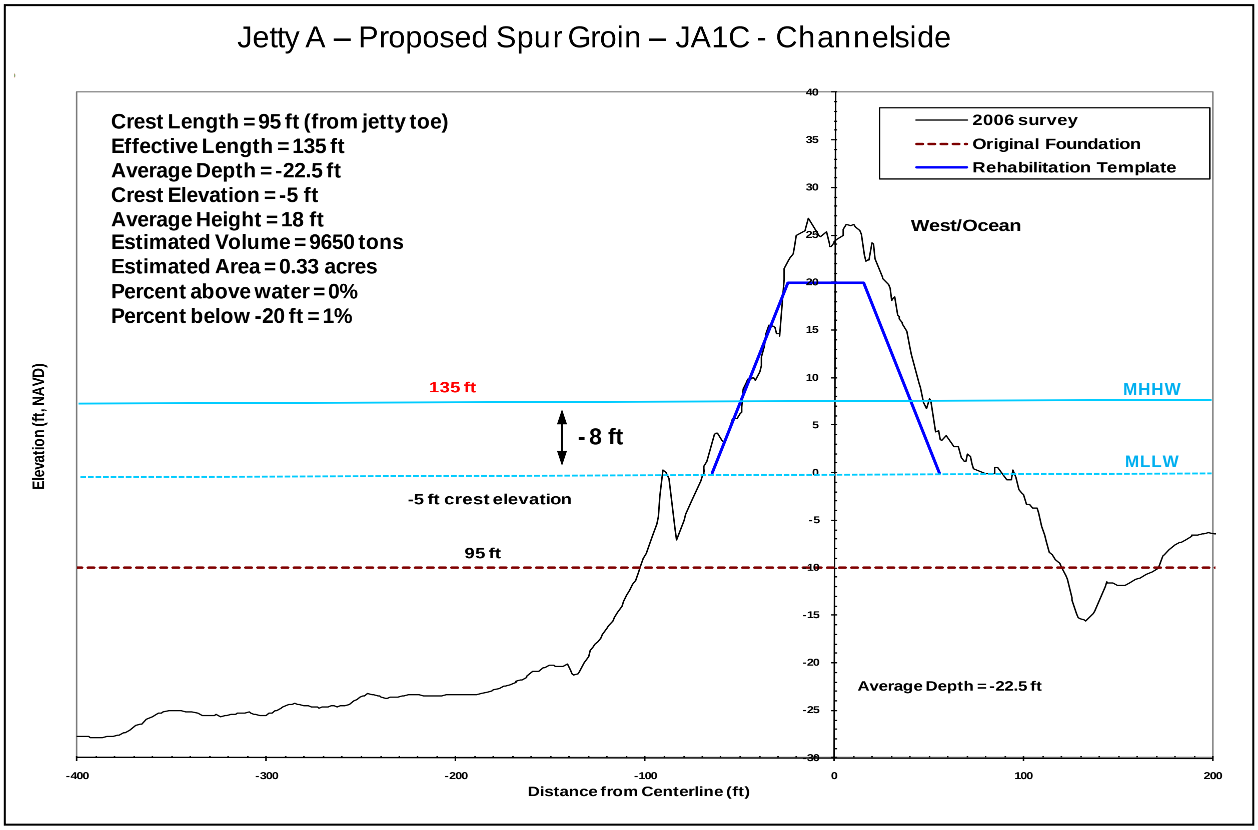
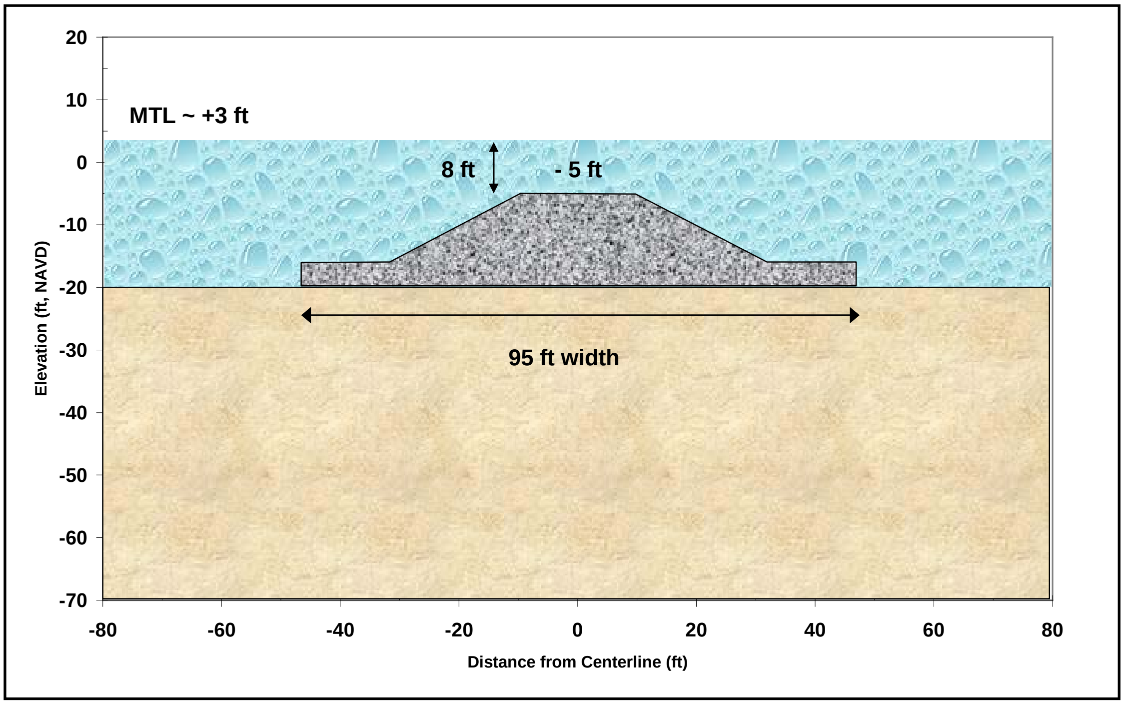
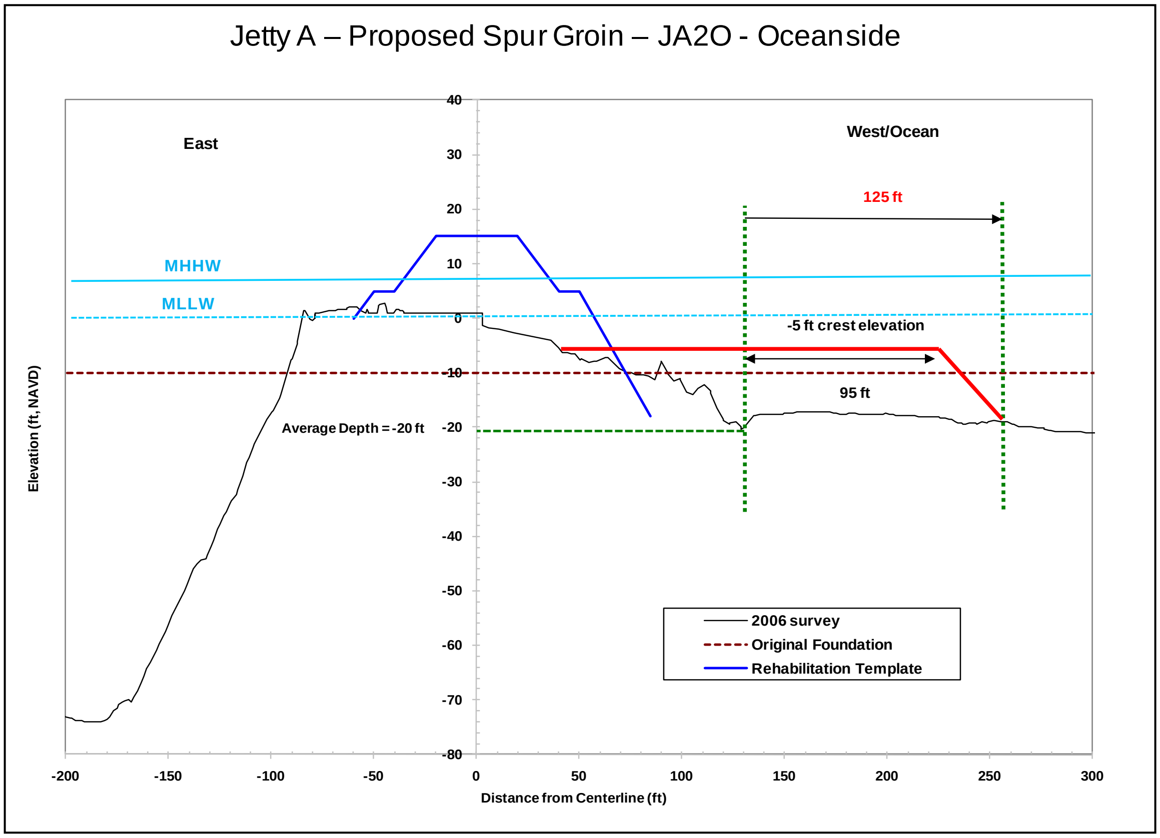


Figure 34. Jetty A Spur Groin JA2O (No Longer Proposed)

Note difference in scale between vertical and horizontal axes.





For all spurs on Jetty A, no stone would have been placed above MLLW, and there is very little to no existing jetty stone expected to be present within either of these elevation ranges. About 10,800 cy of rock would have been placed below MLLW and represented 100% of the overall stone placement on these portions of Jetty A. The footprint of the spurs would have increased from 0 acres to ~ 0.61 acres beyond existing relic stone. In the figures, note that the difference in the vertical and horizontal scales causes a slight representational distortion.

5.4.3. Jetty A Head Capping (Reduced To Stabilization Measures)

As with the other jetties, head-capping is no longer proposed. Instead, a scaled-down version of armoring would occur in order to stabilize the head. This would result in a smaller footprint than previously estimated. Originally, an armor stone cap of approximately 24,000 tons (~ 15,000 cy) or concrete armor units would have been placed on the head of the Jetty A to stop its deterioration (Figure 35). The features of this work are shown in Table 25.

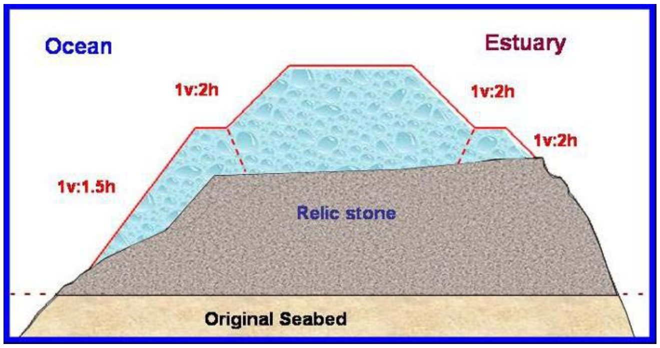
Table 25. Jetty A Head Cap Feature (No Longer Proposed)

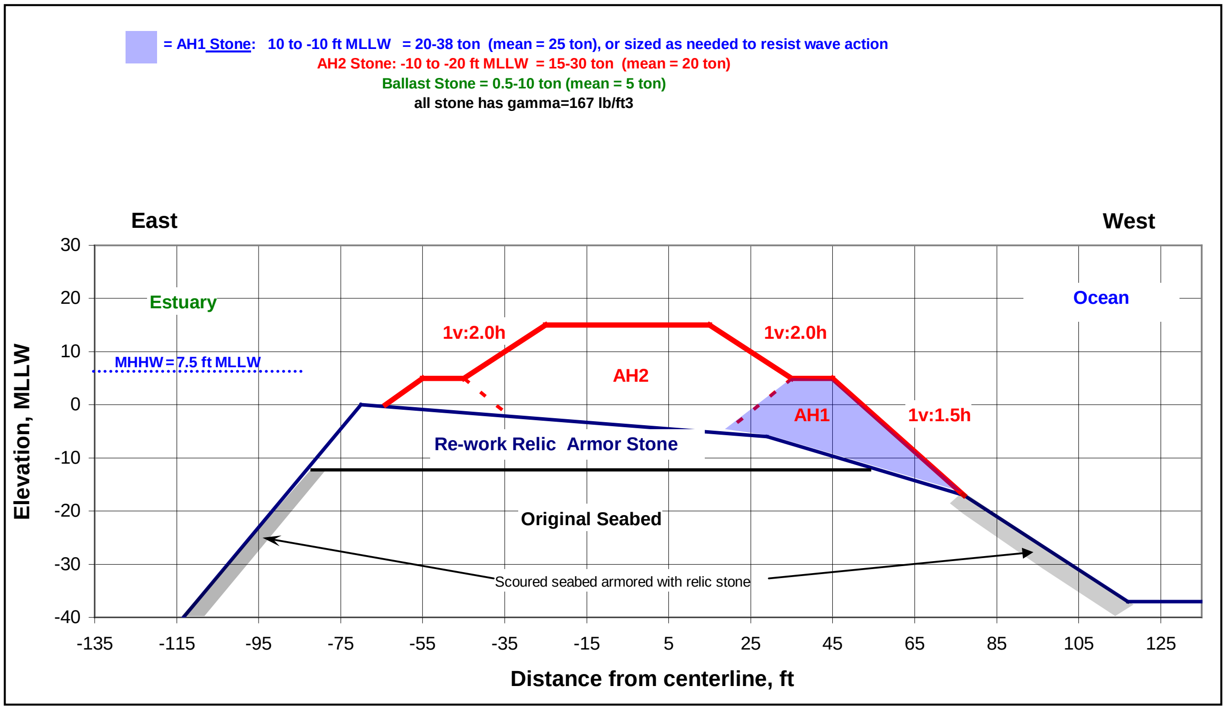
Features	Jetty A
Location of cap	stations 91 to 93
Timing of construction	2015
Dimensions of cap: length x width x height (feet)	200 x 160 x 40 (0.73 acres)
Stone size	30 to 40 tons
Area affected (outside relic stone)	None
% of cap constructed on relic stone	100%
Construction method	Land-based crane

For head capping, when placement was divided into elevation zones, about 7,920 cy of stone would have been placed above MHHW. This represented 44% of the overall stone placement on this portion of Jetty A and there is very little or no existing jetty stone expected to be present within this elevation range. About 4,740 cy of stone would have been placed between MHHW and MLLW. This represented a 26% of the overall stone placement on this portion of Jetty A and there is very little or no existing jetty stone expected to be present within this elevation range. About 5,420 cy of stone would have been placed below MLLW. This represented 30% of the overall stone placement on this portion of Jetty A and a 1783% change from the existing jetty prism, as there is very little or no existing mounded jetty stone expected to be present within this elevation range.

In all zones, all proposed stone placement would have occurred on existing base relic stone that formed the original jetty cross-section and was displaced and flattened by wave action, and did not include any modification that changes the character or increases the scope or size of the original structure design. The terminus of the head was simply closer to shore on a shorter jetty structure. The footprint of the existing jetty mound on the flattened relic stone is approximately 0.64 acres, and the additional capping on the relic stone increased the width of the prism approximately 0.09 acres, for a total footprint of 0.73 acres on the existing relic stone.

Figure 35. Jetty A Head Cap (No Longer Proposed; Replaced With Reduced Stabilization Measure)





5.5. Construction Measures and Implementation Activities

5.5.1. Construction Measures and Timing

The preferred in-water work window for the Columbia River estuary at the mouth is 1 November to 28 February. However, seasonal inclement weather and sea conditions preclude safe, in-water working conditions during this timeframe. Therefore, it is likely that most of in-water work for constructing, head stabilization, cross-section repairs, constructing off-loading facilities, etc. would occur outside this period during calmer seas, mostly between April and October. To avoid impacts to Southern resident killer whales, pile installation would be prohibited until on or after May 1 of each year.

Most landward work on the jetties would be occurring from 1 April to 15 October. Work is assumed to occur 1 June to 15 October on the more exposed sections of the jetties. Placement work may extend beyond these windows if weather and wave conditions are conducive to safe construction and delivery. Stone delivery by land or water could occur year-round, depending on delivery location, method, and weather breaks. Barge delivery would most likely occur during the months of April through October or at other times of the year depending on breaks in the weather and which jetty is being used. Quarrying of the rock may be limited depending on the regulations pertinent to each quarry.

Work elements fall into four general categories for scheduling: (1) rock procurement, quarrying, and delivery transport, (2) construction site preparation, (3) lagoon fill and dune augmentations, and (4) jetty repair and rehabilitation work with construction of the design features including head stabilization. Site preparation would consist of the preparation of the rock stockpile storage and staging areas, as well as the construction of any barge-offloading facilities that may be required. Approximate transport quantities by method are 30 tons per truck and 6,500 tons per barge. The majority of the jetty rehabilitation work is expected to be conducted from the top of the jetty downward using an excavator or a crane. Areas which may require marine plant work include construction at the South Jetty head.

For design and cost-benefit estimates, the project was modeled and designed for a 50-year operational lifespan. The schedule shown in Figure 36 illustrates construction actions related to building engineered features anticipated to occur at any one or some combination of all three of the jetties for the duration of 8 years. It also includes a predicted schedule of repair actions that the Corps' model estimates will be necessary within that same time period. Additional repairs have also been predicted to occur after the initial 8-year construction schedule and within the 50-year lifespan of the project. Additional repairs beyond the 8-year schedule will be similar in scale and nature to those described above in the standard repair template. Repair actions are generally triggered when a cross-section of the jetty falls below about 30% to 50% of the standard repair template profile. The schedule described further in the narrative is a combined reflection of constructing specific engineered features and forecasting needed repairs. Real-time implementation of repair actions will likely vary based on evolving conditions at the jetties and could be shifted within and beyond this 8-year construction schedule.

In the construction schedule, foredune augmentation begins in 2013 subject to funding. The rock production and stockpiling material for the first jetty installation is scheduled for late spring 2014. Base condition – lagoon fill and North Jetty repairs and the rest of construction continues through 2020. The estimate assumes the work would be accomplished with multi-year contracts.

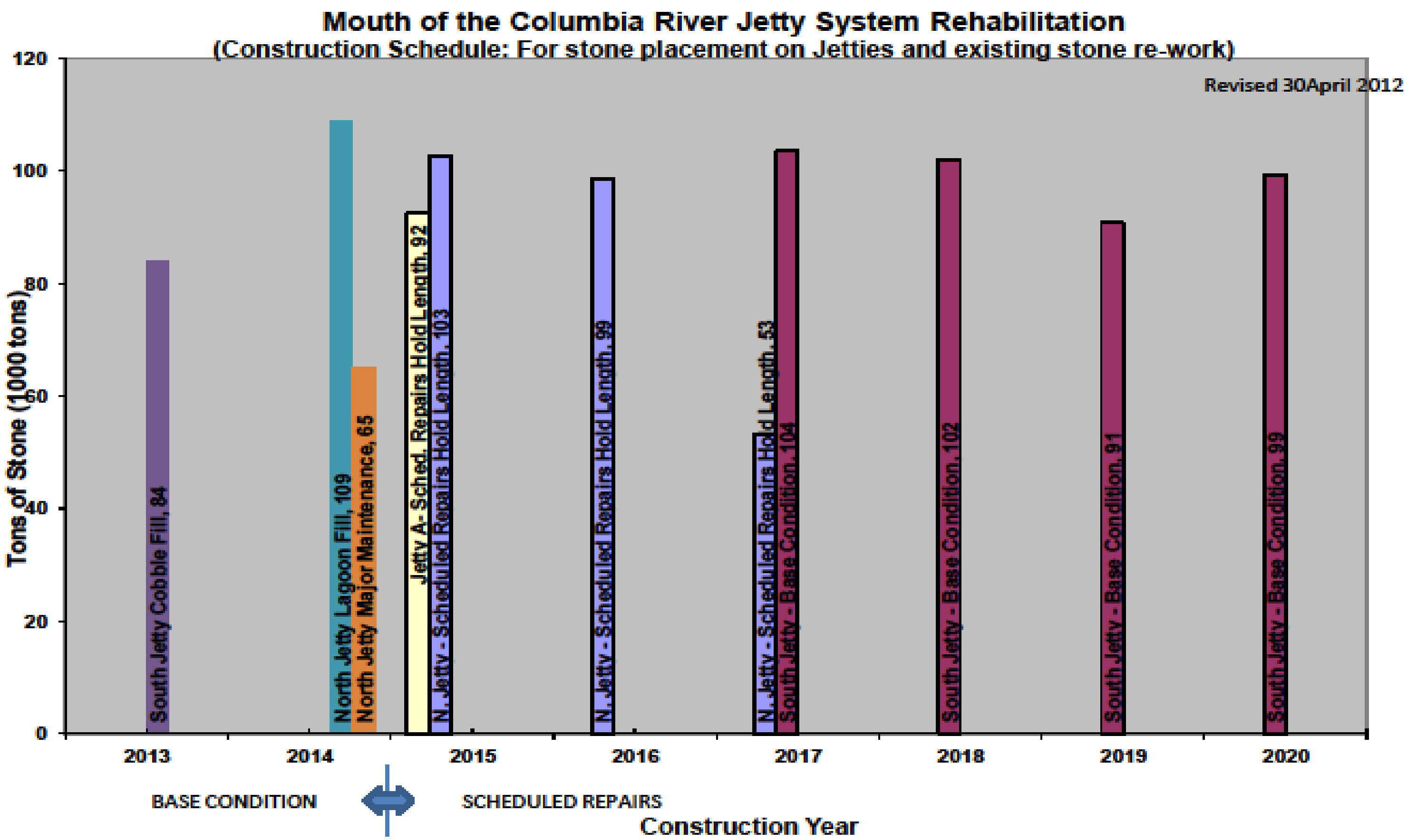
Prior to construction activities, an incidental harassment authorization (IHA) for marine mammals at the South Jetty will be obtained from the NMFS. The Corps anticipates that the new IHA permit would entail requirements similar to those in the previous permit for repair of the South Jetty. These previous requirements included monitoring and reporting the number of sea lions and seals (by species if possible) present on the South Jetty for 1 week before (re)starting work on this jetty. During construction, the Corps provided weekly reports to the NMFS that included a summary of the previous week's numbers of sea lions and seals that may have been disturbed as a result of the jetty repair construction activities. These reports included dates, time, tidal height, maximum number of sea lions and seals on the jetty and any observed disturbances. A description of construction activities at the time of observation was also included. Post-construction monitoring occurred with one count every 4 weeks for 8 weeks to determine recolonization of the South Jetty. The Corps anticipates future monitoring and reporting requirements will be similar and will designate a biologically trained on-site marine mammal observer(s) to carry out this monitoring and reporting. The required reports will be submitted to the NMFS and the AMT. The ODFW, who monitors sea lion use of the South Jetty, will also be apprised of the Corps work and results of the monitoring efforts.

Conservation measures that will be implemented to minimize disturbance to Steller sea lions includes the following: during land-based rock placement, the contractor vehicles and personnel will avoid as much as possible direct approach towards pinnipeds that are hauled out. If it is absolutely necessary for the contractor to make movements towards pinnipeds, the contractor shall approach in a slow and steady manner to reduce the behavioral harassment to the animals as much as possible. Monitoring and reporting will occur as required.

Also, measures 1, 2, and 3 discussed below will be employed during the marbled murrelet nesting season (April 1 to September 15) to reduce impacts from noise to nesting marbled murrelets on the Washington side, and measure 4 will be considered to create western snowy plover nesting habitat:

1. Trucks will only be allowed to use roads through Cape Disappointment State Park during daylight hours.
2. Trucks will not unnecessarily stop along the roads through Cape Disappointment State Park.
3. Trucks will be prohibited from using compression brakes (Jake-brakes) on the roads through Cape Disappointment State Park.
4. The Corps is currently investigating opportunities to create western snowy plover nesting habitat on Clatsop Spit within Fort Stevens State Park. As staging areas could be attractive to plovers, the Corps would consider creation of 10 -20 acres of habitat during or after use of the Spit for rock storage is completed. This habitat would be created with the intent to avoid potential limitations to rock storage and transport on the Spit if plovers begin to nest in construction areas. The options to create plover habitat concurrently with rock storage is preferable if plover use of the created habitats and beaches would not interfere with the Corps' ability to use Clatsop Spit throughout the life of the project. This scenario would instead provide preferable alternative habitat away from the potential attractive nuisance of open sands that the construction disturbance would create. In other words, the Corps would be creating bare sand habitat that would attract birds away from construction site impacts. Habitat maintenance each year after creation would be required to provide functional habitat. The Corps would maintain these sites during construction, but after project completion maintenance would not be the responsibility of the Corps. The Corps has had initial discussions with OPRD regarding plover habitat creation and has signed a Memorandum of Agreement with the OPRD, USFWS, and other agencies regarding management of snowy plovers at Clatsop Spit and on other Corps lands. The Corps would be implementing best management practices (BMPs) that are in alignment with its efforts under the HCP.

Figure 36. Updated Construction Schedule



5.5.2. Construction Sequence and General Schedule

The construction schedule for the MCR jetty system assumes the work would be accomplished with multi-year contracts.

In 2013 South Jetty foredune augmentation would be implemented. This is the earliest possible time this could occur subject to availability of funding.

In 2014, rock procurement activities and critical repairs would be initiated for the North Jetty interim repairs (Stations 86-99). In addition, rock procurement activities for the scheduled repairs would be initiated for the North Jetty in 2014 concurrent with plans and specification development. Quarries utilized are expected to be located in Oregon or Washington, although some rock may be obtained from Canadian quarries.

In 2014, the on-site work would begin with filling the lagoon area behind the North Jetty root (stations 20 to 60) and installing a culvert to divert overland flow to another area that would not impact the North Jetty root stability. The lagoon area would be filled with rock, gravel, and sand. Once the lagoon is filled, it would serve as a staging and stockpile area for the rock delivered to the North Jetty site.

The North Jetty repair work would begin in 2015 repairing cross section damage between stations 20+00 and 45+00. The North Jetty would require installing a barge offloading facility on the channel side of the jetty at approximately station 45 in order to facilitate efficient rock delivery to the site. Dredging of 30,000 cy is anticipated to provide the minimum 25 feet of working clearance. Repair of Jetty A would occur concurrently with the first year of repair for North Jetty. Jetty A work would begin with constructing the off loading facility which requires approximately 60,000 cy of dredging to accommodate the rock delivery by barge, and constructing the jetty crest haul road from stations 40 to 80. Total new stone in 2015 would consist of approximately 170,000 tons of imported rock, equivalent to 5700 trucks or 26 barges.

In 2016, construction would continue on the North Jetty head from stations 45+00 to 76+00. The haul road would need to be constructed with approximately 26,000 tons of rock fill material. Total new stone for 2016 would consist of approximately 86,000 tons of imported rock, equivalent to 2900 trucks or 13 barges. Site preparation work and stockpiling stone at the South Jetty would occur to prepare the staging and stockpile areas for 2017 construction.

In 2017, work continues on the North Jetty with placement of 29,000 tons of small and large armor near between stations 77+00 to 85+00. This ending stations corresponds with the beginning of the repair identified in as a portion of the base condition for this rehabilitation report. Work at these seaward stations requires refurbishing the haul road and building vehicle turnouts. At the North Jetty the 29,000 tons of imported small and large armor stone is equivalent to 970 trucks or 5 barges.

In 2017, construction on the South Jetty is projected to begin, starting with repairing damaged cross-sections between stations 167+00 and 195+00. South Jetty construction would require either a haul road be constructed on top of the jetty or constructed from a marine plant. Total work effort on the South Jetty in 2017 is projected to consist of approximately 90,000 tons of small and medium armor stone; equivalent to 3000 trucks or 14 barges.

In 2018, construction on the South Jetty continues by extending the repairs from station 197+00 to station 222+00. It is anticipated that the haul road would have to be repaired and extended to accommodate the placement of the small, medium and large armor stone. Total work effort in 2018 is projected to consist of approximately 89,000 tons of small and medium armor stone; equivalent to 2970 trucks or 14 barges.

In 2019, construction on the South Jetty continues by extending the repairs from station 223+00 to station 246+00. The haul road would again have to be repaired and extended to accommodate the placement of the armor stone which is evenly divided between medium and large armor stone for these stations. Total work effort in 2019 is projected to consist of approximately 79,000 tons of small and medium armor stone; equivalent to 2640 trucks or 12 barges.

In 2020, the initial repairs for the three jetties are completed with the conclusion of South Jetty repairs on stations 258+00 to 290+00. The haul road would again have to be repaired and extended to accommodate the placement of the stone, which is very large armor stone. The transportation and placement of the stone may be accomplished by marine plant and land based crane depending upon the capabilities of the selected contractor. Total work effort in 2020 is projected to consist of approximately 87,000 tons of imported large and very large armor stone; equivalent to 2980 trucks or 13 barges. The size of the very large armor stone, (16-33 tons) may dictate how they are transported and would require additional time and effort for placement.

5.5.3. Rock Sources and Transportation

Currently, it is not exactly known where jetty rock would come from and how it would be transported to the jetty sites. However, one or more of the options discussed below would be employed (Figure 37 and Table 26). Rock sources located within 150 miles of a jetty would likely be transported by truck directly to the jetty. Stone sources located at further distances, especially if they are located near waterways, are likely to be transported by truck to a barge onloading facility, then transported by tug and barge to either a Government provided or commercial barge offloading site located nearby. Railway may also be an option for transporting stone, provided that an onloading site is convenient to the quarry. Most railroads follow main highway arterials, such as Interstate 5. The closest railroad terminal to the South Jetty is at Tongue Point, east of Astoria, OR, which is about 15 miles from the jetty. The nearest railroad terminal to the MCR on the north side of the Columbia River is at Longview, WA.

The Corps intends to use operating quarries rather than opening any new quarries. The Contractor and quarry owner/operator would be responsible for ensuring that quarries selected for use are appropriately permitted and in environmental compliance with all state and federal laws.

Canadian Quarries. Quarries in British Columbia are typically located adjacent to waterways and rock produced from these quarries will likely have a limited truck haul. Due to the long distance to the MCR, plus the immediate availability to deep water, rock would likely be loaded onto barges and shipped down the Washington Coast to barge offloading sites.

Washington Quarries. Quarries located in northern Washington are typically not on the water, but are generally located within 50 miles of a potential barge on-loading site. As a result, rock would need to be hauled, at least initially, by truck. Rock would be transported by trucks most likely to a barge on-loading facility or possibly all the way to the staging site at the jetty. In the event of a combination of trucking and barging, trucks would be loaded at the quarry, and then traverse public roads to existing facilities. Once the rock is loaded on barges, it would be transported down the coast to barge offloading sites.

It also is possible that railway systems may be used to transport rock much of the way to the jetties. Burlington Northern Railroad operates a rail system that parallels Interstate 5 throughout Washington which would be the most likely route rock would be transported. Rock from the quarry would be taken by truck to a nearby railway station where they would be loaded onto railway cars and transported to an intermediate staging area. Trucks would then again take the rock the remainder of the way to the jetty staging areas.

Truck hauling of rock from northern Washington sources to the North Jetty or Jetty A most likely would be transported by public road to Interstate 5 or any of the main roads over to Highway 101. Trucks using Interstate 5 would either turn at Longview on Highway 4 to Highway 101, or cross over the Longview Bridge to Highway 30 near Rainier, Oregon. From this point they would proceed west to Astoria to Highway 101, crossing the Astoria-Megler Bridge through Ilwaco to the jetty staging areas. Delivery to the South Jetty most likely would use main roads to Interstate 5 or any of the main roads over to Highway 101.

Figure 37. Potential Quarry Locations (red dots) for Repairs to MCR Jetties

See corresponding quarry information located in Table 25.

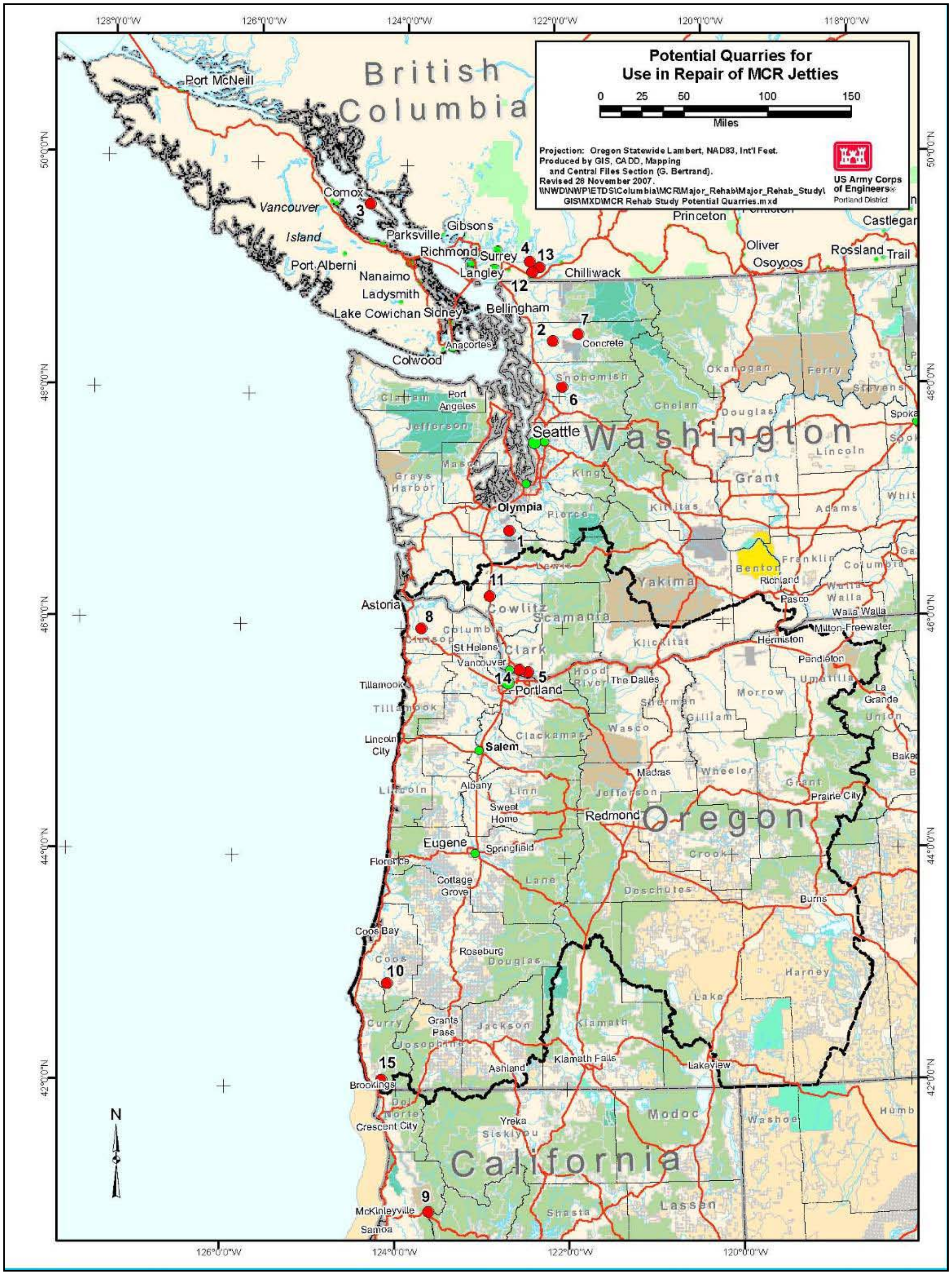


Table 26. Quarry Information

See Figure 37 for site map.

No.	Quarry	County and State	Nearest City	Road Miles from MCR	Unit Weight (pcf)	Reserves Available (tons)	Likely Transportation Method	Nearest Barge Facility
1	Columbia Granite Quarry	Thurston, WA	Vail, WA	129	168.5	28 M	Truck	N/A
2	Beaver Lake Quarry	Skagit, WA	Clear Lake, WA	251	181.1	1.86 M	Truck, then Barge	Anacortes, WA
3	Texada Quarry	BC, CANADA	Texada Island, BC	363	173.5+	275 M	Barge	Onsite
4	Stave Lake Quarry	BC, CANADA	Mission, BC	311	169.1	74 M	Truck, then Barge	Mission, BC, Canada
5	192nd Street Quarry	Clark, WA	Camas, WA	109	168.5	0.5 M	Truck/Barge	Camas, WA
6	Iron Mountain Quarry	Snohomish, WA	Granite Falls, WA	225	174	Unknown	Truck	N/A
7	Marble Mount Quarry	Skagit, WA	Concrete, WA	276	189.7	2 M	Truck, then Barge	Anacortes, WA
8	Youngs River Falls Quarry	Clatsop, OR	Astoria, OR	20	181.8	0.5 M+	Truck	N/A
9	Liscomb Hill Quarry	Humboldt, CA	Willow Creek, CA	515	179.1	0.5 M	Truck, then Barge	Eureka, CA
10	Baker Creek Quarry	Coos, OR	Powers, OR	275	200	Unknown	Truck, then Barge	Coos Bay, OR
11	Phipps Quarry	Cowlitz, WA	Castle Rock, WA	69	167.4	0.5 M	Truck	N/A
12	Cox Station Quarry	BC, CANADA	Abbotsford, BC	313	167.9	150 M	Barge	Onsite
13	Ekset Quarry	BC, CANADA	Mission, BC	309	172.2	10 M	Truck, then Barge	Mission, BC, Canada
14	Fisher Quarry	Clark, WA	Camas, WA	108	168.5	2 M	Barge	Camas, WA
15	Bankus Quarry	Curry, OR	Brookings, OR	347	183 & 195	0.7M	Truck, then Barge	Crescent City, CA

Trucks using Highway 101 south through Washington would likely cross the Astoria-Megler Bridge, go through Warrenton using local roads into Fort Stevens State Park and the staging area. Trucks utilizing Interstate 5 would either turn at Longview on Highway 4 to Highway 101, or on Highway 30 near Rainier, proceeding through Astoria to Highway 101, going through Warrenton through local roads into Fort Stevens State Park and the jetty staging area.

Rock located within southern Washington would likely be trucked to the jetty staging areas. An exception to this would be a quarry that occurs within just a few miles of a port on the Washington Coast or a quarry that is near the Columbia River. In either of these two barge possibilities, rock would be delivered by truck to a barge on-loading facility, loaded on oceangoing or riverine barges, and delivered to one of the barge offloading facilities (see section on barge offloading facilities below). Truck hauling of rock from this area to the jetties would be as described above.

Oregon Quarries. Rock located in northern Oregon within 50 miles of the North Jetty and Jetty A would likely utilize any of the main roads over to Highway 101 or Highway 30. From this point they would cross the Astoria-Megler Bridge and proceed west through Ilwaco to the jetty staging areas. Quarries exceeding 50 miles from the jetties would likely utilize main roads at a farther distance from the jetty sites. This would involve longer haul distances on Highways 101, 30, 26, and others before crossing the Astoria-Megler Bridge and proceeding to the staging areas.

Truck hauling of rock from quarries within 50 miles of the South Jetty will most likely utilize any of the main roads over to Highway 101 or Highway 30. From this point they would proceed through Astoria and Warrenton, or Seaside and Gearhart to local roads leading to Fort Stevens State Park and the jetty staging areas. Quarries exceeding 50 miles from the jetty would likely utilize main roads at a farther distance from the jetty site. This would involve longer haul distances on Highways 101, 30, 26, and others before going through Astoria and Warrenton, or Seaside and Gearhart to local roads leading into Fort Stevens State Park and the staging areas.

The likely mode of transportation from southern Oregon quarries is trucking, or a combination of trucking and barging. Many of the quarries may be near the Oregon Coast; however, they may not be near a port facility that has barge on-loading capability. Providing that barge facilities are available, rock located south of Waldport would be loaded at the quarry onto trucks and traverse main public roads to the barge on-loading site, loaded on ocean-going barges, and shipped up the Oregon Coast to one of the barge offloading facilities (see section on barge offloading facilities below). Quarries north of Waldport would most likely be hauled by truck the entire distance.

Southern Oregon rock sources requiring trucking would be loaded onto lowboy trucks one to three at a time and would traverse main roads to more main arterials such as Highway 101 or, to a lesser degree, Interstate 5. An effort would be made to use the least distance possible to transport the rock without sacrificing transport time.

California Quarries. For northern California quarries, there would be a very long haul distance required to get rock to the jetty repair areas. Barging of rock would be the only economically feasible option. Rock would be transferred by truck from the quarries along main roads leading to Highway 101 to a barge offloading facility.

For water-based delivery of rock, a tow boat and barge would deliver the rock to the channel side of the jetties where water depth, waves, and current conditions permit. During rock offloading, the barge may be secured to approximately 4 to 8 temporary dolphins/H-piles to be constructed within 200 feet of the jetty. Rock would be off-loaded from the barge by a land- or water-based crane and either placed directly within the jetty work area or stock piled on the jetty crest for subsequent placement at a later time.

For land-based delivery of rock, jetty access for rock hauling trucks would be via an existing paved road to the Benson Beach parking lot at Cape Disappointment State Park (North Jetty) and via an existing paved road to the Parking Lots C and D at the South Jetty. An existing overland route between Jetty A and North Jetty may also be used for land-based hauling. Work areas for delivery of rock, maneuvering of equipment, and stockpiling of rock near the jetties have been identified and are discussed in the next section.

5.5.4. Barge Offloading Facilities

Stone delivery by water could require up to four barge offloading facilities that allow ships to unload cargo onto the jetty so that it can then be placed or stockpiled for later sorting and placement. The range of locations for these facilities is shown in Figures 38-40. Depending on site-specific circumstances, offloading facilities may be partially removed and rebuilt, may be permanently removed, or may remain as permanent facilities upon project completion. Facility removal will depend on access needs and evolving hydraulic, wave, and jetty cross-section conditions at each offloading locations.

Additionally, in the draft EA released in January 2010, a third offloading facility was under consideration for the South Jetty in the bay adjacent to the area known as Social Security Beach. Due to the size of the footprint and the possible effects to shallow-water habitat in the vicinity, this option has been withdrawn from further consideration in order to avoid and minimize environmental impacts. The site near Parking Area D at the South Jetty was deemed to have a smaller footprint, was likely to require less dredging, and had fewer impacts to shallow-water habitat.

Facilities will range from approximately 200- to 500-feet long and 20- to 50-feet wide, which ranges from about 0.48 to 2.41 acres in total area. Examples are shown in Figure 41. For initial construction of all four facilities combined, approximately up to 96 Z- or H-piles that are 12-16-inches in diameter could be installed as dolphins, and up to 373 sections of Z- or H-piles installed to retain rock fill. Figure 41 shows a cross-section diagram for stone access ramp at potential barge offloading facilities and photos illustrating typical barge offloading facilities. Facilities will have a 15-foot NGVD crest elevation and will be installed at channel depths between -20 and -30 feet NGVD. A vibratory hammer will be used for pile installation and only untreated wood will be used, where applicable. Removal and replacement of the facilities could occur within the duration of the construction schedule. Volume and acreage of fill for these facilities are shown in Table 27.

Figure 38. North Jetty Offloading, Staging, Storage and Causeway Facilities

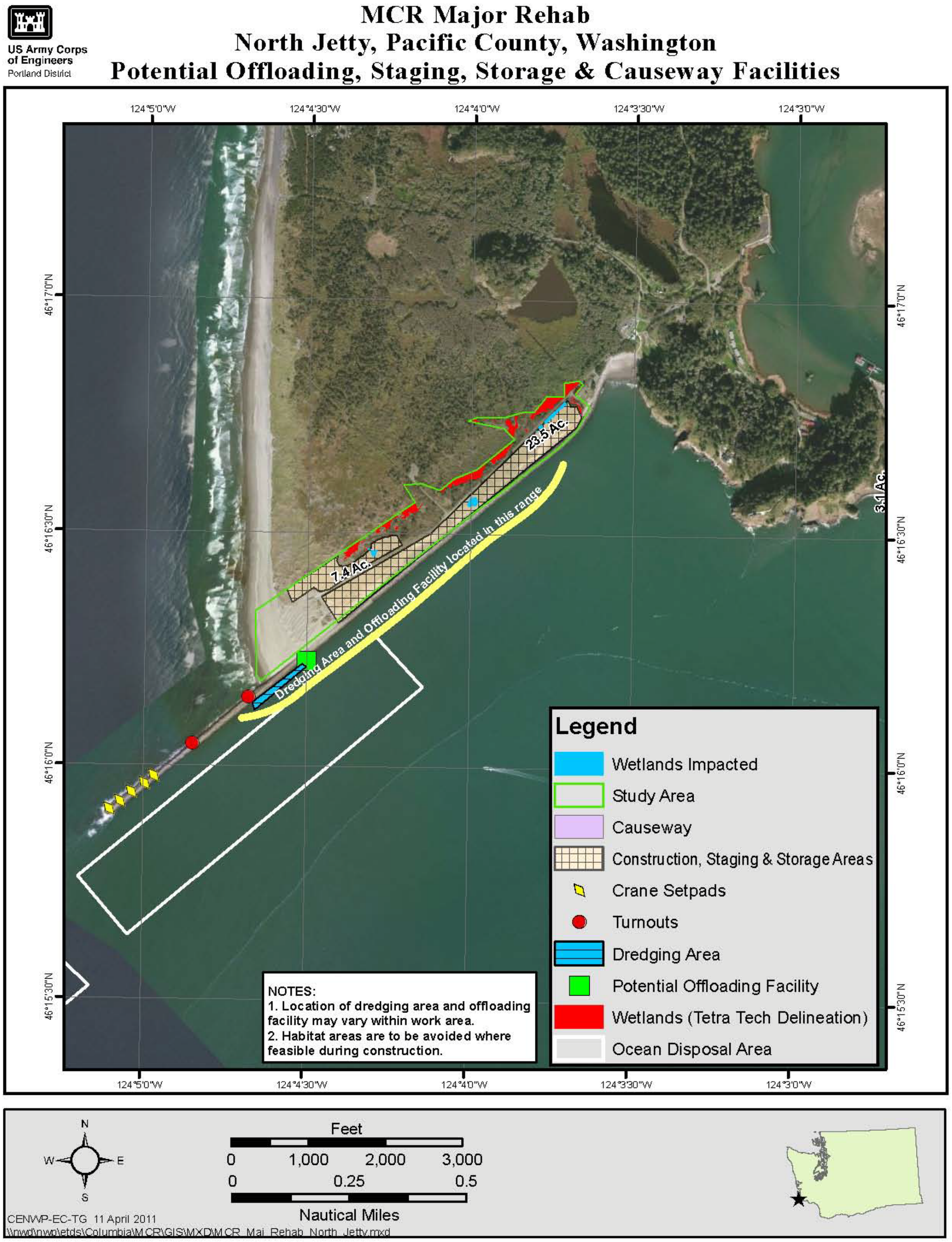


Figure 39. South Jetty Offloading, Staging, Storage and Causeway Facilities

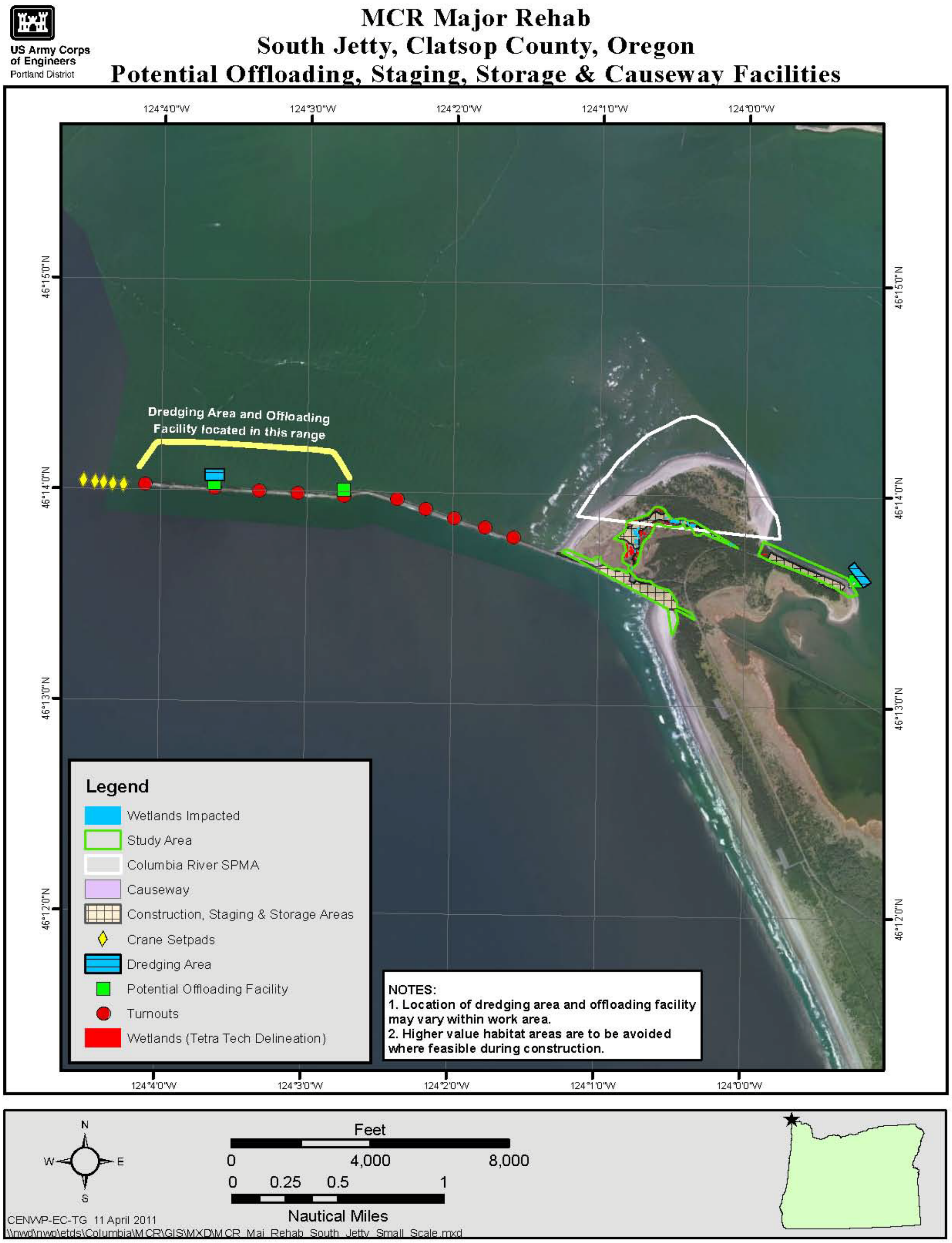


Figure 39 (continued)

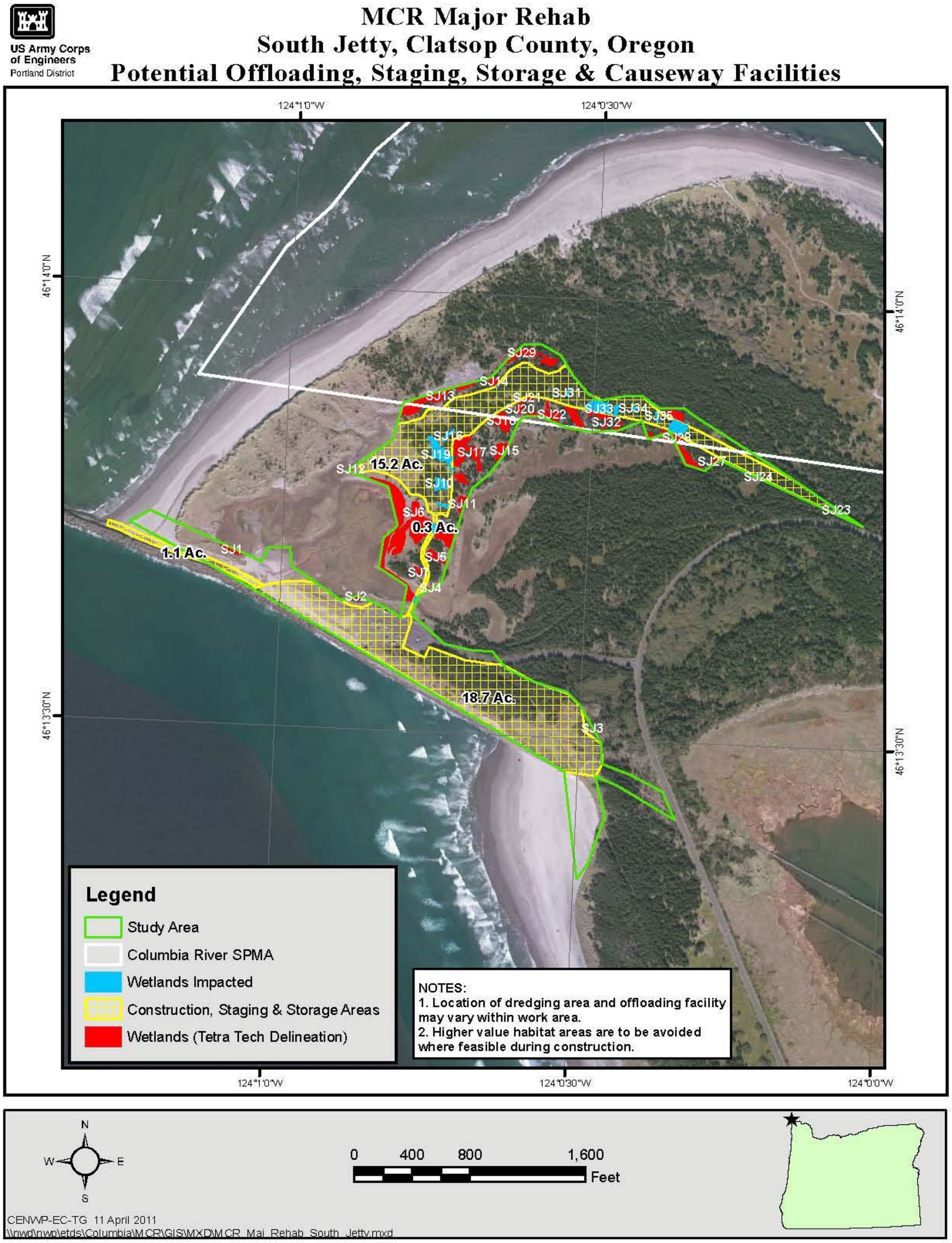


Figure 40. Jetty A Offloading, Staging, Storage and Causeway Facilities

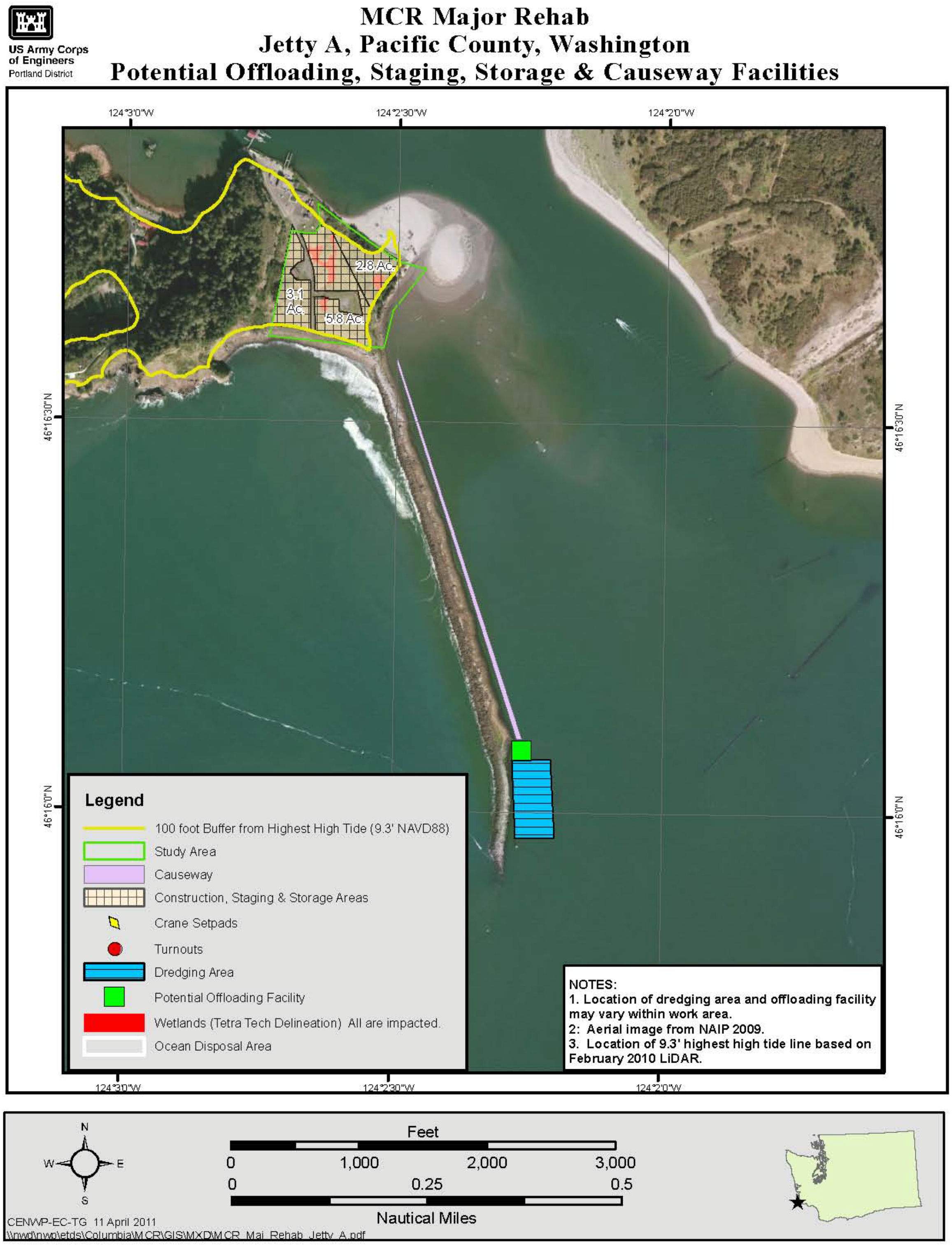


Figure 41. Cross Section of Stone Access Ramp at Barge Offloading Facilities at East End of Clatsop Spit near Parking Area D and Photos of Typical Barge Offloading Facilities

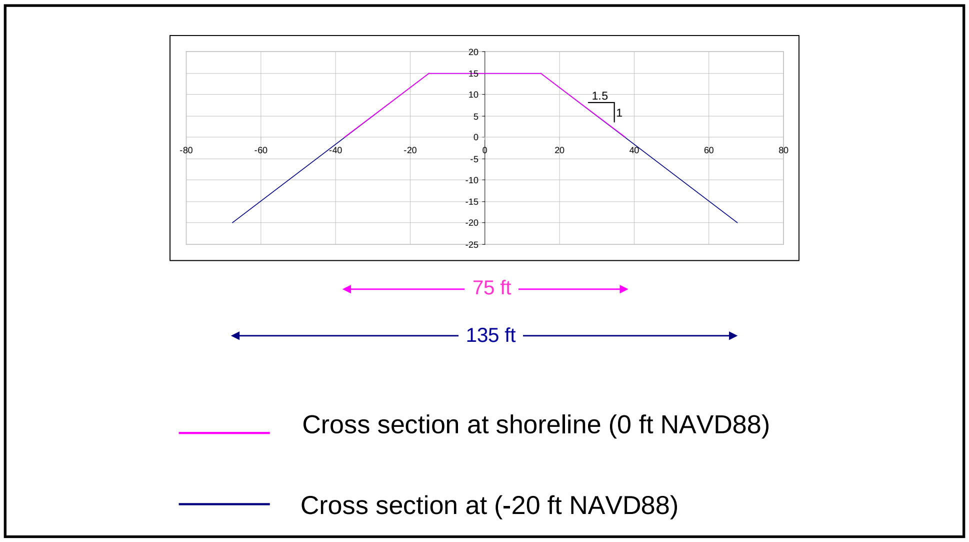


Figure 41 (continued)

The following existing private facilities may serve as potential offloading sites depending on availability for Corps' use:

- Commercial Site in Ilwaco. For the North Jetty, barges would pull up to a dock at Ilwaco where rock would be transferred by crane onto trucks that would proceed by public road to Cape Disappointment State Park. Trucks would then pass through the park grounds to the staging area adjacent to the jetty. For Jetty A, trucks would proceed through the Coast Guard facility to the staging area near the root of the jetty.
- Commercial Site in Warrenton. Nygaard Logging has a deep-water offloading site that could be used to offload rock. For the North Jetty/Jetty A, rock would be transferred to trucks that would likely use Highway 101 into Astoria, cross the Astoria-Megler Bridge, and head west through Ilwaco to Cape Disappointment State Park. Trucks would then pass through the park grounds to the staging area adjacent to the jetty. For the South Jetty, rock would be transferred to trucks which would then proceed west through Hammond to Fort Stevens State Park and use the existing park road to staging area adjacent to the jetty. This site needs no improvement to accommodate deep-draft vessels.

If existing facilities are not available or do not have adequate capacity to provide access, barge offloading facilities could be constructed at each jetty.

- North Jetty: Between Stations 50 and 70, a barge offloading facility will be constructed in the reach such that wave conditions allow safe offloading. This offloading facility will require 4-8 dolphins of 3 piles each for vessel tie-up, and sheet-pile installation will be required to shore-up and retain rock at the offloading point.
- Jetty A: An offloading facility will be sited around station 81, at the upstream portion of the jetty near the head. A 15-foot causeway will also be constructed along the entire length of the jetty on existing relic stone that runs adjacent to and abutting the upstream eastern portion of the jetty. This facility will likely remain a permanent facility, but may deteriorate due to wave and tidal action. This offloading facility will require 4-8 dolphins of 3 piles each for vessel tie-up, and sheet-pile installation will be required to shore-up and retain rock at offloading point.
- South Jetty: The South Jetty could have up to two associated offloading sites. One will be located at Parking Area D near the northeastern-most corner of the spit. The second facility will be located along the jetty and will resemble an extra-large turn-out facility. It is likely to be located somewhere on the northern, channel-side of the jetty and west of Station 270 in order to take advantage of deeper bathymetry and subsequently less need for dredging. The facility at Parking Area D may be removed after 5 or more years depending on hydraulic impacts of the structure and spit. The facility along the jetty will likely be partially removed and rebuilt after each repair to avoid the potential for wave-focusing on the jetty. Otherwise, it will remain in place until about 2033. Each offloading facility will require 4-8 dolphins of 3 piles each for vessel tie-up, and sheet-pile installation will be required to shore-up and retain rock at offloading point.

Table 27. Rock Volume and Area of Barge Offloading Facilities and Causeways

Location	Approximate Length (ft)	Approximate Rock Volume (cy) Below 0 MLLW	Total Approximate Rock Volume (cy)	Approximate Square Feet	Acres
North Jetty	200	7,778	29,640 cy	21,000	0.48
Jetty A near head	200	7,778	29,640 cy	21,000	0.48
Jetty A mid-section causeway	5000	38,888	38,888	105,000	2.41
South Jetty Parking Area D	450	17,417	33,688 cy	47,250	1.08
South Jetty along jetty turn-out	200		18,640 cy	21,000	0.48

5.5.5. Dredging for Barge Offloading Facilities

Transport of rock would most likely be done by ocean-going barges that require deeper draft (20-22 feet) and bottom clearance when fully loaded than river-going barges. Therefore, dredging will be required to develop each of the barge offloading facilities. Under-keel clearance should be no less than 2 feet. The elevation at barge offloading sites should have access to navigable waters and a dredge prism with a finish depth no higher than -25 feet MLLW, with advance maintenance and disturbance zone depths not to extend below -32 feet MLLW. These facilities should also provide for a maneuvering footprint of approximately 400 feet x 400 feet. The depth along the unloading sites would be maintained during the active period for which the rock barges will be unloaded.

A clamshell dredge would likely be used for all dredging, although there is a small chance that a pipeline dredge could be used. The material to be dredged is medium to fine-grained sand, typical of MCR marine sands. Disposal of material would occur in-water at an existing, previously-evaluated and designated or other approved disposal site. The volume of material to be dredged is shown in Table 28; these estimates are based on current bed morphology and may change. Also, maintenance dredging to a finish depth of -25 feet MLLW will be needed before offloading during each year of construction. Dredging is likely to occur on a nearly annual basis for the duration of the project construction period, but this will be intermittent per jetty, depending on which one is scheduled for construction in a particular year.

Table 28. Estimated Dredging Volumes for Barge Offloading Facilities

Location*	Estimated Dredging Volume (cy)		Approximate Acres
	Initial	Est. Maintenance**	
North Jetty	30,000	30,000	3.73
Jetty A	60,000	None (1 year only)	3.73
South Jetty – Along Jetty	20,000	20,000	4.19
South Jetty – Parking Area D	20,000	20,000	4.19

* Some of the locations will not be used on an annual basis; it depends on the construction schedule for each jetty.
**All dredging will be based on surveys that indicate depths shallower than -25 feet MLLW.

Clamshell dredging is done using a bucket operated from a crane or derrick that is mounted on a barge or operated from shore. Sediment removed from the bucket is generally placed on a barge before disposal. This type of dredge is typically used in shallow-water areas.

The following overall impact minimization practices and best management practices (BMPs) will be used for all maintenance dredging for offloading facilities.

1. To reduce the potential for entrainment of juvenile salmon or green sturgeon, the cutter-heads on pipeline dredges will remain on the bottom to the greatest extent possible and only be raised 3 feet off the bottom when necessary for dredge operations.

2. To reduce turbidity, if a clamshell bucket is used, all digging passes shall be completed without any material, once in the bucket, being returned to the wetted area. No dumping of partial or half-full buckets of material back into the project area will be allowed. No dredging of holes or sumps below minimum depth and subsequent redistribution of sediment by dredging dragging or other means will be allowed. All turbidity monitoring will comply with State 401 Water Quality Certification Conditions.

3. If the Captain or crew operating the dredges observes any kind of sheen or other indication of contaminants, he/she will immediately stop dredging and notify the Corps' environmental staff to determine appropriate action.

4. If routine or other sediment sampling determines that dredged material is not acceptable for unconfined, in-water placement, then a suitable alternative disposal plan will be developed in cooperation with the NMFS, EPA, Oregon Department of Environmental Quality (ODEQ), Washington Department of Ecology (WDOE), and other appropriate agencies.

5.5.6. Dredged Material Disposal Sites

Two dredged material disposal sites, the Shallow Water Site (SWS) and the North Jetty site, are located near the North Jetty. The SWS is the most likely sites to be used for disposal of dredged material. Modeling has showed that the potential changes to the two disposal sites from the proposed action would not inhibit their use as disposal sites. As previously mentioned, these disposal sites have been previously vetted through the appropriate regulatory agencies, were evaluated for their effects, and were subsequently designated or approved after such review. There is also a Deep Water Site (DWS) further offshore, west of the North Jetty. It is less likely that this site would be used, though it is also an approved disposal site. The current proposed action and use of the SWS or other designated disposal site will maintain compliance with approved use. This will likely be covered in the Annual Use Plan which includes a request for use and is approved by the EPA. This involves a request for concurrence that the Corps' proposed Annual Use Plan is in compliance with the Site Monitoring and Management Plan.

5.5.7. Pile Installation and Removal

As mentioned earlier, inclement weather and sea conditions during the preferred in-water work window preclude safe working conditions during this time period. Therefore, installation of piles is most likely to occur outside of the in-water work window. For initial construction of all four facilities combined, approximately up to 96 Z- or H-piles could be installed as dolphins, and up to

373 sections of sheet pile to retain rock fill. They will be located within 200-ft of the jetty structure. Because the sediments in the region are soft (sand), use of a vibratory driver to install piles is feasible and will be used when necessary. The presence of relic stone may require locating the piling further from the jetty so that use of this method is not precluded by the existing stone. The dolphins/Z- and H-piles would be composed of either untreated timber or steel piles installed to a depth of approximately 15 to 25 feet below grade in order to withstand the needs of off-loading barges and heavy construction equipment. Because vibratory hammers will be implemented in areas with velocities greater than 1.6 feet per second, the need for hydroacoustic attenuation is not an anticipated issue. Piling will be fitted with pointed caps to prevent perching by piscivorous birds to minimize opportunities for avian predation on listed species. Some of the pilings and offloading facilities will be removed at the end of the construction period.

5.5.8. Rock Placement

Placement of armor stone and jetty rock on the MCR jetties would be accomplished by land or limited water-based equipment. Only clean stone will be used for rock placement, where appropriate and feasible. Where appropriate, there may also be some re-working and reuse of the existing relic and jetty prism stone. Fill for the jetty haul roads will not be cleaned prior to installation. Dropping armor stone from a height greater than 2 feet will be prohibited. During placement there is a very small chance of stone slippage down the slope of the jetty. However, this is unlikely to occur due to the size and cost of materials and placement.

Another approach to water-based rock placement would be via a jack-up barge. This would only be applicable at the South Jetty. For armor stone and rock placement at the head, a jack-up barge with crane could be used to serve as a stable work platform (Figure 42). Once into place, the jack-up barge would be jacked up on six legs so that the deck is at the same elevation as the jetty. The legs are designed to use high-pressure water spray from the end of the legs to agitate the sand and sink the legs under their own weight. The jacking process does not use any lubricants that contain oils, grease, and/or other hydrocarbons. The stone and rock will be barged to the jack-up barge and offloaded onto the jetty head. The jack-up barge will keep moving around the head of the jetty to complete the work. A jack-up barge would not be used on the North Jetty or Jetty A to avoid interference with navigation of fishing boats and crab and fish migrations.

Figure 42. Illustration of a Jack-up Barge

For land-based rock placement, a crane or a large track-hoe excavator could be situated on top of the jetty. The placement operation would require construction of a haul road along the jetty crest within the proposed work area limits. The crane or excavator would use the haul road to move along the top of jetty. Rock would be supplied to the land-based placement operation by land and/or marine-based rock delivery. For marine-based rock, the land-based crane or excavator would pick up rock directly from the barge or from a site on the jetty where rock was previously offloaded and stockpiled, and then place the rock within the work area. For land-based rock, the crane or excavator would supply rock via a truck that transports rock from the stockpile area. The crane or excavator would advance along the top of the jetty via the haul road as the work is completed.

In order to place stones, a haul road will be constructed on the 30-foot crest width of each jetty to allow crane and construction vehicle access. Roads will consist of an additional 3 feet of top fill material, which could also entail an additional 2 feet of width spill-over. These roads will remain in place for the duration of construction. Due to ocean conditions and the wave environment, these roads will likely need yearly repair and replacement. They will not be removed upon completion. Ramps from the beach up to the jetty road will also be constructed to provide access at each jetty.

At approximately 1,000-foot intervals, turnouts to allow equipment access and passage will be constructed on the North and South jetties. These will consist of 50-foot long sections that are an additional 20-feet wide. Some of this stone for these facilities may encroach below MLLW. On the North Jetty, there will be approximately two turnouts. South Jetty will have approximately eight turnouts with two additional larger-sized turnouts. These larger turnouts will be in the range of 300-feet long with an additional 20-foot width. One of these larger turnouts will function as an offloading facility on South Jetty. At Jetty A, the causeway will function as the turnout facility.

Towards the head of each jetty, additional crane set up pads will be constructed at approximately 40-ft increment to allow crane operation during the placement of the larger stabilization stones. Set-up pads will roughly entail the addition of 8 feet on each side of the crest for a length of about 50 feet.

Some of this stone for these facilities may encroach below MLLW. Approximately five set-up pads will be required to construct each jetty head.

5.5.9. Construction Staging, Storage, and Rock Stock Piles

Jetty repairs and associated construction elements entail additional footprints for activities involving equipment and supply staging and storage, parking areas, access roads, scales, general yard requirements, and rock stock pile areas. It was determined that for most efficient work flow and placement, a 2-year rock supply would be maintained on site and would be continuously replenished as placement occurred on each jetty. In order to estimate the area needed, a surrogate area was determined for a reference volume of 8,000 cy, which was then used to extrapolate the area needed at each jetty. These results are shown in Table 15.

Table 29. Acreages Needed for Construction Staging, Storage, and Rock Stock Piles

Location	Approximate Acres
North Jetty	31
Jetty A	23
South Jetty	44

Several actions will be taken to avoid and minimize environmental impacts from these activities. Staging and stockpiles will remain above MHHW and where feasible, have been sited to avoid impacts to wetlands and habitats identified as having higher ecological value. In order to maintain erosive resilience along the shoreline, a vegetative buffer would be preserved. When available and possible, partial use will be made of existing parking lots. Additional measures specific to each jetty have also been considered. Besides access roads in the areas identified in Figures 38-40, no additional roadways or major roadway improvements are anticipated. Some roadway repair and maintenance will likely be required on existing roads experiencing heavy use by the Corps.

For the North Jetty, the lagoon fill necessary for root stabilization will also serve a dual purpose for the bulk of staging and storage activities at this structure.

At the South Jetty, a small spur road will be required to connect the existing road with the proposed staging area and is indicated in Figures 38-40. The existing road along the neck of the South Jetty to be used for dune augmentation work may require minor repair/improvements for equipment access. Construction access to the area receiving dune augmentation will be limited to the existing access road along the relic jetty structures at the neck of the spit. Equipment will be precluded from using the access point from Parking Lot B for delivery in order to avoid impacts to water quality and razor clam beds in the vicinity of the proposed dune fill area. Grading equipment may have to access the area by driving along the shore, but this route will be used as a last resort and equipment will be limited to dry sand where feasible. Additionally, the proposed actions will avoid the more sensitive habitat areas south of Parking Lot D.

If possible, the project will avoid and minimize impacts to the adjacent marshland by allowing crossing between the construction area and the South Jetty via a Bailey bridge, which may require small removable abutments on either end of the marsh crossing. Otherwise a series of culverts and associated fill will be installed, or equipment will be required to enter and exit from the same access road on the northeast end of the main staging area indicated in Figures 38-40.

At the outlet of the marsh complex, a culvert will be installed under the construction access road, which will allow continuous hydrologic connectivity between affected portions of the marsh and ocean exchange through the South Jetty. This will also avoid equipment passage through marsh waters. To connect the staging area to the jetty haul road, a temporary gravel access road would be constructed from the staging area nearest the jetty to the jetty crest. The access road would measure approximately 400 feet in length by 25 feet in width, would be above MHHW, would require approximately 4,000 cy of sand, gravel and rip rap, and would require the installation and removal of a temporary culvert near station 178+00 to maintain tidal exchange into and out of the intertidal wetland and through the jetty. The staging areas and haul roads, except for the jetty haul road, would be removed and restored to pre-construction conditions once repairs to the jetty are completed.

Prior to in-water work for installing the construction access road and culverts across the southern portion of the marsh wetland outlet at the South Jetty, the Corps will conduct fish salvage and implement fish exclusion to and from the wetland complex upstream of the proposed culvert. Also, post-installation of the culvert, the Corps will develop and implement fish monitoring as necessary to ensure that no listed fish species are stranded. If listed fish species are found, NMFS will be contacted immediately to determine the appropriate course of action.

At Jetty A, adequate area may not be available for the estimated storage and staging needs. Therefore, construction sequencing will accommodate the supply that can be fit into the acreage available. Land-based delivery options may be precluded due to road access constraints, though some existing access may prove available and feasible depending on load and truck sizes.

The following measures will also be required at each location to further avoid and minimize impacts to species. Before alteration of the project area, the project boundaries will be flagged. Sensitive resource areas, including areas below ordinary high water, wetlands and trees to be protected will be flagged. Chain link fencing or something functionally equivalent will likely encircle much of the construction, stockpile, and staging areas.

5.5.10. Temporary Erosion Controls

Temporary erosion controls will be in place before any alteration of the site. If necessary, all disturbed areas will be seeded and/or covered with coir fabric at completion of ground disturbance to provide immediate erosion control. Erosion control materials (and spill response kits) will remain on-site at all times during active construction and disturbance activities (e.g., silt fence, straw bales). If needed these measures will be maintained on the site until permanent ground cover or site landscaping is established and reasonable likelihood of erosion has passed. When permanent ground cover and landscaping is established, temporary erosion prevention and sediment control measures, pollution control measures and turbidity monitoring will be removed from the site, unless otherwise directed.

An Erosion Sediment and Pollution Control Plan or Stormwater Pollution Prevention Plan, as applicable to each state, will outline facilities and Best Management Practices (BMPs) that will be implemented and installed prior to any ground disturbing activities on the project site, including mobilization. These erosion controls will prevent pollution caused by surveying or construction operations and ensure sediment-laden water or hazardous or toxic materials do not leave the project site, enter the Columbia River, or impact aquatic and terrestrial wildlife. The Corps retains a general 1200-CA permit from Oregon Department of Environmental Quality (DEQ), and will also work with

EPA to obtain use of the NPDES General Permit for Stormwater Discharge from Construction Activities. At a minimum, these plans will include the following elements and considerations:

- Construction discharge water generated on-site (debris, nutrients, sediment and other pollutants) will be treated using the best available technology.
- Water quality treatments will be designed, installed, and maintained in accordance with manufacturer's recommendation and localized conditions.
- Straw wattles, sediment fences, graveled access points, and concrete washouts may be used to control sedimentation and construction discharge water.
- Construction waste material used or stored on site will be confined, removed, and disposed of properly.
- No green concrete, cement grout silt, or sandblasting abrasive will be generated at the site.

5.5.11. Emergency Response

To avoid the need for emergency response a Corps' Government Quality Assurance Representative will be on-site or available by phone at all times throughout construction. Emergency erosion/pollution control equipment and best management practices will be on site at all times; Corps' staff will conduct inspections and ensure that a supply of sediment control materials (e.g., silt fence, straw bales), hazardous material containment booms and spill containment booms are available and accessible to facilitate the cleanup of hazardous material spills, if necessary. In the event of spill or leak, appropriate response and reporting requirements will be implemented per State and Federal requirements.

5.5.12. Hazardous Materials

A description of any regulated or hazardous products or materials to be used for the project, including procedures for inventory, storage, handling and monitoring, will be kept on-site. Regulated or hazardous products will be appropriately stored according to manufactures suggestions and regulatory requirements. Fuels or toxic materials associated with equipment will not be stored or transferred near the water, except in a confined barge. Equipment will be fueled and lubricated only in designated refueling areas at least 150 feet away from the MHHW, except in a confined barge or when in-place via the Wiggins system, or an equivalent as described below.

5.5.13. Spill Containment and Control

A description of spill containment and control procedures will be on-site, including: notification to proper authorities, specific cleanup and disposal instructions for different products, quick response containment and cleanup measures that will be available on the site including a supply of sediment control materials, proposed methods for disposal of spilled materials, and employee training for spill containment. Generators, cranes, and any other stationary power equipment operated within 150-feet MHHW will be maintained as necessary to prevent leaks and spills from entering the water. Vehicles / equipment will be inspected daily for fluid leaks and cleaned as needed before leaving staging and storage area for operation within 150 feet of MHHW. Any leaks discovered will be repaired before the vehicle / equipment resumes service. Equipment used below MHHW will be cleaned before leaving the staging area, as often as necessary to remain grease-free. Additionally, the Corps proposes to use a Wiggins fast fuel system or equivalent (uses a sealed vehicle tank with automatic shut-off fuel nozzle) to reduce leaks during fueling of cranes and other equipment in-place on the jetties. Also, spill pans will be mounted under the crane and monitored daily for leaks.

5.5.14. Water Quality Monitoring

In-water work will require turbidity monitoring that will be conducted in accordance with conditions in the Oregon and Washington 401 Water Quality Certifications to ensure the project maintains compliance with state water quality standards. Turbidity exceedences are expected to be minimal due to the large size of stone being placed. Dynamic conditions at the jetties in the immediate action area preclude the effective use of floating turbidity curtains (or approved equal). Sedimentation and migration of turbid water into the Columbia is not expected to reach harmful levels. Best management practices will be used to minimize turbidity during in-water work. Turbidity monitoring will be conducted and recorded each day during daylight hours when in-water work is conducted. Representative background samples will be taken according to the schedule set by the resource agencies at an undisturbed area up-current from in-water work. Compliance samples will be taken on the same schedule, coincident with timing of background sampling, down-current from in-water work. Compliance sample will be compared to background levels during each monitoring interval. Additional 401 water quality certification conditions and protocols may be required.

5.6. Wetland and Waters Fill and Associated Mitigation

The Preferred Alternative for repair and rehabilitation of the MCR jetties has been developed and refined to take advantage of opportunities to avoid and minimize, to the maximum extent practicable, the proposed project's ecological impacts to wetland, aquatic habitats, and species per requirements under the Clean Water Act and Executive Order (EO) No. 11990. Efforts were made to reduce the project footprint and to locate staging areas away from wetland and waters areas. However, there would be unavoidable effects to wetlands and waters as aquatic habitat would be filled and converted as a result of the project. The process used to determine mitigation was to first maximize avoidance of the impacts. However, some impacts to wetlands and waters remained unavoidable. Mitigation for unavoidable impacts was then based on the extent and quality of the habitat affected.

As mentioned initially, the actions evaluated in this EA include South Jetty dune augmentation, actions at the North Jetty described in the *North Jetty Major Maintenance Report* (MMR), May 2011, and actions described in the Major Rehabilitation Report (MRR) (*MCR Jetty System Major Rehabilitation Evaluation Report*, June 2012). Though these actions will be funded as separate projects, they were analyzed together. The following mitigation is required as a result of their associated cumulative effects. The breakdown of effects from fill are indicated in the Table 30 below and then described in further detail.

Table 30. Estimated Acreages for 404 Wetland and Waters Mitigation

Area Affected	Impacted Acreage	Mitigation Acreage	Comment
North Jetty			
Wetland	1.14	2.28	Base Condition: MMR
404 Waters Lagoon	8.02	12.03	Base Condition: MMR
Other 404 Waters	4.36	6.54	
South Jetty			
Wetlands	2.65	5.30	
404 Waters	13.84	20.76	
Jetty A			
Wetlands	0.91	1.82	
404 Waters	6.60	9.90	

Impacts associated with wetlands had a known and quantified footprint and were the same under all the construction alternatives. Specific wetland mitigation sites and methods were identified and developed. The exact extent of impacts to 404 waters of the US remained unknown because they were contingent upon the delivery method of the rock which would be determined during contract bidding. Therefore, the extent of mitigation for impacts to 404 waters remained uncertain and variable based on the mode of stone delivery and placement. Impacts would be greater if the contractor chooses to use offloading facilities; hence, the maximum potential effects were evaluated in this EA (and in the BAs). Because of this, maximum mitigation requirements were also assumed for 404 waters. Mitigation requirements would be further coordinated with the AMT and may be reduced if offloading facilities are not constructed.

Staging and rock stockpile areas are required to work with the large stone and to construct the repairs. A balance was struck to provide and locate such staging areas that allowed project completion in an efficient and timely manner while minimizing both the areal and temporal extent of project impacts to wetlands and waters. This also includes siting offloading facilities in areas that minimize the extent of dredging and impacts to critical shallow water habitat. To avoid and reduce shallow-water impacts, the Corps determined that offloading facilities would avoid locations within Baker Bay as well as in the small bay area along the north shore of Clatsop Spit. Further, by potentially utilizing barging operations to supply and place the large-sized and large volume of stone, this both reduces the impacts of traffic and somewhat avoids and reduces safety issues with large trucks entering and exiting the Coast Guard and State Park facilities, respectively.

It is assumed all wetlands are expected to be impacted for more than 1 year. Impacts to 404 waters of the US would also occur for more than one year with maintenance dredging and continuous use. Facilities may be removed or left in as permanent fixtures depending on hydraulic conditions at the offloading sites and along the adjacent jetties themselves. For these reasons, this analysis assumed a worst-case scenario so the impacts were considered permanent. Mitigation would be commensurate with the project footprint, which may be reduced further depending on whether or not the final implementation requires barge offloading facilities.

Official wetland delineations have now been completed for all three jetties. Prior to this at release of the Draft EA, preliminary available information allowed the Project Delivery Team (PDT) to initially locate construction activities and features to reduce anticipated impacts to wetlands. This information was also used to calculate initial estimates regarding potential wetland impacts. The original estimates, pre-delineation, approximated wetland acreages potentially impacted to be: North

Jetty ~4.78 acres, South Jetty up to ~22 acres, and Jetty A up to ~11 acres, for an estimated total of ~38.28 acres of potential wetlands impacts. Post wetland delineations and after further minor refinement of locations for staging areas since the release of the draft EA, these impact numbers have been revised and dramatically reduced.

Ultimately, the project seeks to achieve no net loss in wetland habitat, to protect, improve and restore overall ecosystem functions, and to provide mitigation actions that are anticipated to restore affected benefits to aquatic species in the vicinity of the project. Towards that end, specific project footprints and activities described above have been identified, categorized, and quantified with conservative estimates where appropriate. Per initial consultation with resource agencies and as a result of the wetland types, functional values and aquatic habitat proposed to be impacted, a preliminary ratio of 2:1 was suggested for wetland mitigation, and a ratio of 1.5:1 for waters other than wetlands to offset impacts that would occur to aquatic resources. As required, the Corps would mitigate for impacts which could not be otherwise avoided or minimized. Mitigation plans currently address three general categories: actions that create wetlands, offsetting actions for 404 impacts in-water, and actions that re-stabilize and replant construction-disturbed upland habitats. Onsite or adjacent mitigation to address impacts is preferred.

The Corps coordinated with the States, USFWS, and NMFS to determine appropriate mitigation ratios based on wetland types, functional values and typical compliance requirements. Proposed wetland mitigation is at a 2:1 ratio and mitigation for waters other than wetlands is at a 1.5:1 ratio. Though WQCs have not yet been obtained, the Corps has been working closely with the Certifying agencies to ensure it is meeting its legal responsibilities. The Consultations evaluated effects from a larger project footprint than the current preferred alternative. The current proposed action has further minimized impacts subsequent to the Consultations with the Services, and the following quantities represent the worst-case scenario from effects of barge offloading facilities after minimization measures have been implemented to the maximum extent practicable. It is anticipated that through meetings and discussions with the AMT, the total for proposed mitigation would reflect the reduced project footprint if barge offloading sites are not constructed. All agencies will be kept abreast of project construction and development to ensure mitigation commitments are appropriate and realized.

5.6.1. Wetland Fill and Wetland Mitigation

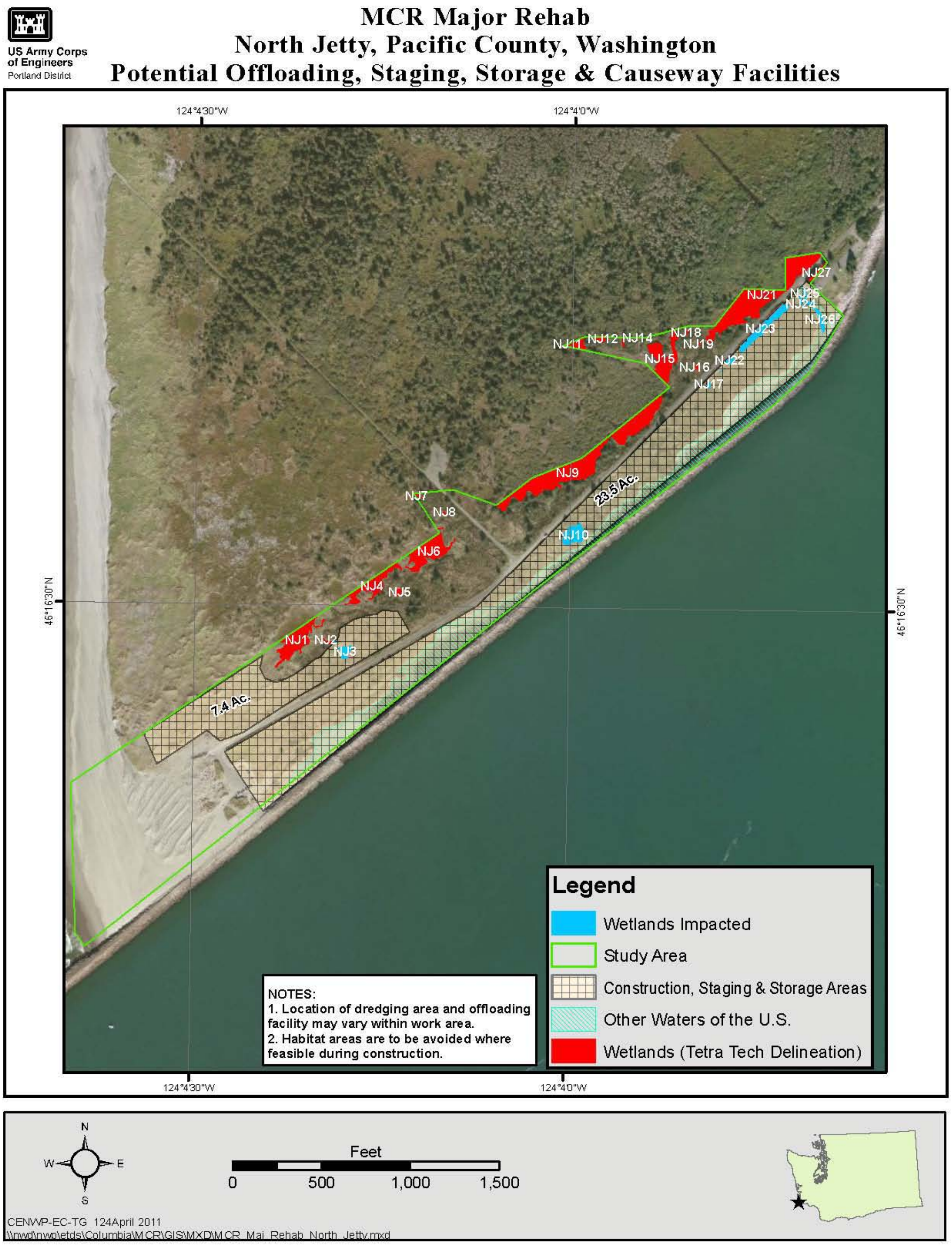
Impact to wetland types and other waters of the U.S. now include the following amounts at each jetty:

North Jetty: Wetland fill at the North Jetty would occur as a result of critical repairs at the root and lagoon fill and are further detailed in this EA as well as the *North Jetty Major Maintenance Report*. Rock storage and staging activities require a minimum of 31 acres to meet the project need for implementation. All wetlands south of the North Jetty Access Road would be impacted and filled in order to reduce processes eroding and undermining the jetty root, to which the lagoon also contributes. Additionally, a few small wetlands north of the roadway would be impacted in order to provide the necessary space for adequate rock storage (enough for 2 years-worth of rock placement) and efficient construction, staging, and access areas. There would also be some wetland impacts during replacement of the damaged culvert crossing under the North Jetty Access Road. The lagoon fill would then be used as a staging area in order to avoid additional impacts elsewhere. After avoidance and minimization measures, including implementation of an 80-ft buffer around conserved wetlands north of the roadway and a 200-ft shoreline buffer beyond the Highest High Tide, unavoidable total wetland impacts come to about 1.14 acres out of the 31 acres of staging area identified for construction actions, and impacts to other waters of the U.S. via the lagoon fill equals about 8.02 acres.

Of the wetlands impacted, 0.11 acre is part of a wetland mosaic complex which rated as Category IV Interdunal, Depressional wetlands. About 0.65 acres are part of a wetland mosaic complex which rated as Category III Interdunal, Depressional wetlands. About 0.25 acre is rated as Category II Interdunal Riverine wetlands; and 0.13 acres rated as Category 1 Estuarine, Freshwater Tidal Fringe. All these wetlands all would be mitigated onsite adjacent to the project area, in an area north of the North Jetty Access Road adjacent to the conserved wetland fringe that extends further north.

At a 2:1 mitigation ratio, this equals about 2.28 acres of wetland mitigation, plus the required buffer. This amount of upland area is available, and wetland creation via excavation to appropriate depths, appropriate native plantings, invasive species removal, and buffer requirements would offset impacts to wetland within the same vicinity in which they are proposed. This 2:1 ratio also aligns with mitigation requirements in WA that were developed in partnership with WA Department of Ecology (DOE) (a 401 Certifying Agency), EPA, and the Corps (WADOE 2006). According to this guidance, estuarine ratios are developed on a case-by-case basis (WADOE 2006). The Corps has worked closely with WA DOE to determine the appropriate mitigation ratio of 2:1. Given the ample rainfall and close proximity to higher functioning wetlands, the likelihood of successful wetland establishment further supports the proposed amount of wetland mitigation. Though these buffers, ratios, and acreages are likely close to the final amounts, they may change following further coordination with WA Department of Ecology and receipt of conditions in the WA State Clean Water Act 401 Water Quality Certification and the determination of Coastal Zone Management Act Consistency.

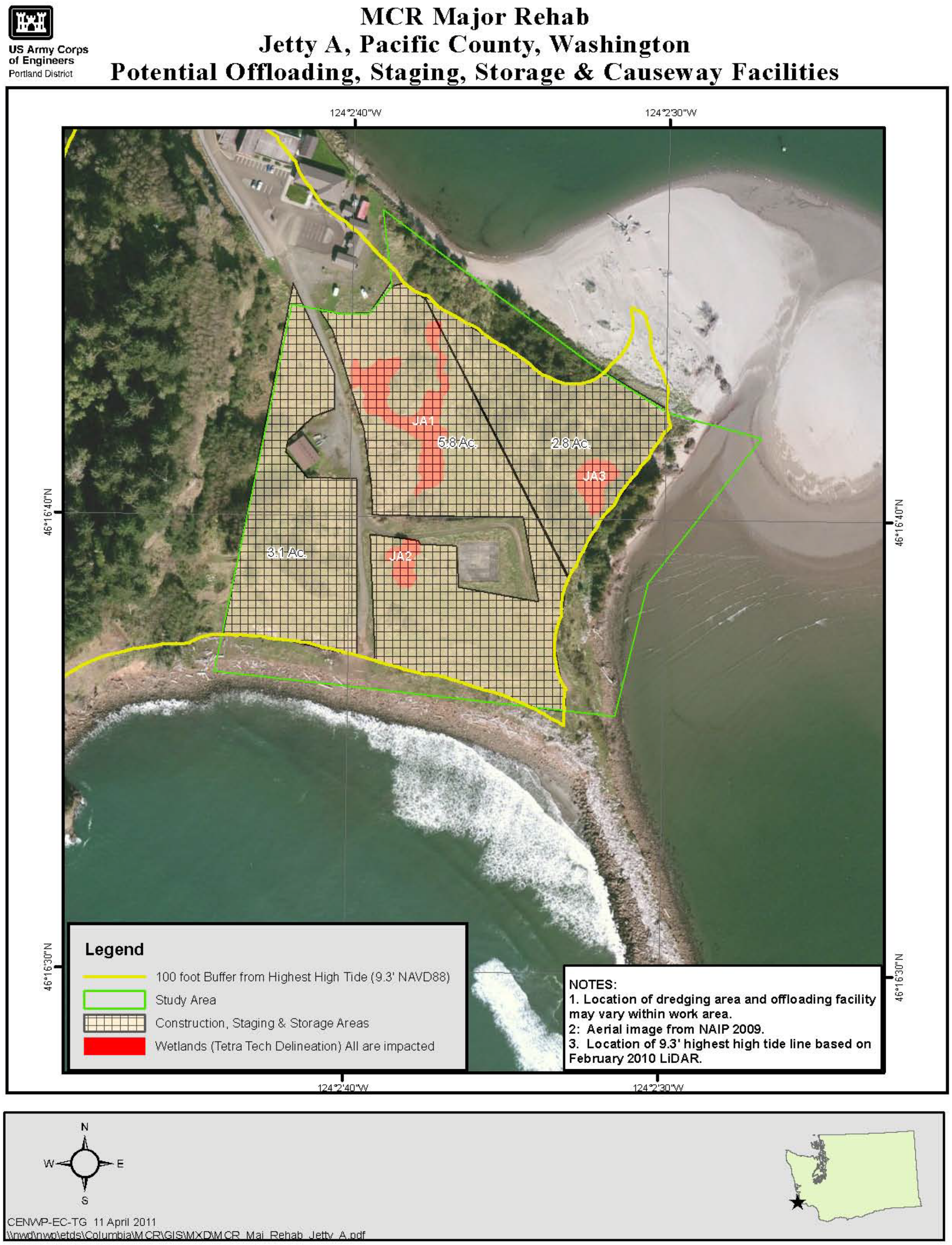
Figure 43. Illustration of Avoidance, Minimization, and Wetland and Waters Impacts at North Jetty



Jetty A: Wetland fill at Jetty A occurs as a result of work during the Major Rehabilitation actions described in this EA and in the MRR. Rock storage and staging activities require a minimum of about 23 acres to meet the project need for implementation at Jetty A. This encompasses most of the area adjacent to the jetty root at the Coast Guard Station. A total of about 0.91 acre of wetland at Jetty A would also be filled due to rock storage and construction staging activities. Unfortunately, these wetlands cannot be avoided, but impacts to adjacent water of the U.S. would be minimized by implementing a 100-ft buffer beyond the Highest High Tide elevation, which is consistent with the setbacks required for lands designated as "Conservancy" by Pacific County. Of the wetlands impacted, 0.74 acre is rated as a Category III Interdunal, Depressional wetlands with scores under 26. About 0.17 acre is rated as Category 1 Estuarine, Freshwater Tidal Fringe wetlands.

Because of onsite space constraints and site conditions, these wetlands at Jetty A would be mitigated in the same vicinity as the mitigation area identified at the North Jetty, north of the North Jetty Access Road. At a 2:1 mitigation ratio, this equals about 1.82 acres of wetland mitigation, plus the required buffer. As with the North Jetty these requirements were determined as described for the North Jetty and align with joint COE and WADOE guidance (2006). Wetland creation would occur in conjunction with and in addition to the area and process described for mitigation at the North Jetty. Reduced disturbance coupled with improved potential hydrology and adjacent functioning wetlands at North Jetty compared to at Jetty A make the success of wetland creations more likely at the location at the North Jetty compared to any creation at Jetty A. Therefore with Jetty A mitigation included, the total mitigation acreage at the North Jetty is 4.1 acres, and this area is available as described. As with the North Jetty, though these mitigation ratios and acreages are likely close to the final amounts, they may change following further coordination with WA Department of Ecology and receipt of conditions in the WA State Clean Water Act 401 Water Quality Certification and the determination of Coastal Zone Management Act Consistency.

Figure 44. Illustration of Avoidance, Minimization, and Wetland and Waters Impacts at Jetty A



South Jetty: Wetland fill at South Jetty occurs as a result of work during the Major Rehabilitation actions described in this EA and in the MRR. In order to acquire the 44 acres needed for staging and rock stockpiles, 2.65 acres of unavoidable wetland impacts would occur at the South Jetty. However, by slightly revising locations, maintaining hydrologic connections at wetland and lagoon crossings, and by maintaining a 50-ft wetland, shoreline, and riparian buffer for preserved areas whenever possible, these impacts have been greatly reduced and minimized relative to initial conservative impact estimates. This includes limiting the roads required to cross wetlands to a 20-ft width and requiring culverts to maintain hydrologic connectivity at crossings. In addition to wetlands, about 3.5 of the existing 5.2 acres of other waters of the US would be impacted in the form of fill in a lagoon area adjacent to and along the jetty. There would be a road and crossing over these waters, which would be crossed with culverts in order to maintain flows into and out of the marsh wetland complex; and the 40-ft wide causeway/jetty access roadway would be constructed immediately adjacent to the jetty in order to minimize interference with and impacts to the inlet of the marsh complex.

According to the Cowardin Classification system (1979), of the wetlands impacted, approximately: 0.77 acres are classified as Estuarine-Intertidal-Emergent-Persistent; 0.66 acres are classified as Palustrine-Forested-Needled-leaved-Evergreen; 0.75 are classified as Palustrine-Emergent-Non-persistent; and, 0.47 acres are classified as Palustrine-Forested-Broad-leaved-Deciduous.

As described in the South Jetty section under Landforms 2.1.3., wetlands were scored for grouped service functions as define by ORWAP (2010), and the categories depressional and estuarine were identified.

It is notable that Cowardin and Hydrogeomorphic (HGM) classifications are not necessarily the same thing. For ORWAP scoring purposes, the HGM class for Estuarine appears broader than the Cowardin class. Because a portion of the wetlands preserved and impacted may be small, fringe parts of a larger wetland complex or feature (with possibly a tenuous connection to those other wetlands); therefore the dominant hydrological influence of the greater wetland area was considered. In some cases though the wetland was classified under Cowardin as Palustrine (considering landscape position and degree of connectivity of the delineated area to the greater wetland area), the greater dominating hydrologic regime was tidal (therefore the Estuarine classification in ORWAP).

Following this method in determining the types of wetland impacts, this brings the totals under the ORWAP categories to 1.15 acres of impacts to depressional wetlands at the South Jetty, which were ranked relatively as follows: low for hydrologic function and fish support group; and high for water quality, carbon sequestration, aquatic support, and terrestrial support. Alternatively, the relative scores for the grouped service values were: low for hydrologic function, terrestrial support, and public use and recognition; equal for provisioning services, and high for water quality, fish support, and aquatic support. The wetlands also ranked relatively high for ecological condition and sensitivity, and low for stressors.

In comparison to State wetland scores for grouped service functions as define by ORWAP (2010), 1.49 acres of impacts would affect estuarine wetlands at the South Jetty which are ranked relatively as follows: low for hydrologic function, aquatic support, and terrestrial support; and high for water quality, carbon sequestration, and fish support group. Alternatively, the relative scores for the grouped service values were: low for hydrologic function, aquatic support, terrestrial support, and public use and recognition; equal for provisioning services, and high for water quality and fish support. The wetlands also ranked relatively high for ecological condition, and low for stressors and sensitivity.

Figure 45. Illustration of Avoidance, Minimization, and Wetland Impacts at South Jetty

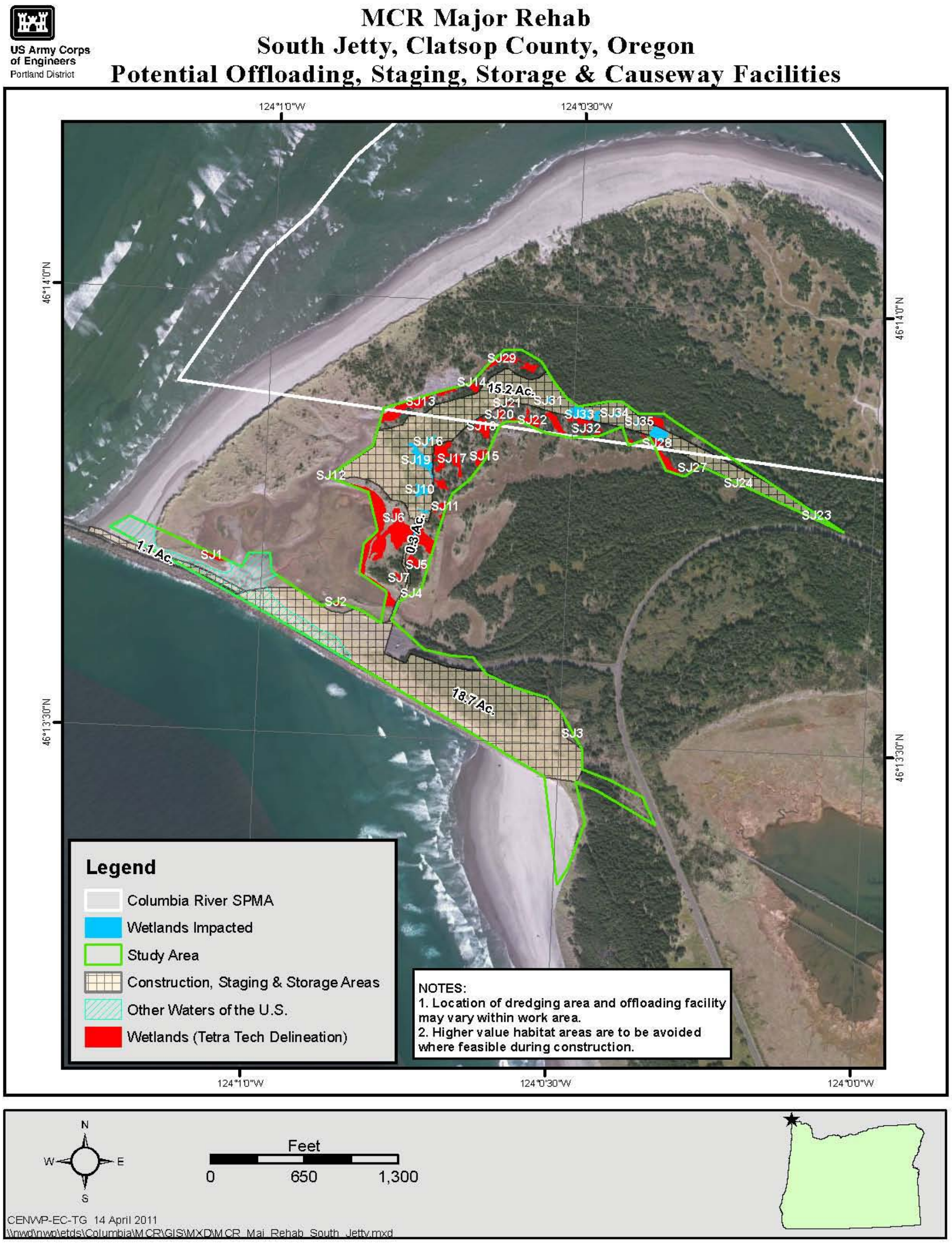


Figure 45 Continued: Illustration of Avoidance, Minimization, and Wetland Impacts at South Jetty

These wetlands would be mitigated near the impact site in an area identified in Trestle Bay near the channel entrance to Swash Lake. At a 2:1 mitigation ratio, this equals about 5.3 acres of wetland mitigation. Anecdotally, it is thought that the uplands in this area are the result of previous historic fill from the dredging the adjacent channel, so that excavation of uplands would result in restoration of wetland that are likely to be intertidal. There is also a former Oregon Department of Transportation (ODOT) mitigation site that the Corps would likely abut. This is an appropriate mitigation site because it is within the same sub-watershed (HUC 7), and per the ORWAP scoring and Cowardin classification, the adjacent areas have wetland types similar to those being impacted. The likelihood of successful wetland plant establishment is also higher because of proximity to already functioning native wetland communities and existing hydrology.

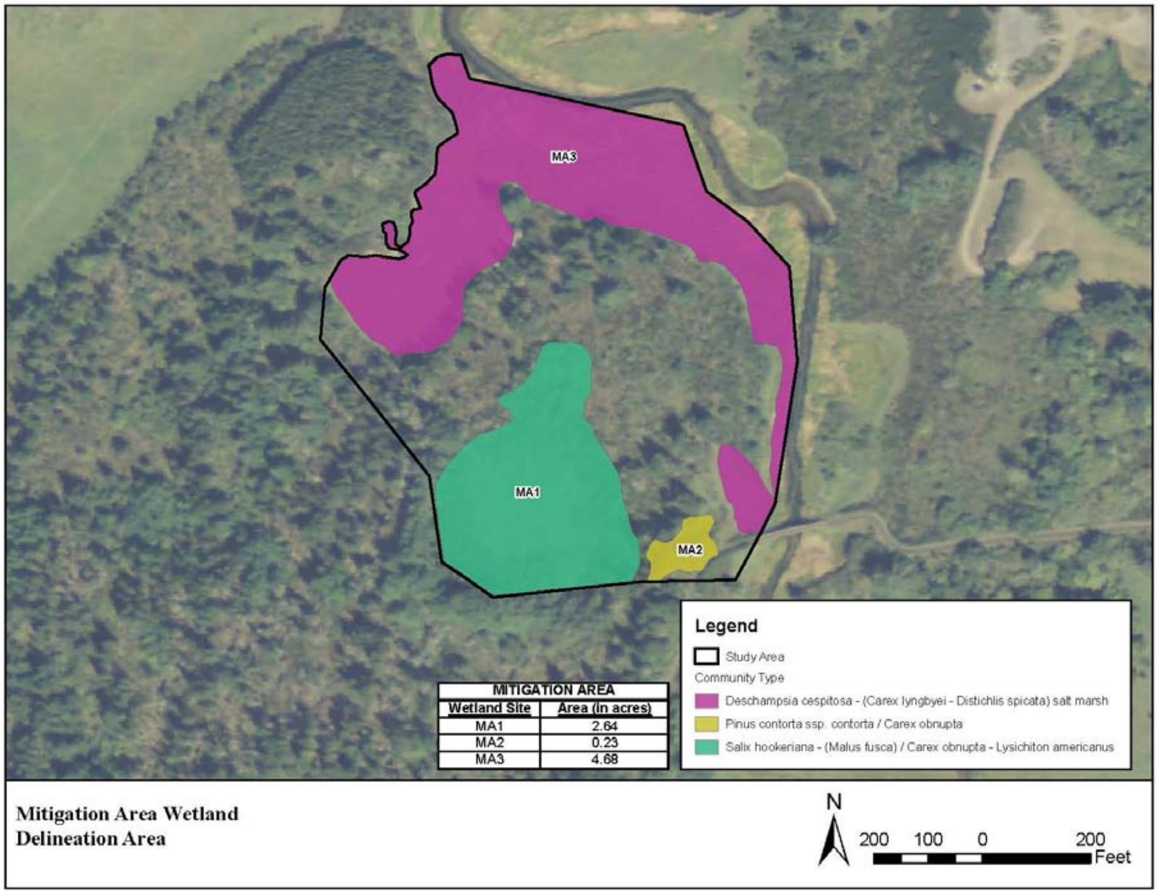
In comparison to State wetland scores for grouped service functions as define by ORWAP (2010), depressional wetlands at the South Jetty mitigation area are ranked relatively as follows: low for hydrologic function, carbon sequestration, fish support group, and aquatic support; and high for terrestrial support; and equal for water quality. Alternatively, the relative scores for the grouped service values were: low for hydrologic function, aquatic support, terrestrial support, and public use and recognition; equal for provisioning services, and high for water quality and fish support. The wetlands also ranked relatively high for ecological condition and sensitivity, and low for stressors.

In comparison to State wetland scores for grouped service functions as define by ORWAP (2010), estuarine wetlands at the South Jetty mitigation area are ranked relatively as follows: low for hydrologic function and water quality; and high for carbon sequestration, fish support group, aquatic support, and terrestrial support. Alternatively, the relative scores for the grouped service values were: low for hydrologic function, aquatic support, terrestrial support, and public use and recognition; equal for provisioning services, and high for water quality and fish support. The wetlands also ranked relatively high for ecological condition and stressors, and low for sensitivity.

Proximity of the uplands proposed for wetland conversion to the existing wetlands from both classes that had similar ORWAP scores at the mitigation site, in addition to tidal and precipitation hydrology should serve as reasonable indicators for potential success of the mitigation site. For all proposed mitigation, detailed designs, plans, and specifications will be further determined in the next stages of project development and will be constructed concurrent with wetland impacts.

Actions adjacent to or onsite of the North and South Jetties that were identified to mitigate wetland impacts include excavation of low and high saltwater marsh wetlands and new interdunal wetlands adjacent to existing wetlands; establishment of native wetland plant communities and removal of invasive species around a buffer zone for wetlands; restoration or provision of hydrology to newly excavated wetlands via appropriate elevation design; and/or restoration of wetland connectivity between existing fragmented wetlands. Offsite opportunities for wetland mitigation in the estuary that warranted further investigation were associated with: levee breaches, inlet improvements, or tide gate retrofits, as appropriate. However, these are not the preferred mitigation as part of the Preferred Alternative as they were further away from the impacted areas and were not of similar wetland or habitat type impacted. Purchasing mitigation bank credits was considered as a possibility, though this is currently constrained by limitations of service area and availability of appropriate wetland types. Hydrology and vegetative communities are heavily influenced by elevation; therefore, providing improved hydrology combined with strategic excavation and appropriate plantings should result in a simple and self-sustaining design and outcome.

Figure 46. Illustration of Wetland Mitigation Area Near the South Jetty



5.6.2. Fill in Waters Other Than Wetlands and Mitigation

In-water habitats (below MHHW), both shallow intertidal and deeper subtidal areas would also be affected by the project. These waters are also considered “waters of the US” as defined by the Clean Water Act. Habitat conversions and impact to 404 waters would occur from lagoon fill, maintenance dredging, jetty cross-sections, turnouts, barge offloading facilities, and causeways. Effects to waters and the aquatic resources residing there would occur on a temporal and spatial scale. Though dredged areas may refill over time and some facilities and fill may be removed, there would still be repeated and chronic site disturbance in these waters over the duration of the project. There would also be permanent lagoon fill at the North Jetty root and temporary, partial lagoon fill at the South Jetty for construction access. Fill would be in place for several years. Barge offloading facilities are a potential method of delivery for stone and other construction materials. If barge offloading facilities are used, this would create the largest impacts to 404 waters of the US and associated aquatic habitat. Therefore, the associated fill acreages and volumes represent the worst-case scenario for spatial and temporal effects.

The calculated extents of impacts were strictly based on the area of habitat that was converted by fill or removal. They did not include value or functional assignments regarding the significance of the conversion, whether it was a beneficial, neutral, or detrimental effect to specific species, nor if conversions created unforeseen, indirect far-field effects. For example, acreage of conversion for shallow sandy sub-tidal habitat to rocky sub-tidal habitat was calculated in the same manner as conversion from shallow intertidal habitat to shallow sub-tidal habitat. Multiple aquatic species utilize these waters, including macro-invertebrates like crabs, benthic organisms, marine mammals, and various other fish and wildlife species. It is also notable that impacts to 404 waters of the US would occur in an area that is listed as Essential Fish Habitat (EFH) for various species as well as in Critical Habitat for several listed ESA species. This impact was described in the 404 (b) (1) analysis.

In WA at MCR, the CWA beneficial use designations for fresh waters by Water Resource Inventory Area (WRIA) include the following general and specific uses: Aquatic Life Uses - Spawning/Rearing; Recreation Uses; Water Supply Uses; Misc. Uses - Wildlife Habitat, Harvesting, Commerce/Navigation, Boating, and Aesthetics. In OR, the following list of beneficial uses were identified: Anadromous Fish Passage; Drinking Water; Resident Fish and Aquatic Life; Estuarine Water; Shellfish Growing; Human Health; and Water Contact Recreation. These designated beneficial uses also include specific water quality criteria to protect the most sensitive uses, which includes use by salmonids for rearing and migration. For this reason, mitigation under the CWA also complements protections and conservation measures under the ESA for salmon and steelhead.

Without drawing a distinction between depths or tidal elevations, initial acreage estimates for all in-water impacts and habitat conversions in 404 waters of the US include:

- <u>North Jetty</u> ~12.38 acres (8.02 lagoon fill – this would occur during Major Maintenance; 0.63. barge offloading facilities, crane set-up pads, and turnouts; 3.73 dredging at offloading facility – the latter actions would occur during the Major Rehabilitation scenario.)
- <u>South Jetty</u> ~13.84 acres (3.5 lagoon fill; 0.4 crane set-up pads, and turnouts; 1.56 barge offloading facilities; 8.38 dredging at offloading facilities – all actions would occur during the Major Rehabilitation scenario.)
- <u>Jetty A</u> ~ 6.62 acres (2.89 barge offloading facility and causeway; 3.73 dredging at offloading facility– all actions would occur during the Major Rehabilitation scenario.)

This results in an estimated total of ~ 32.84 acres of potential in-water conversions and effects to 404 waters of the US other than wetlands.

Shallow-water habitat is especially important to several species in the estuary; thus, specific initial estimates were calculated regarding shallow-water habitat (shallow here defined as -20-feet or -23-feet below MLLW). About 21 acres at these depths would be affected by maintenance dredging and construction of the causeways and barge offloading facilities. About 12 acres would be affected by lagoon fill. However, this estimate does NOT include any expansion of the jetty's existing footprint or overwater structures from barge offloading facilities. For this analysis, there was no distinction drawn between periodically exposed intertidal habitat and shallow-water sandflat habitat. These approximations would be updated as project designs are refined and as additional surveys are completed to quantify changes in jetty and dune cross sections. However, these shallow-water footprints are very small as a relative percentage of the ~19,575 acres of shallow-water habitat available within a 3-mile proximity to the MCR.

Because of these impacts, the Corps has proposed mitigation actions at a ratio of 1.5:1 to offset temporal and spatial impacts to 404 waters and associated aquatic resources. This ratio was determined with input from the resource agencies considering several factors including: beneficial use listings that involve species with EFH and critical habitat designations in the impacted areas, the duration of the construction period, the number of different beneficial uses in the area impacted by the project, and the temporal and spatial extent of the actions. These actions are not proposed to directly mitigate or compensate for any project-related impacts to ESA-listed species but will mitigate for effects to CWA 404 waters of the US. However, the 404 mitigation actions would also complement but are not driven by Conservation Recommendations in the NMFS BiOp for recovery of ESA-listed salmonid habitats and ecosystem functions and processes.

Mitigation features would be commensurate with impacts and would be designed to create or improve aquatic habitat. In-kind mitigation opportunities for impacts to 404 waters were investigated specifically tidal marsh, swamp, and shallow water and flats habitat. Though a specific site or action has yet to be determined for mitigation of impacts to waters other than wetlands, if possible fish access to these mitigation features would be an important consideration.

From the list of possible mitigation features shown in Table 31, one or a combination of actions would be selected for further development and implementation in order to offset actions affecting 404 waters. Selection would occur by the Corps with input from the AMT regarding appropriate project design and possible completion of supplementary compliance documentation, and work is anticipated to be completed concurrent with jetty repair actions.

Table 31. Summary of Estimated Acreages for 404 Wetland and Waters Mitigation

Jetty	404 Wetland Mitigation (2:1)	404 Waters Mitigation (1.5:1)
North Jetty total acres	2.28 (1.14 x 2)	18.57 (12.38 x 1.5)
South Jetty total acres	5.3 (2.65 x 2)	20.76 (13.84 x 1.5)
Jetty A total acres	1.82 (.91 x 2)	9.93 (6.62 x 1.5)
Approximate total acres of mitigation	9.4 (4.7 x 2)	49.26 (32.84 x 1.5)

Table 32. Possible Mitigation Features for Impacts to 404 Waters of the US – Final to be Determined

Feature/Site	Area Affected	Type and Function
Trestle Bay	5-8 acres with potential of additional acres	Estuarine Saltwater Marsh Wetland and Intertidal Mudflat Creation and Restoration • Create and expand estuarine intertidal brackish saltwater marsh wetland habitat • Expand and restore Lyngby sedge plant community • Expand/increase intertidal shallow water habitat, including dendritic mud flats and off-channel habitat • Remove and control invasive species and improve/restore diversity and density of native plant assemblages • Increase habitat complexity for fisheries benefit • Potentially expand floodplain terrace and improve riparian function • (Re)introduce natural tidal disturbance regime to area currently upland dunes
Wetland Creation at Cape Disappointment	Up to ~ 10 acres	Creation and Expansion of Inter-dunal Wetland Complex • Excavation of new interdunal wetlands adjacent to existing wetlands • Establishment of native wetland plant communities and removal of invasive species around a buffer zone • Restoration or provision of hydrology to newly excavated wetlands via appropriate elevation design • Restoration of wetland connectivity between existing fragmented wetlands via culvert retrofits, if feasible
Tide Gate Retrofits for Salmonid Passage	Variable	Select Tributaries from ODFW Priority Culvert Repair List - Tributary Reconnection • Restore and improve existing fish passage and provide access throughout greater range of flows to off-channel juvenile rearing, refuge, and foraging habitat • Restore and increase habitat complexity for fisheries benefit • Restore and improve adult salmonid access to headwaters and potential spawning habitat
Pile Dike Removal	Variable	Remove Existing Pile Dike Fields • Restore and improve existing aquatic habitat • Restore and increase habitat complexity for fisheries benefit
Beneficial Use of Dredge Material	Variable	Beneficial Placement of Dredge Material • Restore and improve existing aquatic habitat • Restore and increase habitat complexity for fisheries benefit

Specific opportunities were investigated in the Columbia River estuary and Youngs Bay (see Table 30) and several are under consideration to mitigate for impacted aquatic functions in 404 waters of the US. Depending on further development and determination of appropriate mitigation siting for final impacts to 404 waters, a specific project or combination of projects would be designed and constructed concurrently as the proposed repair and rehabilitation options are completed over time. Proposed projects are subject to further analysis, and unforeseen circumstances may preclude further development of any specific project. In all cases, final selection, design, and completion of specific mitigation features is contingent on evolving factors and further analyses including: potential reduction in estimated impact acreage due to alterations in project implementation, hydraulic and hydrologic conditions, cultural resource issues, etc. For this reason a suite of potential proposals has been identified and subsequent selection of one or some combination of these or other projects and designs would occur during continued discussion with resource agencies participating on the AMT. The Corps would make a decision regarding the specific mitigation proposal for waters other than wetlands and then would vet the final designs through the AMT in order to obtain necessary clearances.

Actions considered and investigated to provide mitigation for in-water habitat impacts include levee breaches, inlet improvements, or tide gate retrofits. However, mitigation efforts must consider in-kind mitigation and are constrained by the project's O&M authority, which precludes acquisition of private property and does not authorize breaches of federal levees. Additional associated actions that were investigated and may be implemented with the wetland mitigation include: excavation in sand dunes and uplands to specified design elevations in order to create additional intertidal shallow-water habitat with dendritic channels and mud flats, and excavation for potential expansion of the floodplain terraces. Though conceptually considered, other specific opportunities for mitigation projects such as the following were not identified but warrant further investigation if none of the projects in the list is determined to be feasible: removal of overwater structures and fill in the estuary; removal of relic pile-dike fields; removal of fill from Trestle Bay or elsewhere; removal of shoreline erosion control structures and replacement with bioengineering features; beneficial use of dredge material to create shallow water habitat features; and restoration of eelgrass beds. Certain pile fields and engineering features may be providing current habitat benefits that could be lost with removal, and such actions would require appropriate hydraulic analysis coordination with engineers and resource agencies.

For potential mitigation projects located in Trestle Bay, there is additional monitoring and assessment opportunity. A separate hydraulic/engineering study under a different project authority could investigate whether or not an expansion of low-energy, intertidal habitat near Swash Lake could effectively provide additional storage capacity and affect circulation in the bay such that erosive pressure at neck of Clatsop Spit could be reduced. This would not be covered under the existing project authority. A previous Section 1135 action that breached a section of the relic jetty structure is speculated to have been the cause of increased circulation and erosion. It would be worth evaluating whether or not projects that expand floodplain and intertidal areas in Trestle Bay provide demonstrable energy dissipation and additional low-energy storage capacity to offset or redirect erosive pressures. Alternatively, if other mitigation concepts are pursued that include removal of additional piles or creation of additional inlets, it would be worth investigating whether these actions could have indirect positive impacts that further reduce concern with erosion at the neck. Evaluating actions in this light would provide valuable information and insight regarding possible solutions and concerns for erosion and breaching at the neck area of Clatsop Spit on Trestle Bay.

5.6.3. General Wetland Mitigation Design and Monitoring

As mentioned, wetlands at Jetty A and North Jetty would be mitigated immediately north of the North Jetty Road adjacent to the project site. This is an appropriate location for the North Jetty impacts because mitigation remains as near the impact area as possible and compensates for mostly the same wetland types, of which the majority are interdunal depressional. For Jetty A, space is unavailable near the jetty, and the likelihood of successful creation is higher in the North Jetty location due to the land use requirements and disturbance from Coast Guard activities at Jetty A. Based on adjacent reference wetlands at the North Jetty of the same type, appropriate elevations would be determined, and existing uplands would be cleared of invasive species and excavated and graded to the appropriate depths and contours.

Materials removed from impacted wetlands would be reused in the created wetlands as appropriate to take advantage of the existing wetland seed bank and hydrologic soils constituents. Plantings, revegetation, and invasive species removal would also be implemented, including the required buffer around the new wetland area. It is anticipated that upland material removed during wetland creation would be placed as part of the lagoon fill. With ample precipitation, functioning adjacent reference sites, and appropriate plantings, the likelihood of successful wetland establishment is reasonably high.

At the South Jetty, wetland mitigation would take place adjacent to an existing mitigation site further southwest of the impact area at the bottom of Trestle Bay such that there are reference elevations and hydrophytic species to facilitate design planning and vegetation establishment, respectively. The mitigation location near Swash Lake is not as close to the area of impacts as the site at the North Jetty, but the proposed location is further away from areas experiencing heavy recreation and all-terrain vehicle (ATV) use such as is occurring in the existing wetlands on Clatsop Spit. Therefore, the likelihood of successful wetland establishment is greater in the proposed location.

The process for creating the wetlands at the South Jetty site would be similar to that at the North Jetty, but an additional dendritic channel may also be included as appropriate such that newly created wetlands experience an estuarine connection like those that are being impacted by the project. This would also involve excavation to create hydrologic conditions based on tidal and reference site elevations

Monitoring of all mitigation sites is expected to occur prior to, during, and for three years after mitigation implementation. For wetlands, sample reference plots would be established along with a photo point, and success criteria would be based on achievement similar or better functions and values scores relative to those indicated by the delineations for those impacted by the project. Monitoring components would likely include the following elements, which may be modified as further mitigation development details are available: percent survival; percent cover; percent of native vs. non-native species; and achievement of appropriate hydrology. Hydrologic indicators would include establishment of topography and contouring/geomorphology that is similar to adjacent representative sites, and in the case of South Jetty, achievement of regular tidal inundation. Appropriate monitoring criteria would also be developed for the mitigation to waters other than wetlands.

Refinement and implementation of this overall mitigation plan would help protect species and habitats while restoring wetland, inwater, and upland functions affected by the proposed action. Monitoring and maintenance of mitigation will be required to ensure successful establishment of mitigation goals and satisfactory return on investment. These mitigation actions and monitoring results would also be recorded on the Corps mitigation website at: https://sam-db01mob.sam.ds.usace.army.mil:4443/pls/apex/f?p=107:1:1390572094248259. Regular coordination with the AMT would further facilitate implementation of appropriate mitigation for impacts to wetlands and waters that appropriately offset affected habitat and are complementary to the framework for successful protection and preservation of aquatic resources, ESA listed species, and high-value habitat.

5.7. Uplands Disturbance and Re-stabilization

As described in the Construction Implementation section, rock storage and staging areas would impact both wetlands as well as uplands. Best Management Practices (BMP) to reduce the environmental footprint and to avoid, and minimize impacts have been incorporated and would be implemented, including appropriately locating staging sites, implementing stormwater management plans, and stabilizing the site during and after construction. Post-construction upland re-stabilization to meet CWA National Pollution Discharge Elimination System (NPDES) requirements would include re-establishing native grasses, shrubs, and trees where appropriate; controlling and removing invasive species like scotch broom and European beach grass in the project vicinity; and re-grading/tilling the area to restore pre-project natural contours. The Oregon Parks and Recreation Department (OPRD) has requested that the Corps utilize the State Forester as one resource for determining optimal revegetation plans.

Upland Replanting - (1:1) NPDES site stabilization

- North Jetty total acres: 28.7
- South Jetty total acres: 18.7-28.7 (Depending on snowy plover habitat creation)
- Jetty A total acres: 12
- Approximate total acres of stabilization: 69.4

As mentioned, on Clatsop Spit, there is a unique opportunity to partner with USFWS and OPRD regarding creation and management of snowy plover habitat. The OPRD (2010) developed a HCP to manage snowy plover habitat. There may be locations in the vicinity and away from projected construction and staging areas to convert upland habitat to snowy plover habitat via invasive species removal, tilling, and application of shell hash. Operation and maintenance during the project via regular tilling and shell hash distribution could possibly be coordinated between the agencies through a Memorandum of Agreement (MOA) or similar avenue. This scenario would also provide preferable alternative habitat away from the potential attractive nuisance of open sands that the construction disturbance would create. The Corps currently has a signed MOA indicating it will cooperate with OPRD in the implementation of the snowy plover management plan under development. Habitat creation would also be consistent with the intent of the HCP and the Conservation Measures recommended by USFWS.

6. ENVIRONMENTAL CONSEQUENCES

The Corps has determined that elements of the proposed action could have effects discussed in the following section. However, through this EA and associated Biological Assessments and completed Consultations with resource agencies, the Corps has come to a determination that the proposed actions under the selected plan will not result in long-term or large-scale adverse impacts to the human environment.

- Rock Transport
- Construction Access, Staging, Storage, And Rock Stockpiling
- Rock Placement
- Dredging
- Disposal
- Barge Offloading Facilities
- Pile Installation and Removal
- Lagoon And Wetland Fill And Culvert Replacement
- Dune Augmentation
- Water Quality
    - Suspended sediment
        - Dredging
        - Disposal
        - Pile Installation and Removal
    - Spills Leaks
    - Contamination
- Hydraulic and Hydrological Processes
    - Water Velocity
    - Salinity and Plume Dynamics
    - Bed Morphology
- Wetland and Waters Mitigation

6.1. Rock Transport

Barge transport of stone from quarry sites is likely and would occur mostly during daylight hours along major navigation routes in existing harbors and navigation channels. The number of additional barge trips per year attributable to the proposed action is expected to be somewhere between 8 and 22 ships. This is small annual percentage increase relative to the current number of other commercial and recreational vessels already using any of these potential routes. The MCR is the gateway to the Columbia-Snake River system, accommodating commercial traffic with an approximate annual value of $20 billion dollars a year. Loaded water-borne container traffic identified as foreign in- and outbound to/from Portland that would likely have crossed the MCR in 2008 totaled approximately 195,489 ships (Corps 2010). Traffic from the proposed action will also be limited mostly to summer months when fair weather allows safe passage. Though transport will occur on an annual basis, stone may or may not be delivered to one or more jetties seasonally. Due to the infrequency of these vessel trips, their geographic limitation to existing navigation channels, and their minimal duration in any particular area, the disturbance effects are expected to be discountable. The proposed action will not cause any meaningful increase (less than 1%) in annual vessel traffic along the routes or around the MCR jetty system. Any increase in acoustic levels from barge traffic during delivery will be transient. Sound levels are expected to return to background near the source, and are not expected reach harmful levels. Therefore, these effects are negligible and discountable.

6.2. Construction Staging, Storage, and Rock Stock Piles

Construction activities will occur on an annual basis, could happen throughout the year, and may occur at one or more jetties simultaneously. Upland effects could include repetitive disturbance; de-vegetation; residual rock side-cast; and soil compaction. Changes in soil structure and composition could also result in localized habitat conversion of the vegetative and biological communities. Invasive species are located in the vicinity of all three jetties, and chronic disturbance can increase the spread and establishment of such species. Changes in the plant communities can also cause trophic effects on the faunal communities that rely on these ecosystems for forage and habitat. However, The Corps is not aware of any listed plant or invertebrate species present in the proposed action area. The Corps expects effects to aquatic listed species from associated construction activities for staging, roadways, and stockpiles to be localized at all jetties, as the majority of these construction features are located in upland areas above mean high tide elevation. Thus, species exposure is highly unlikely.

Avoidance and minimization measures have also reduced and contained the construction footprint where possible, and higher value habits like marsh wetlands and slough sedge communities have been preserved such that activities are limited to areas where previous disturbance and development have already occurred. Wetland fill effects from these activities are discussed in the wetland fill section. Whenever feasible, stabilizing dune vegetation is being preserved and little if any riparian or vegetative cover will be removed or disturbed. Furthermore, protective fencing, set-backs, and an Erosion and Sediment Control Plan or Stormwater Protection Plan will be implemented so that BMPs avoid stormwater erosion and run-off from disturbed areas. The topography in this area is flat, and proposed impact minimization measures for construction will reduce the likelihood for sediment to enter the Columbia River. When construction activities are suspended for the season, appropriate demobilization and site stabilization plans will limit the distribution and duration of any effects. No pollutants are expected to enter waterways. There may be some disturbance from equipment sounds and human presence, but these will be indirect and of low intensity, mostly during daylight hours and summer months. Therefore, disturbance effects from these activities are expected to be minimal.

Any increase in acoustic levels from truck traffic during delivery will be transient and intermittent. Conservation measures limit the hours for stone delivery as well as the use of compression brakes, which will reduce species exposure to acoustic effects. Trucks will only be allowed to use the roads through Cape Disappointment State Park during daylight hours. Sound levels are expected to return to background near the source, and are not expected reach harmful levels. Therefore, these effects are negligible and discountable. There may be some disturbance from equipment sounds and human presence, but these will be indirect and of low intensity, mostly during daylight hours and summer months. The geographic area will be limited, and species will be able to avoid work areas. Therefore, disturbance effects from these activities are expected to be minimal and discountable.

6.3. Rock Placement

Rock placement will occur on an annual basis starting in the late spring through the late to early fall seasons. Placement may occur at more than one jetty per season and will occur regularly throughout the duration of the construction schedule. Some permanent habitat conversion and modification will occur as a result of stone placement for repair and rehabilitation of jetty features. Along specific portions of North and South jetties and along the entire length of Jetty A, substrate will be converted to rocky sub and intertidal habitat, and associated benthic communities will be covered. In addition, crane set-up pads and turnouts will require placement of rock that could extend slightly off the current centerline of the jetty trunk. However, this total area is a relatively small percentage of the existing jetty structures. Generally, effects to in-water habitat could include the following: sub-tidal and intertidal habitat conversion from sandy to rocky substrate and potential unforeseen indirect far-field effects from hydraulic influence (slight, localized changes to accretion, currents, velocities, etc). However, relatively little habitat conversion and footprint expansion will occur because a majority of the stone placement for construction of the jetty head, trunk, and root features will occur on existing relic jetty stone and within the existing structural prism. Moreover, aquatic species would experience limited exposure since stone placement for cross-section repair and rehabilitation actions occurs mostly above the MHHW elevation. This is summarized below for each jetty.

6.3.1. North Jetty

- About 58% of overall stone placement on the jetty will be placed above MHHW, about 25% of the volume between MHHW and MLLW, and about 18% of the volume below MLLW. Thus, about 83% of the volume placed for trunk and root cross-section repairs is above MLLW. There is no expected expansion of the footprint beyond relic jetty stone/structure.
- Stone placement for offloading facilities, turn-outs, and set-up pad facilities will cover and convert about 0.63 acres and will be confined within the same location as the stone placed for repairs. This is a small percentage relative to the existing acreage of jetty structure and available adjacent remaining shallow-water sand habitat in the vicinity.

6.3.2. South Jetty

- Stone placement for offloading facilities, causeways, turn-out, and set-up pad facilities will cover and convert about 1.96 acres. This is a small percentage relative to the existing acreage of jetty structure and available adjacent remaining shallow-water sand habitat in the vicinity.

6.3.3. Jetty A

- Stone placement for barge offloading facilities, causeways, turn-out, and set-up pad facilities will cover and convert about 2.89 acres. This is a small percentage relative to the existing acreage of jetty structure and available adjacent remaining shallow-water sand habitat in the vicinity.

Indirect disturbance effects due to placement activities will be localized and occur mostly during daylight hours in the summer months. Disturbance effects are expected to be of limited duration and minimal, since a majority of the placement is above MHHW and on existing relic stone. Acoustic effects of construction on the jetties similar to those mentioned in the Construction and Staging section are less likely to reach the land at levels much above background. There may be temporary disturbance to species using the jetty structure in the vicinity of placement activities. However, the Corps does not expect long-term negative effects from these actions.

6.4. Dredging

Dredging will be needed for construction and maintenance of barge offloading facilities and is likely during early summer prior to rock delivery; it may not occur at all facilities annually. If all facilities were dredged, this would total about 16 acres near the jetties. However, it is likely only one or two facilities would be used seasonally for short durations and would be dredged on a periodic basis as needed. The effects of dredging on physical habitat features include modification of bottom topography, which in the vicinity of the jetties is extremely dynamic. Dredging may convert intertidal habitats to subtidal, or shallow subtidal habitats to deeper subtidal. Such conversions may affect plant and animal assemblages uniquely adapted to the particular site conditions these habitats offer. However, the dredge prisms would be very small as a relative percentage of the ~19,575 acres of shallow-water habitat available within a 3-mile proximity to the MCR. The proposed dredging of offloading facilities would affect bottom topography, but is unlikely to cause large-scale or long-term effects to habitat features. Dredging activities will also have some contribution to increased acoustic disturbance that could occur for a limited duration while dredging is underway. These effects are expected to attenuate rapidly such that they return to background levels within a short distance from the source. Dredging effects on water quality and suspended sediment are discussed below in the Water Quality section.

6.5. Disposal

Disposal is likely to occur on an annual basis originating from one or more of the offloading facilities. The duration of disposal will be limited to daylight hours for a few days out of the year and will likely occur earlier in the construction season in the spring or summer when ocean and wave conditions permit safe operations and prior to use of offloading facilities. All disposal of dredged material will be placed in previously evaluated and USEPA-approved ODMDS or other approved disposal sites. No new or different impacts to species or habitats than those previously evaluated by USEPA or other resource agencies for disposal approval are expected from these actions. Per USEPA guidelines, the ODMDS have a Site Management and Monitoring Plan that is aimed at assuring that disposal activities will not unreasonably degrade or endanger the marine environment. This involves regulating the time, quantity, and physical/chemical characteristics of dredged material that is placed in the site; establishing disposal controls; and monitoring the site environs to verify that unanticipated or deleterious adverse effects are not occurring from past or continued use of the site and that permit terms are met. The relative quantities, characteristics, and effects of the proposed action would not be expected to have different or measurable negative impacts to these sites.

The effects of disposal on physical habitat features include modification of bottom topography. In some cases, disposal may result in the mounding of sediments on the bed of the disposal site. Such conversions may affect plant and animal assemblages uniquely adapted to the particular site conditions these habitats offer. However, the area impacted by disposal would be relatively small compared to the thousands of acres of shallow and deeper water habitats at and beyond the MCR and would occur in deeper habitat offshore or in the littoral cell. The proposed disposal is unlikely to cause large-scale or long-term effects to habitat features. Disposal effects on suspended sediment are discussed below in the Water Quality section.

6.6. Barge Offloading Facilities

Barge offloading facilities are a potential method of delivery for stone and other construction materials. If barge offloading facilities are used, this would create the largest impacts to 404 waters of the US and associated aquatic habitat. Therefore, the associated fill acreages and volumes represent the worst-case scenario for spatial and temporal effects.

Installation of offloading facilities is likely to occur once in the late spring or early summer prior to or during the first season of construction on the associated jetty. Subsequently, periodic maintenance may be required as facilities weather wave and current conditions. Effects associated with dredging are discussed in that section. Facilities may also occasionally be partially removed and reconstructed, which could slightly increase the frequency of disturbance. Depending on the specific facility and contemporary conditions at the time, removal would then occur at the end of the scheduled construction duration. Temporally, this limits the repetition of disturbance activities associated with the construction of these facilities. Use of the facilities may be annual with periodic breaks in between, depending on the construction schedule and conditions at the jetties. Annual use is likely at least one of the facilities and will be seasonally concentrated in the spring, summer, and fall. Although unlikely, occasional breaks in weather could allow offloading at other times of the year.

Stone placement for barge offloading facilities could have the same minimal effects described previously under rock placement, with the exception of the facility at Parking Lot D on the Clatsop Spit. Construction and maintenance of the facility and associated and piles would be equivalent to actions already occurring from jetty repair and stone placement, and would not cause a separate or cumulative increase in disturbance. Also as mentioned previously, chemically treated wood would not be used for decking material, as treated decking could leach toxic substances into the water. Therefore, water quality is not expected to be negatively impacted by these facilities. Possible effects of the action to water quality are discussed below in the Water Quality section.

Offloading facilities will be areas of slightly increased activity and vessel traffic, but the intensity of use is expected to be low and seasonal in nature. Additional noise from vessel activities may increase disturbance, but acoustic effects are not expected to reach harmful levels and will be geographically and temporally limited. A return to background noise levels is likely near the source. The anticipated effects from pile installation/removal for these facilities are discussed in the next section.

6.7. Pile Installation and Removal

Pile installation and subsequent removal is likely to occur once in the late spring or early summer prior to or during the first season of construction on the associated jetty. Subsequently, periodic maintenance may be required as piles weather barge use and wave/current conditions. Occasionally, piles may be partially removed and reinstalled, which could slightly increase the frequency of disturbance. Depending on the associated offloading facility and contemporary conditions at the time, removal would occur at the end of the scheduled construction duration. Temporally, this limits the repetition of disturbance associated with the installation and removal of these structures.

For initial construction of all four facilities combined, up to approximately 96 Z- or H-piles could be installed as dolphins, and up to approximately 373 sections of Z or H piles installed to retain rock fill. However, it is unlikely that all facilities would be installed at the same time. Installation is likely to happen early in the construction season sometime between April and June, and is weather dependent. Piles will be located within 200-feet of the jetty and offloading structures. Vibratory drivers will be used and will dampen any acoustic effects to fish and other species. Because of the soft substrates in the lower Columbia River, vibratory drivers can be used effectively to install and remove piles. Sound wave form and intensity is not expected to reach harmful levels and are expected to return to background levels within a short distance from the source. Any acoustic impacts would be short duration and intermittent in frequency. Therefore, this action would not be expected to have any considerable direct effects.

The presence of piles at offloading facilities could increase perching opportunities for piscivorous birds, especially cormorants and brown pelicans. However, the use of piling caps will avoid any measurable increase in new perch sites so that effects would be minimized. Furthermore, because perching opportunities for these birds are abundant in the lower Columbia River, piles associated with the proposed action would not be expected to increase cormorant and pelican use in the area.

6.8. Wetland, Waters, Lagoon Fill and Culvert Replacement

Wetlands near North Jetty.
Wetlands within, fringing, and adjacent to the lagoon will be filled in areas and quantities described previously. Fill of wetlands will be permanent. As described, mitigation commensurate with impacts to these wetlands will be developed and implemented concurrent with actions and in coordination with the appropriate resource agencies. The area selected for mitigation is north of the North Jetty Access Road in existing uplands adjacent to a wetland mosaic complex.

Wetlands near South Jetty (on Clatsop Spit).
Efforts have been made to locate rock stockpiles and offloading facilities such that they will avoid and minimize impacts to wetlands and waters, and protections and BMPs will be implemented for the identified rare and ranked vegetative communities within this area. Strategic use of uplands for rock storage has been done to the most practicable extent in order to avoid and minimize these impacts. Wetland fill will be permanent and in the areas and quantities described previously. As with wetlands near the North Jetty, wetland mitigation will be further developed and implemented commensurate and concurrent with impacts, and the Corps will coordinate closely with the appropriate resource agency during planning and design of the mitigation proposals. The selected mitigation area is in uplands adjacent to existing wetlands near the entrance to Swash Lake in Trestle Bay.

Wetlands near Jetty A.
Permanent wetland fill will occur at Jetty A in the areas and quantities previously described. Commensurate with impacts, mitigation will be implemented at the North Jetty adjacent to the North Jetty mitigation area and existing wetland complex.

Wetland fills and culvert installations at all jetties would occur once and could happen during anytime in the construction season depending on weather. Sequentially, these actions would be required prior to several of the other features of the proposed action. They would be considered permanent in nature for the purposes of mitigation because they would be in place for up to four years and will have temporal impacts even if they are eventually removed. Subsequent removal of construction-related culverts would be likely to occur once and could also happen during anytime in the construction season depending on weather and construction needs. Periodic culvert maintenance may be required during construction. Temporally, this limits the repetition of disturbance activities to single event and season on separate jetties.

Where possible, the construction, access, and staging areas at all jetties have been planned so that the footprint would minimize impacts to wetlands and higher value habitat features. Protections and BMPs would be implemented for the identified rare and ranked vegetative communities within the area. Strategic use of uplands and lower quality wetlands for rock storage would be undertaken to the most practicable extent in order to avoid and minimize these impacts. However, permanent and temporary wetland fill would occur as a result of construction staging, storage, and rock stockpiles at all three jetties. Fill used to protect the North Jetty root would also affect wetlands. Long-term direct and indirect impacts to wetlands could include permanent wetland fill, potential fragmentation of and between existing wetlands, soil compaction, loss of vegetation, altered hydrology, conversion to upland, and loss of ecosystem functions (water quality, flood storage, nitrogen cycling, habitat, etc.). However, it is expected that effects from wetland impacts and lagoon fill would be immeasurable regarding effects on river functions, as the wetlands are not within the channel prism of the Columbia River. Although these wetlands are connected hydrologically to the Columbia River, wetland fill impacts would not be likely to negatively alter groundwater-stream exchange or hyporheic flow because the wetlands are on accreted land that has formed on stabilized sand shoals behind the jetties. Wetland hydrology is mostly elevation and rainfall dependent, and fill impacts would be relatively inconsequential to the Columbia channel. Culverts would be installed to maintain wetland hydrology and connectivity with permanent replacement at the North Jetty and when temporary construction roadways cross wetlands. In addition, the overall effects of the wetland and waters mitigation proposed by the Corps are discussed in Section 5.6.

Fill in 404 waters other than wetlands would occur in the form of lagoon fill, offloading facilities, dredging, and stone placement. Off-loading facilities also have temporal as well as spatial impacts and may or may not be removed post-construction; therefore they have been considered as permanent impacts with proposed associated mitigation even if they are removed and eventually infill natural sand recruitment. Effects of these fill actions are more specifically described in the associated subsections in chapter 6. This includes potentially chronic low levels of associated turbidity from barge operations and dredging, impacts to benthic organisms, and conversion of habitat types.

Lagoon fill is also permanent, especially at the North Jetty. Though culverts and drainage will be provided to minimize impacts to associated wetlands, macro-invertebrates and benthic organisms utilizing the lagoon will be buried when fill is placed. An initial sampling survey would be conducted in the lagoons during peak juvenile salmon outmigration to determine whether or not fish salvage and fish exclusion efforts for ESA-listed species is warranted. The Corps would coordinate with NMFS if listed species are identified. Redesign of this system at the North Jetty may provide an opportunity to accommodate improved hydrology to newly created wetlands excavated adjacent to the existing wetland complex, and would be further investigated during the hydraulic/hydrologic design analysis. This action may also result in temporary turbidity as materials settle in the fill area and migrate through the jetty trunk.

6.9. South Jetty Root Erosion and Dune Augmentation

This action is proposed only at the South Jetty. This action would occur once during a single season and could likely happen in the late spring or early summer depending on weather. Temporally and geographically, this limits the repetition of disturbance activities to single event and season on a single jetty. Sequentially, this action would be required prior to several of the other features of the proposed action. Periodic maintenance may be required, likely on a decadal scale.

This action at the South Jetty would occur above mean high tide; thus, this action would cause limited exposure to aquatic species. Although substrate modification would occur along the shoreline, it is not expected that any measurable changes from in-water habitat conversion below MHHW would occur. Clean cobble material would be placed from an existing roadway and delivery via beach access will be prohibited. Some equipment will be required to move materials around on the dry sand. There is little likelihood of having any direct or indirect negative impacts to water quality or intertidal species, and the amount of dry sand conversion is relatively small as compared to the amount of similar adjacent habitat. Cobble replenishment would likely occur on a decadal scale. Thus, the effects of this action would likely be minimal and species exposure unlikely.

6.10. Water Quality

Effects of the proposed action to water quality could occur by increasing suspended sediments, increasing the potential occurrence of spills and leaks, and increasing the potential for contamination. However, the Corps expects these effects to be negligible.

Placement of rock by heavy equipment, jetty access road construction, dredging, disposal, and pile installation and removal could all cause temporary and local increases in suspended sediment. This is expected to have minimal and limited effects on the environment. Previous tests have confirmed that material to be dredged will be primarily sand with little or no fines, which does not stay suspended in the water column for an extended length of time. During infrequent and limited duration dredging and disposal which could occur for a few days annually or less often, depending on use of the facilities, suspended sediments may increase locally for a short time. These increases will dissipate quickly due to the sandy nature of the sediment, and inwater activities will be further constrained to conditions in the State 401 Water Quality Certification that limit the duration of such exceedences. Light attenuation and water quality effects from increased suspended sediments are expected to be minimal and fleeting. Pile driving is also expected to occur in sand and therefore have similar transient and minimal effects to water quality. Jetty roads could also contribute suspended sediments that would create turbidity during stormy seasons or overtopping events, but since they are above MHHW this will likely be an infrequent occurrence. When erosion of roads does occur, the background turbidity and wave climate is likely to also be in a state of increased turbulence and turbidity such that any additional roadway runoff will be a minimal contribution to the dynamic ocean and channel-forming processes churning the waters during overtopping events. Small increases in turbidity from construction activities on the jetties will likely occur on a nearly daily basis but will be of limited extent and duration, as rock placement will involve clean fill of large, individual boulders with a majority of the placement actions occurring above MLLW. Turbidity monitoring and compliance with expected likely conditions of the 401 State Water Quality Certification would also ensure protection of aquatic life and other beneficial uses in the vicinity of the inwater work. Wave and current conditions in the action area naturally contribute to higher background turbidity levels; and such conditions also preclude the effective use of isolating measures to minimize turbidity. However, other BMPs described for the proposed action would further reduce effects of turbidity from the proposed action. Effects from potential stormwater runoff were addressed in the Construction Staging and Stockpile section. Therefore, impact from suspended sediments should be inconsequential.

The Corps will require the contractor to provide a spill prevention and management plan that will include measures to avoid and minimize the potential for spills and leaks and to respond quickly to minimize damages should spills occur. Good construction practices, proper equipment maintenance, appropriate staging set-backs, and use of a fast fueling system would further reduce the likelihood of leak and spill potential and exposure extent and its associated effects.

Test results on dredge material described earlier further indicated that materials in the area are approved for unconfined in-water disposal and do not contain contaminants in concentrations harmful to organisms occupying the action area. The prohibition of treated wood will also avoid contamination from the migration of creosote and its components (e.g., copper and PAHs) from treated wood in the lotic environments.

Temporally, effects to water quality from suspended sediment and turbidity could occur on a daily basis, but are not expected to be continuous throughout the day. Clean, large boulders are not expected to create much discharge, and the substrate on which they are being placed also includes large, weathered boulders. Any other inwater work such as construction or dredging of offloading facilities will involve sandy materials that settle out very quickly. Turbidity levels and durations will be limited to conditions required in the State Water Quality Certifications which will likely include exceedence windows that are protective of beneficial uses such as salmonids and other aquatic life. Spills or leaks are expected to be infrequent and unlikely. Although the repetition of disturbance may be greater, it is still expected to remain within safe ranges that would not have long-term or deleterious effects. Furthermore, effects are expected to be geographically limited, short term, and minor.

6.11. Hydraulic and Hydrologic Processes

The USGS and ERDC conducted numerical modeling to evaluate changes in circulation and velocity, salinity, and sediment transport at the MCR for various rehabilitation design scenarios for the MCR jetty system. A 2007 USGS model evaluation assessed the functional performance for rebuilding the jetty lengths in order to aid in the assessment of potential impacts to fish from the rebuilt lengths. Ultimately, even in the larger rebuild scenario only negligible and inconsequential changes were predicted to the overall hydraulic and hydrological process at the MCR.

<u>For the proposed action addressed in this EA, rebuilding of the jetty lengths is not included</u>. However, model results under the larger jetty length rebuild scenario are still relevant for comparing and evaluating potential changes to the MCR system as a whole. This earlier modeling work also remains valid because the current proposed action in this EA caps the jetties at their present lengths, which is essentially the same length as the “base condition” used in the models.

Modeling by the USGS was performed for two time periods, August-September and October-November. Existing conditions were established using actual data collected in August-September 2005. The October-November model period was established for engineering purposes as this time period represents extreme conditions at the MCR. Plots were produced to show existing and post-rehabilitation conditions for the following parameters: residual (average for all tides) velocity and current direction for bed and near surface, residual bed load transport, residual total load transport (bed load + suspended load), and mean salinity for bed and near surface.

The ERDC analyzed the impacts of the presence of spur groins at the MCR in 2007. This analysis was done independently of the USGS modeling and was conducted with the coastal modeling system (CMS) and other models that operate within the surface water modeling system (SMS). A regional circulation model (ADCIRC) provided the tidal and wind forcing for the boundaries of project-and local-scale wave, current, sediment transport, and morphology change calculated by the CMS. The half-plane version of the wave transformation model, STWAVE, was coupled with two-dimensional and three-dimensional versions of the CMS, which calculates current, sediment transport, and morphology change. These models were coupled to provide wave forcing and update calculated bathymetry used in both models at regular intervals (Connell and Rosati 2007).

The results of these modeling efforts are discussed in the following sections. In summary, the 2007 modeling work remains valid because the current proposed action caps the jetties at their present lengths, which is essentially the same length as the "base condition" used in the 2007 modeling. Modeling results showed that the changes to velocities, currents, salinity, plume dynamics, and bed morphology would be small to negligible under the larger jetty length rebuild scenario with spur groins. Any small changes to the system would be even less unlikely under the current proposed action because it does not involve rebuilding the length of the jetties or adding the spur groins. Therefore, no fundamental overall changes to the current hydraulics or hydrology of the MCR system are anticipated under the current proposed action.

6.11.1. Water Circulation and Velocity

For the August-September period, the USGS model predicted an increase to residual bed layer velocity on the west side of the south portion of Jetty A to currents oriented in a south-southeast direction (Figure 47) but mean differences (existing to predicted) were less than 0.1 meter/second in this area. Smaller changes in residual velocities were predicted for near surface waters in the vicinity of Jetty A (Figure 48; USGS 2007, Moritz 2010). These changes are small (10% or less) relative to the natural variation in the MCR's high-energy environment. In the velocity figures, length of arrows indicates magnitude of velocity, red arrows indicate existing conditions, and black arrows indicate predicted conditions resulting from rebuilding the jetty lengths.

Under the length rebuild scenario, surface current direction for the August-September period was predicted to change slightly toward the north as water flowed around Jetty A forming a more pronounced clockwise eddying effect west of Jetty A and tending to force water more directly toward the North Jetty. However, residual velocities toward the North Jetty were predicted to decrease and this effect would have protected the North Jetty. Predicted changes to current direction in the bed layer are less pronounced than in the surface layer (Figure 49). Changes to current direction and velocities are negligible in the vicinity of the South Jetty (Figure 50; USGS 2007, Moritz 2010).

Figure 47. Residual Velocity Bed Layer for August/September Period

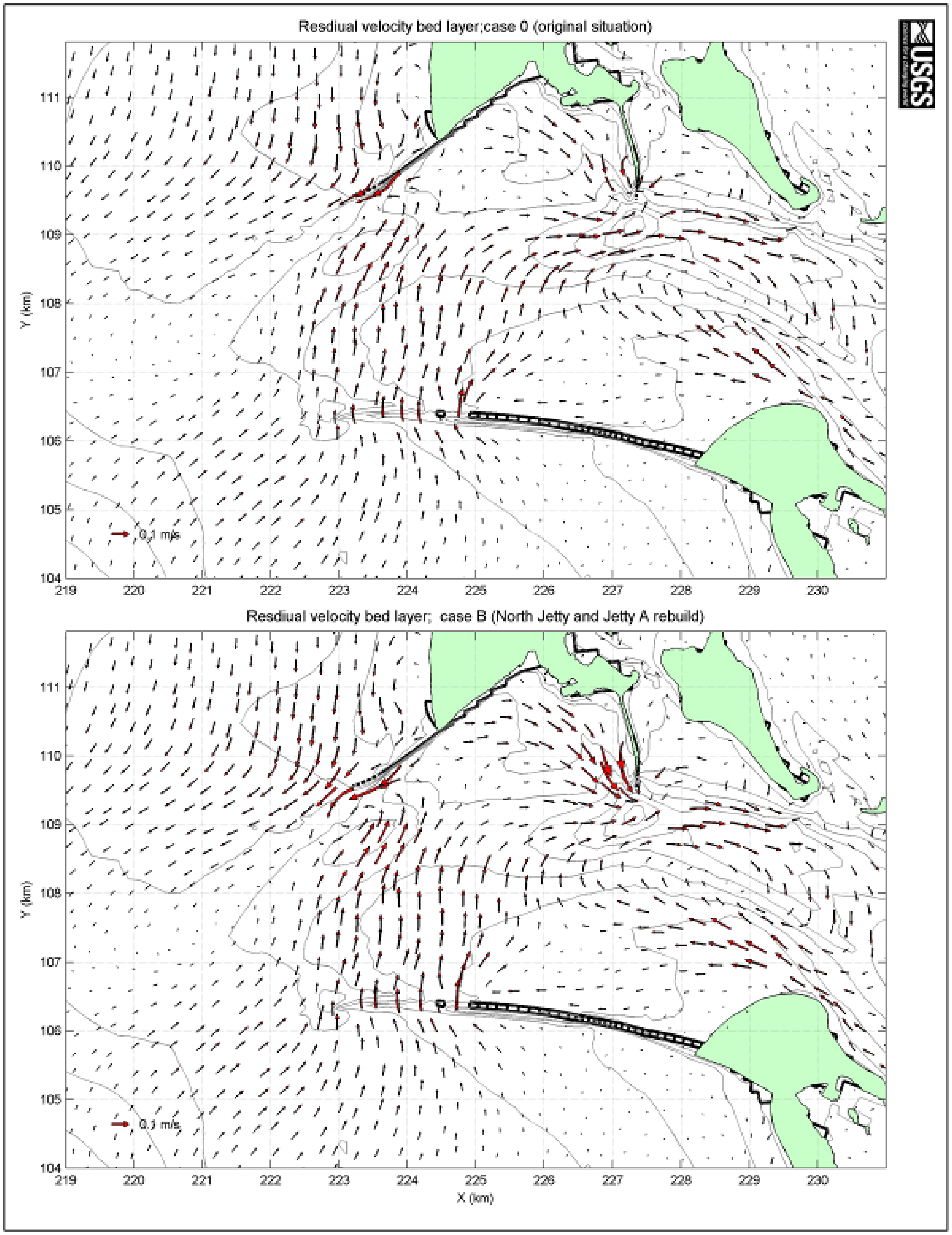


Figure 48. Residual Velocity Surface Layer for August/September Period

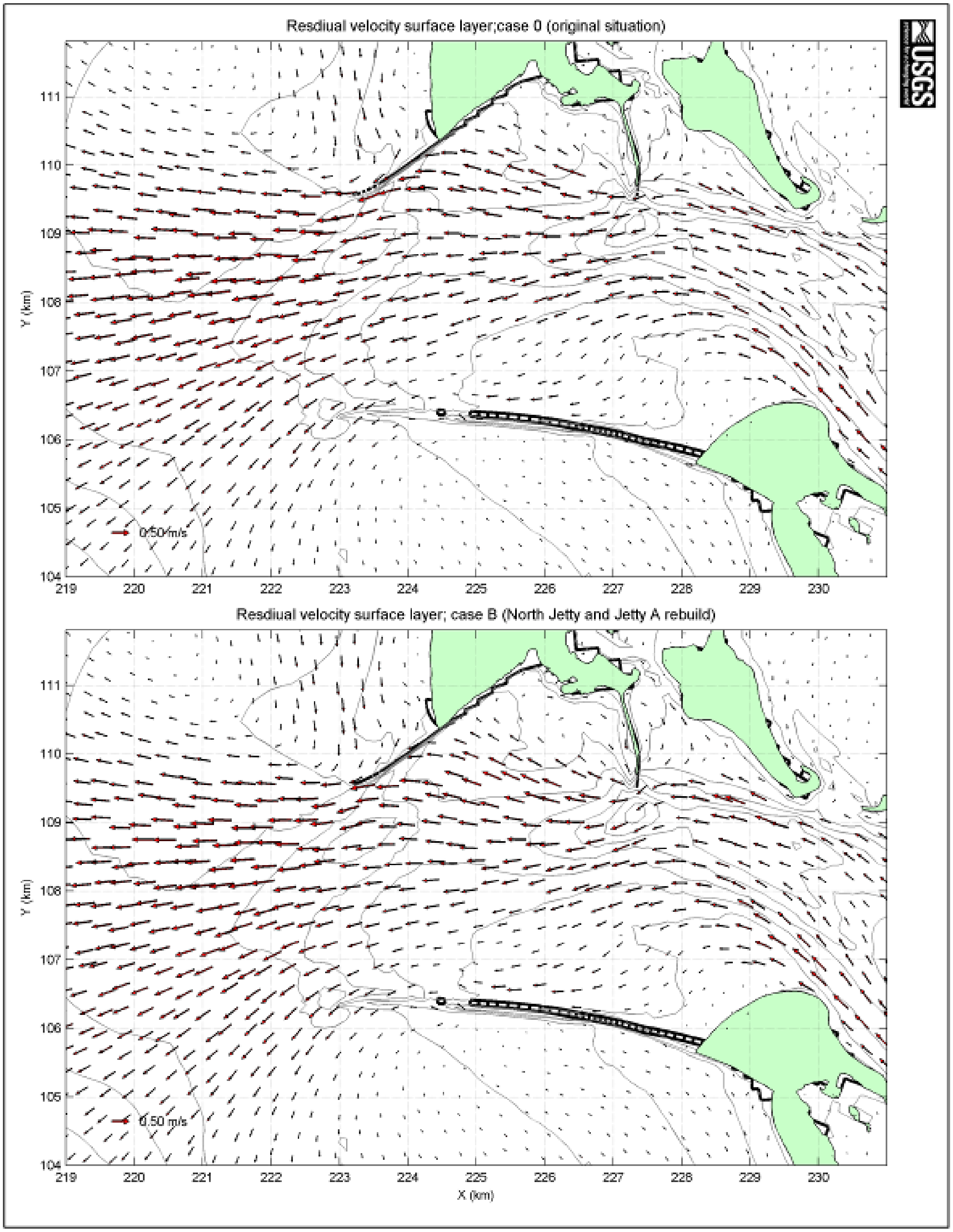


Figure 49. Residual Velocity near North Jetty and Jetty A for August/September Period

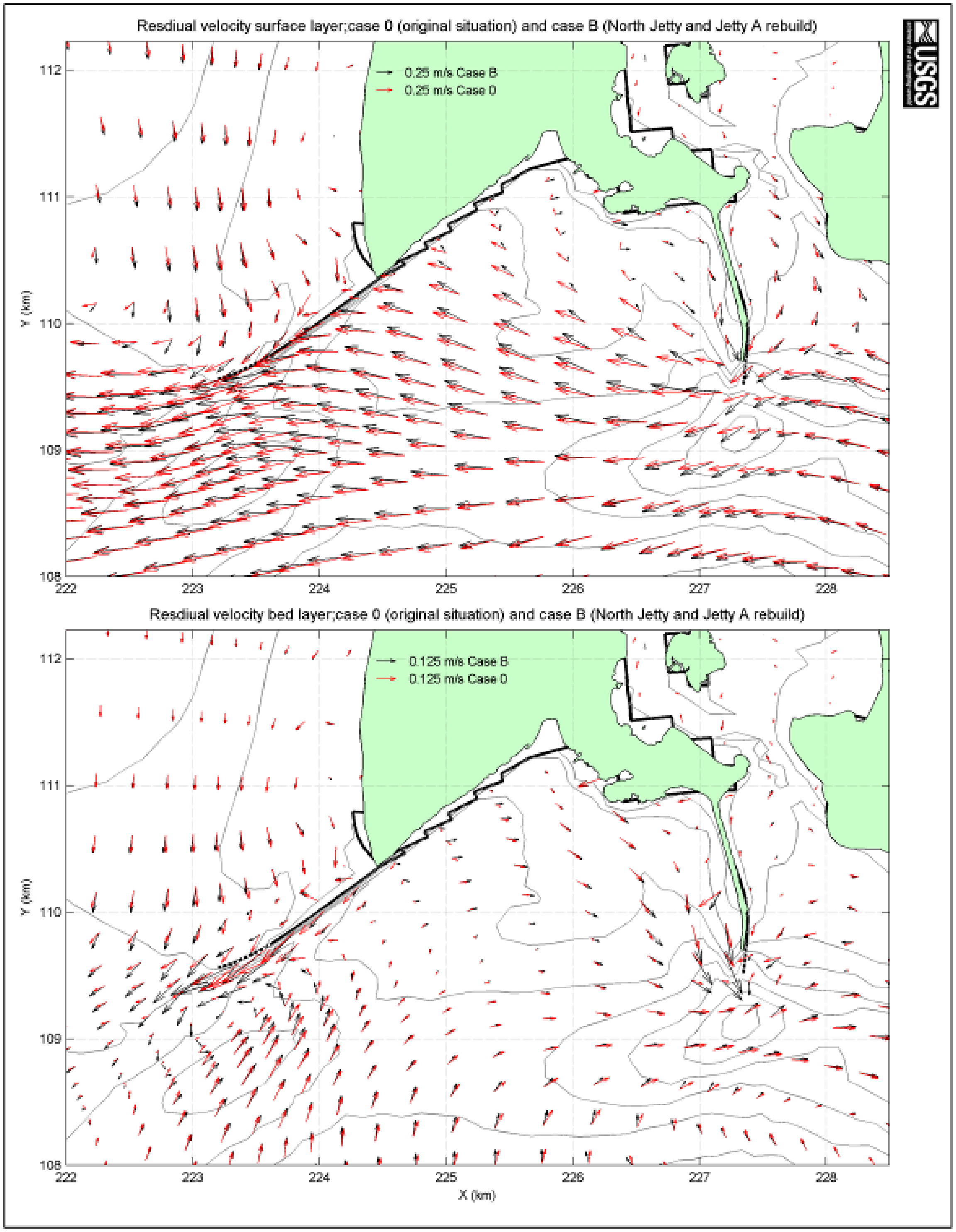
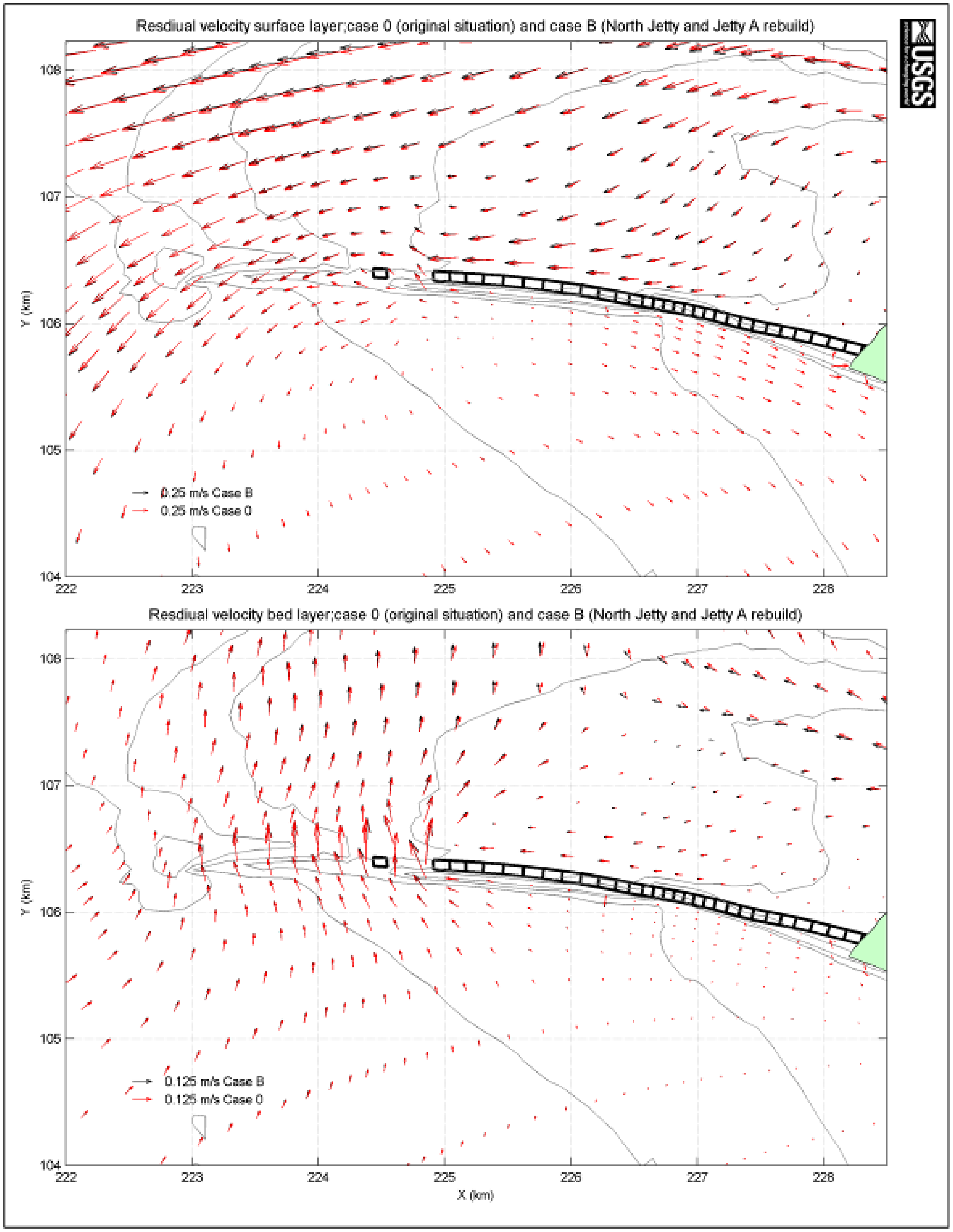


Figure 50. Residual Velocity near South Jetty for August/September Period



For the October-November period, the situation was similar to the August-September period in that a relatively large increase to residual bed layer velocity, as compared to other areas in the MCR, was predicted on the west side of the south portion of Jetty A to currents oriented in a south-southeast direction (Figure 51; USGS 2007, Moritz 2010). However, as with the August-September period, these changes were small as compared to natural variability.

For the October-November period, current direction was predicted to change slightly toward the north as water flows around Jetty A forming a more pronounced clockwise eddying effect west of Jetty A and tending to force water more directly toward the North Jetty (Figure 52). However, residual velocities toward the North Jetty are predicted to decrease and this effect would act to protect the North Jetty, as is the case with the August-September period (Moritz 2010, and USGS 2007). Such small changes to velocities and currents would be less likely since the current proposed action does not involve rebuilding the length of the jetties nor the spur groins.

For the October-November period, there also were predicted increases in bed layer velocity near the terminus of the North Jetty (Figure 53). Only small changes in residual velocities were predicted for near surface waters near the North Jetty terminus. Changes in surface current direction are similar to those described above for the August-September period. Changes to velocities and current directions were predicted to be minimal for areas near the South Jetty (see Figure 53), because these parameters at the South Jetty are essentially unaffected by alterations on the north side of the river (USGS 2007, Moritz 2010). Again, such small changes to residual velocities would be less unlikely since the current proposed action does not involve rebuilding the length of the jetties nor the spur groins.

Figure 51. Residual Velocity Bed Layer for October/November Period

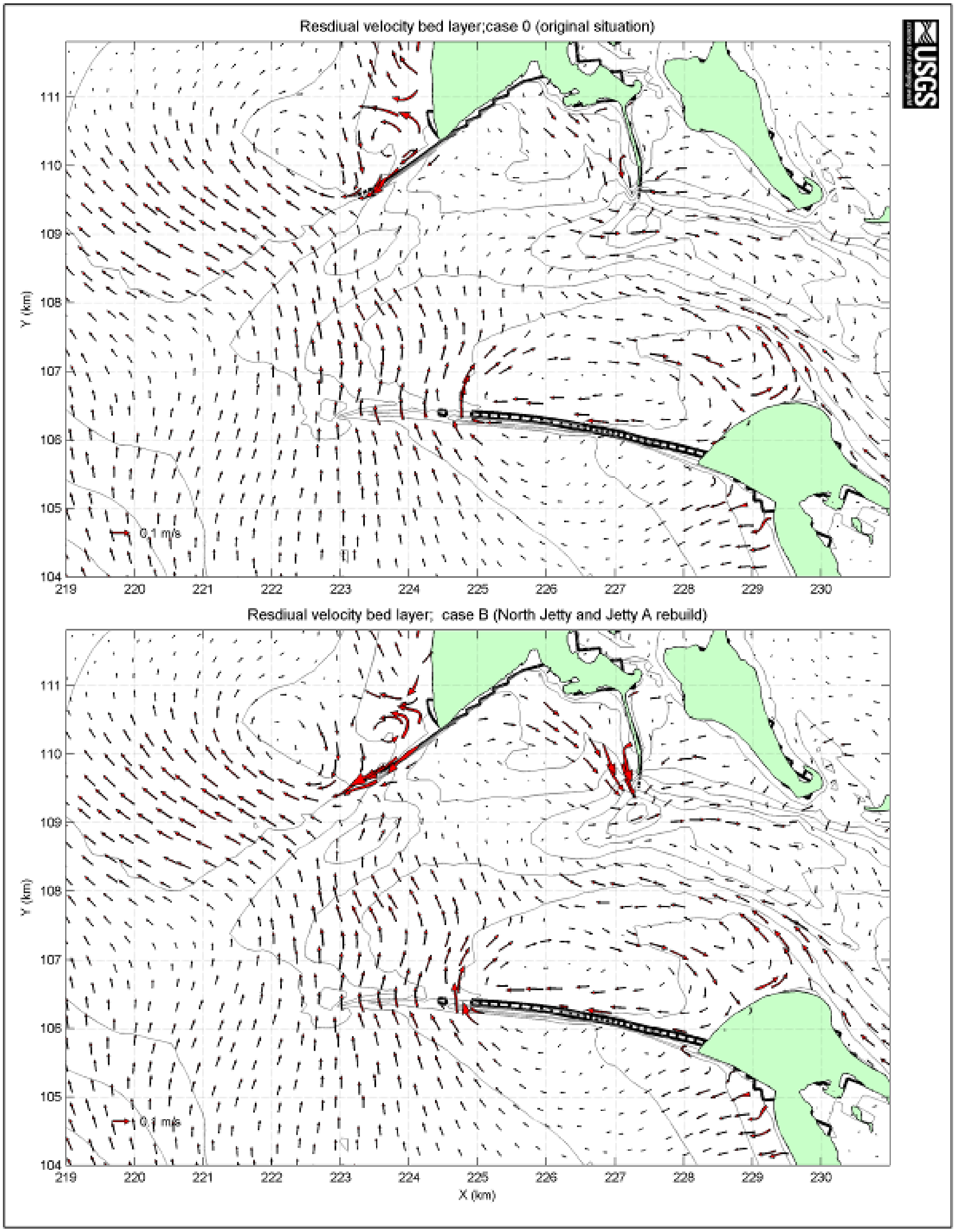


Figure 52. Residual Velocity near North Jetty and Jetty A for October/November Period

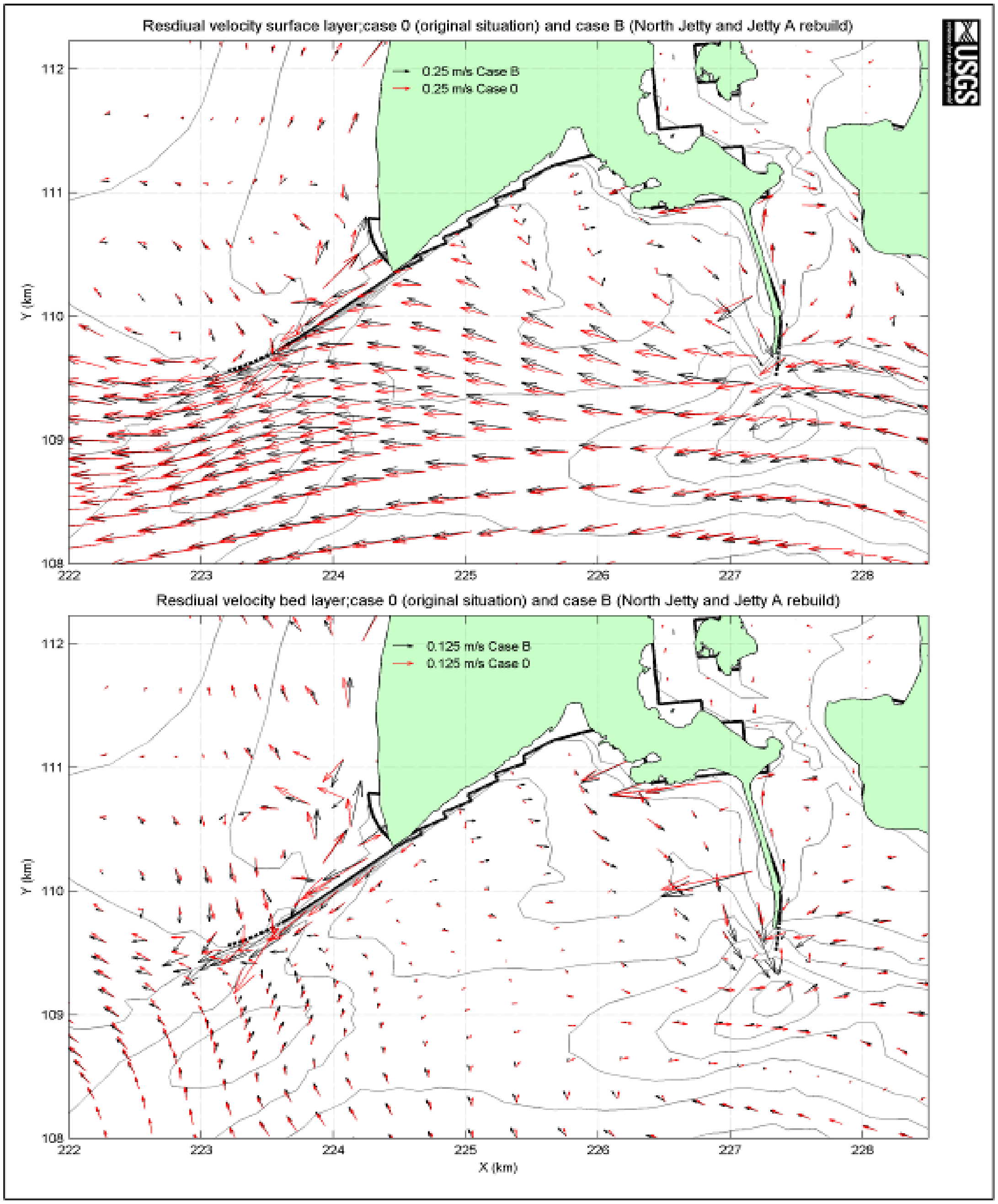
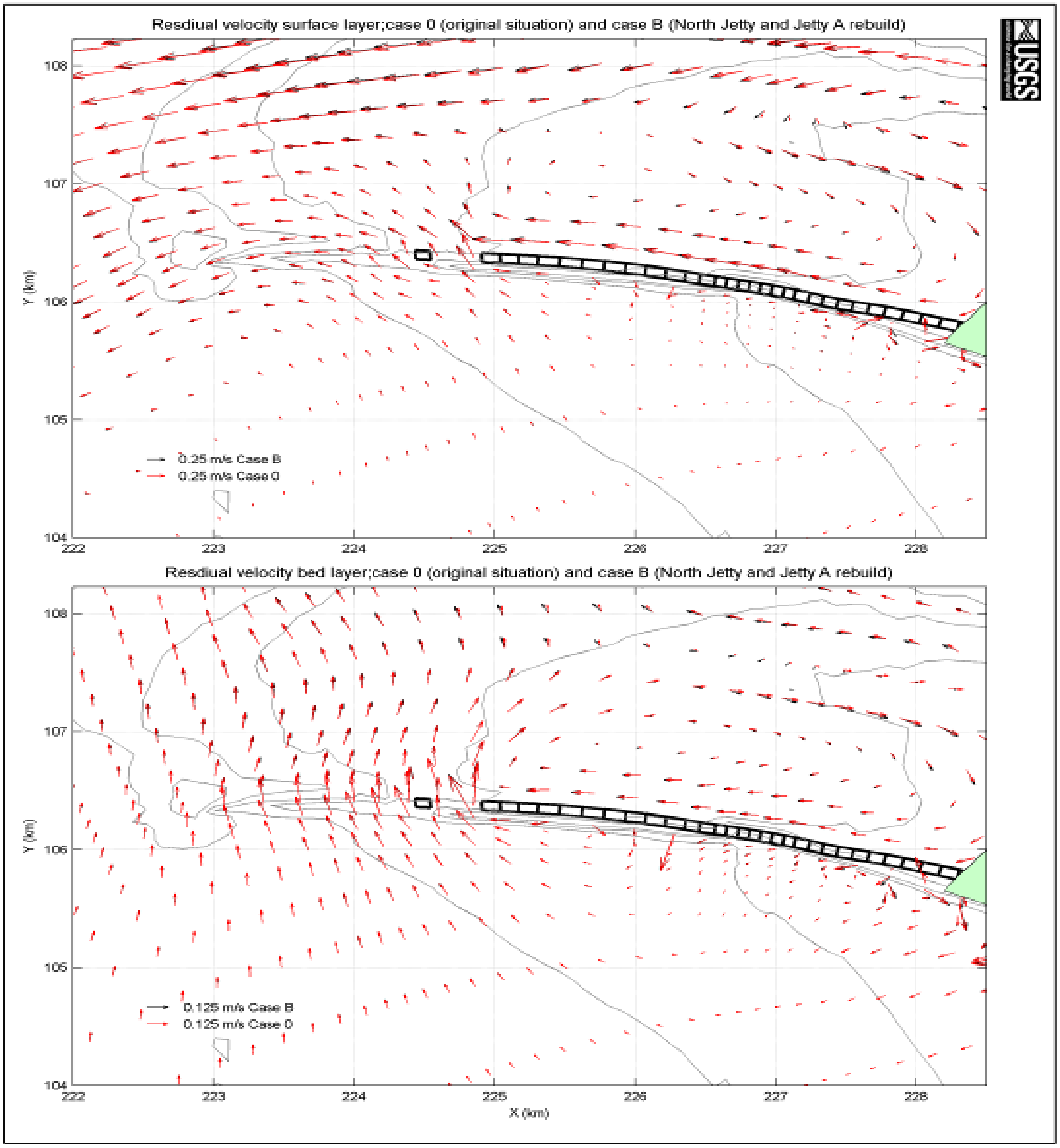


Figure 53. Residual Velocity near South Jetty for October/November Period



6.11.2. Salinity

Salinity distribution in the Columbia River estuary is determined by the circulation patterns and the mixing process driven by tidal currents. The 2007 USGS modeling results showed that in near-surface waters near the landward portions of the North Jetty, salinity naturally varies with tides to 20 parts per thousand (ppt) during October-November (USGS 2007, Moritz 2010).

The USGS model predicted minor, local changes to mean salinity as a result of jetty length rebuilds. For the August-September period, changes to bed layer salinity were predicted in waters between Jetty A and the North Jetty (Figure 54). An increase in mean salinity of 0-4 ppt (from 26-28 ppt to 28-30 ppt) was predicted to occur over some of this area (USGS 2007, Moritz 2010. This could be calculated as up to ~15% change, but was still well under the 20 ppt change in range of natural variability. A similar but less extensive salinity pattern was predicted for the near surface layer in waters between Jetty A and the North Jetty, where mean salinity was also predicted to increase 0-4 ppt (from 18-20 ppt to 20-22 ppt; Figure 55). For the near surface layer, note that this increase in mean salinity included the area in close proximity to much of the landward portion of the North Jetty. For the near surface layer, a decrease in mean salinity of 0-4 ppt (from 12-14 ppt to 14-16 ppt) was predicted to occur over a relatively small area south of West Sand Island, which is located just east of Jetty A (USGS 2007, Moritz 2010).

For the October-November period, small patterns of salinity change were also predicted. For the bed layer, a small-scale extrusion of higher salinity water was predicted for the main channel and along the South Jetty as a result of jetty length rebuilds (Figure 56). For example, for the existing condition, salinity in the range of 28-30 ppt occurs just upstream of Jetty A, whereas after the jetty length rebuilds, this zone of salinity ended directly south of Jetty A. Only small changes in salinity were predicted in the bed layer near the North Jetty. For the surface layer, extrusion of higher salinity water in the main channel was not predicted, but higher salinity was predicted for waters near the South Jetty (Figure 57). For the existing condition, salinity in the range of 24-26 ppt was predicted along the seaward 1/3 of the South Jetty, whereas after the jetty length rebuilds this area was predicted to support salinity in the range of 22-24 ppt. A minor reduction of lower salinity waters, in the range of 18-20 ppt, was predicted along the landward half of the North Jetty (USGS 2007, Moritz 2010).

In summary, minor local changes to mean salinity were predicted to occur as a result of jetty length rebuilds. However, these minor changes were within range of natural variability. Such small changes to mean salinity would be even less likely since the current proposed action does not involve rebuilding the length of the jetties nor the spur groins.

Figure 54. Mean Salinity for Bed Layer for August/September Period

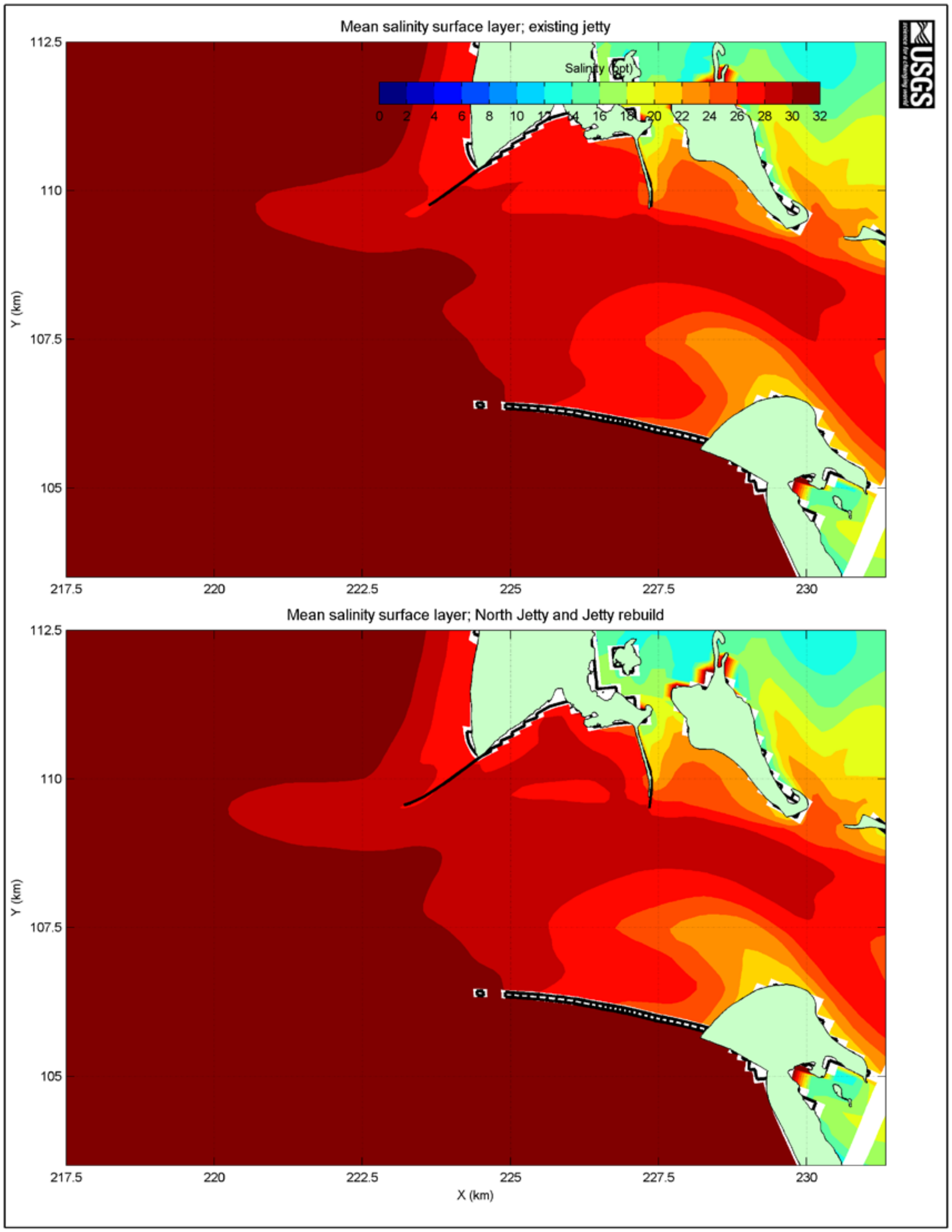


Figure 55. Mean Salinity for Surface Layer for August/September Period

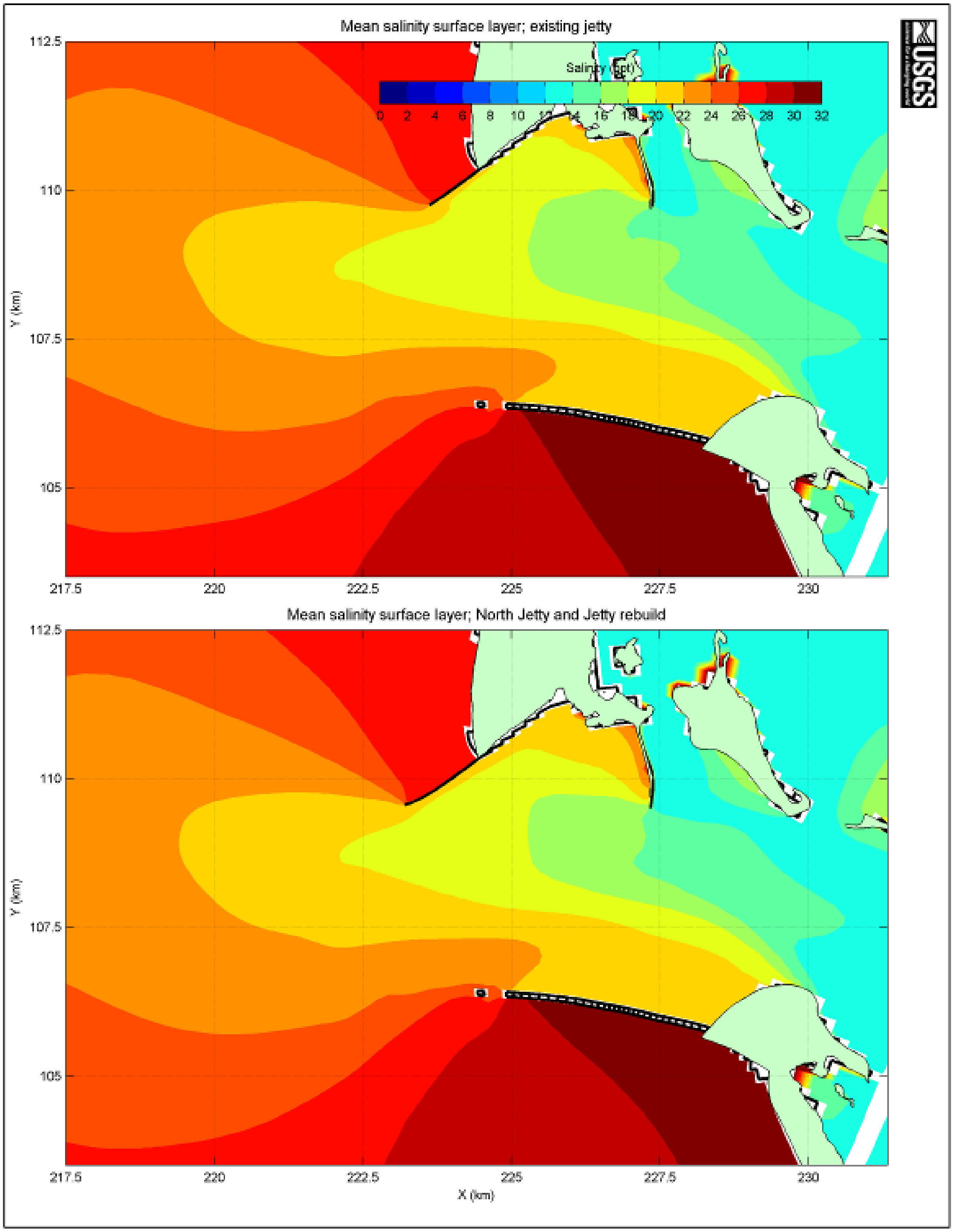


Figure 56. Mean Salinity for Surface Layer for October/November Period

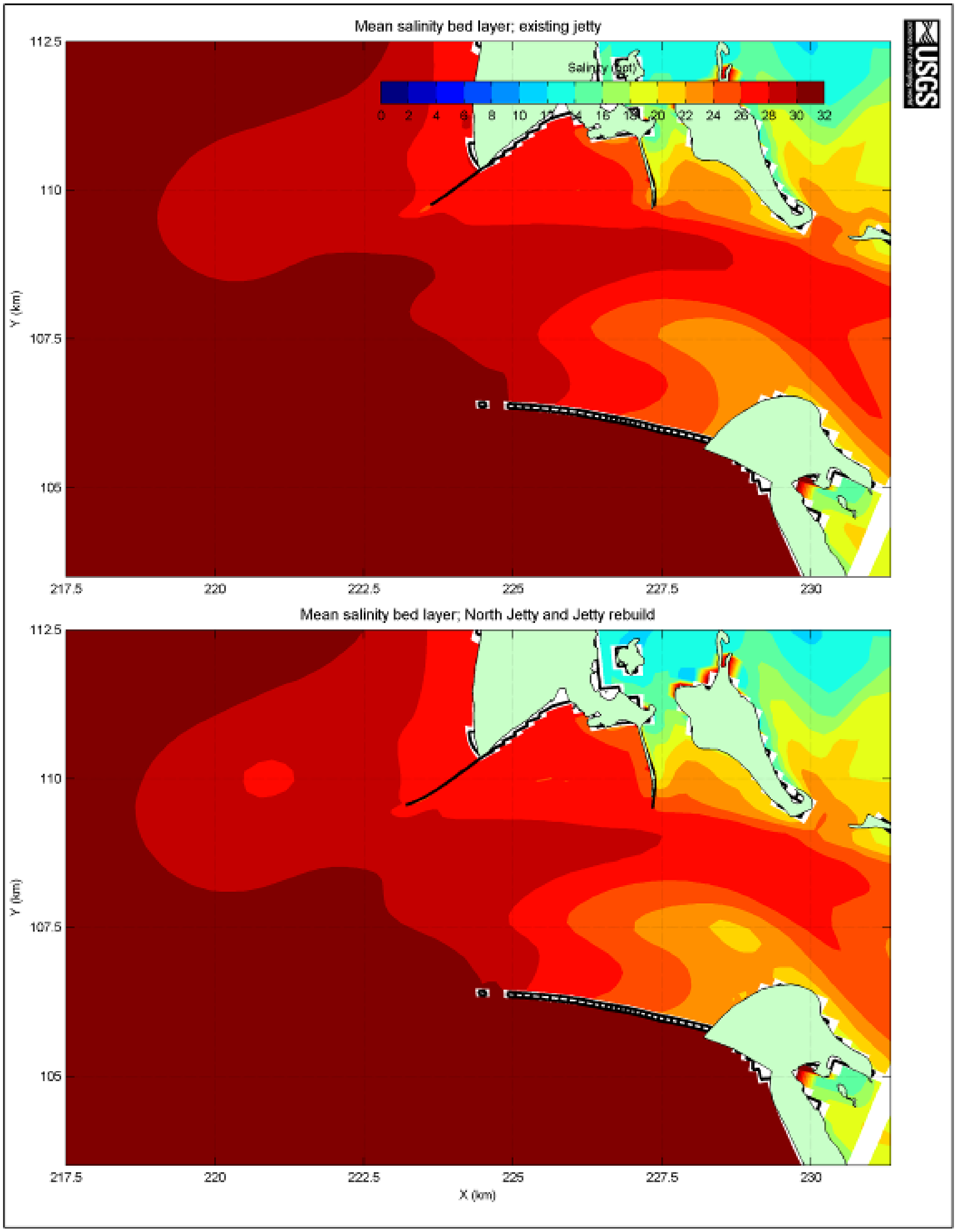
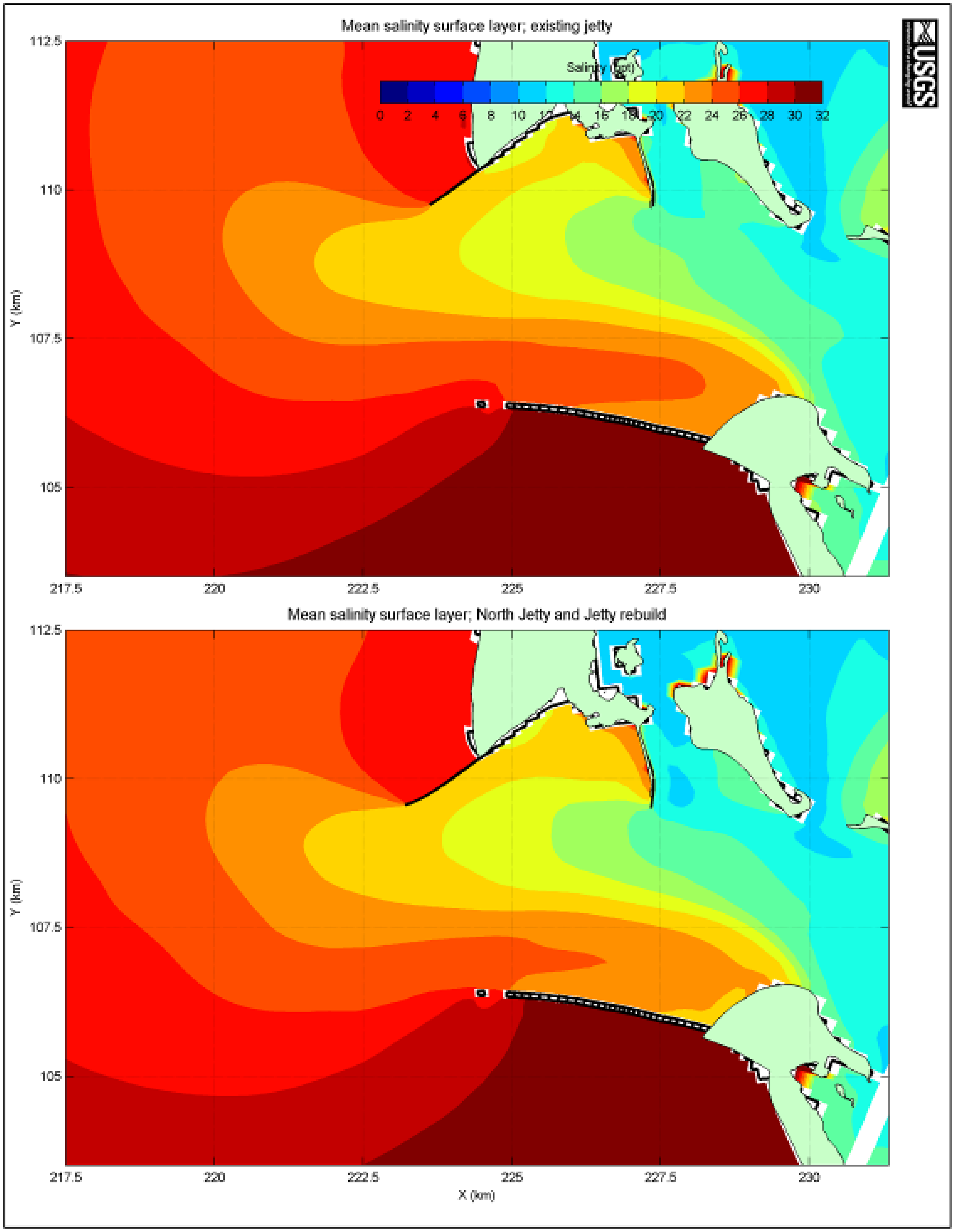


Figure 57. Mean Salinity for Surface Layer for October/November Time Window



6.11.3. Plume Dynamics

For the larger jetty length rebuilds, the parameters in the 2007 USGS modeling were predicted to be less affected in the plume than in the entrance itself. As shown in the above figures, there would be only small predicted changes to residual velocity and current directions for both bed layer and near surface layer for the August-September and October-November periods in the plume. A decrease in bed layer salinity of 0-4 ppt (from 28-30 ppt to 26-28 ppt) was predicted in the plume over an oval area west of the terminus of the North Jetty. Only small changes were predicted to residual bed load transport and residual total load transport within the plume for the August-September and October-November periods (USGS 2007, Moritz 2010). Under the current proposed action in this EA, no jetty length rebuilds are included. Because of the smaller scale of the current proposed action, the small changes previously predicted by the model would be minimal to nonexistent.

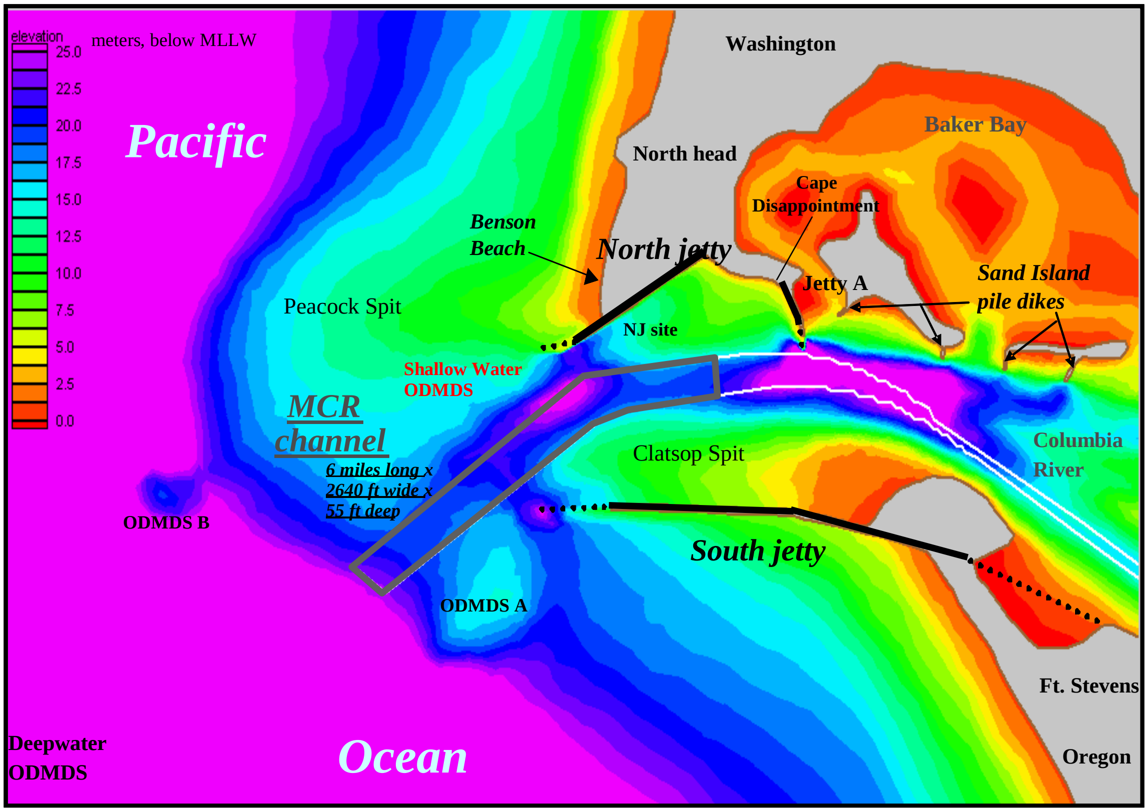
6.11.4. Bed Morphology

The bathymetry at the MCR is shown in Figure 58. The 2007 USGS model predicted some bed level changes along the seaward channel-side of the North Jetty due to the jetty length rebuild and spur groins. With longer jetty lengths, changes were predicted for both modeled periods, but were more pronounced in winter (October-November period) with about an 8.3% difference in bed elevation of about 4 to 5 feet. This change is relatively small, however, considering that water here is 39 to 79 feet deep and the dynamic environment at the MCR (Connell and Rosati 2007, Moritz 2010).

Bed morphology changes were predicted to occur in similar areas during the August-September and October-November periods but more scouring and deposition was predicted to occur during the latter. In addition to the result described above for the channel side of the seaward portion of the North Jetty, decreases to bed level with implementation of the proposed action were predicted for a broad area in deep waters of the navigation channel off of Jetty A and deep waters around the seaward portion of Jetty A and for locations north of the North Jetty, which includes shallow nearshore waters. Areas predicted to have an increase in bed level occurred upstream and downstream of Jetty A, downstream of the above-mentioned broad area in the navigation channel, on the ocean side of the North Jetty, and downstream of Clatsop Spit (Connell and Rosati 2007, Moritz 2010). As mentioned before, the scale of the current proposed action is much smaller and precludes a length rebuild. Therefore, any changes previously predicted would be even smaller or unlikely.

From ERDC model results for spur groins, it was predicted that a temporary increase in bed level due to sedimentation would occur upstream of the spurs, but that a temporary decrease in bed level due to erosion would occur immediately downstream of the spurs. This is no longer anticipated since spur groins are no longer proposed for this action.

Figure 58. Bathymetry at the MCR



Temporally, effects from hydraulics and hydrologic process would occur as a single event with construction as described under Rock Placement. Any minor subsequent effects would be long-term, but are discountable within the range of natural dynamic conditions and are of limited geographical extent.

In summary, previous modeling results indicated the changes to velocities, currents, salinity, plume dynamics, and bed morphology were minimal under the much larger jetty length rebuild scenario. Also, the existing or "original" conditions of the previous model represented lengths that are retained under the current proposed action. Because of previous results, no overall adverse changes to the hydraulics or hydrology of the MCR system are anticipated under the new, smaller proposed action.

Figure 59. Difference in Bed Level (meters) for August/September Time Window

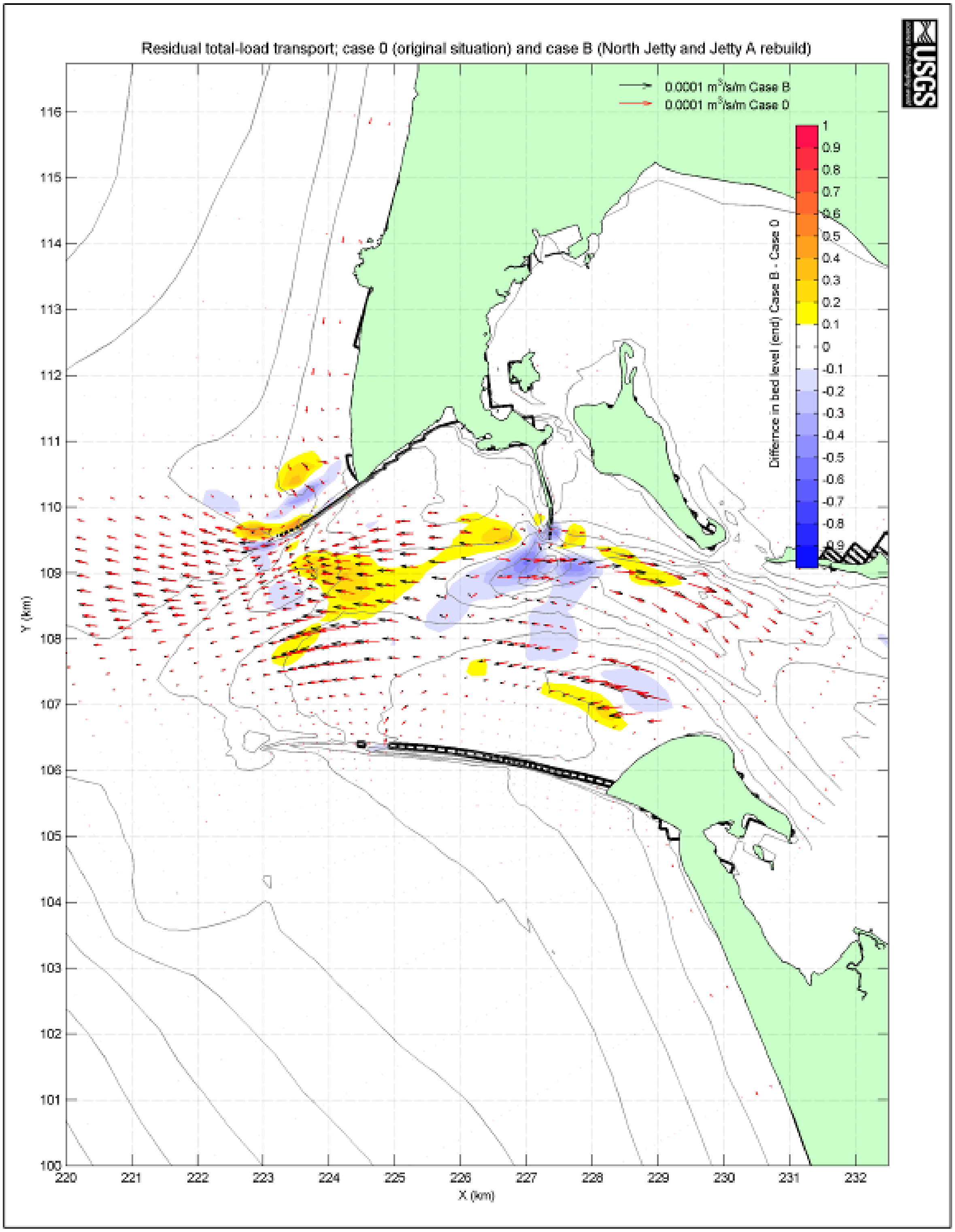
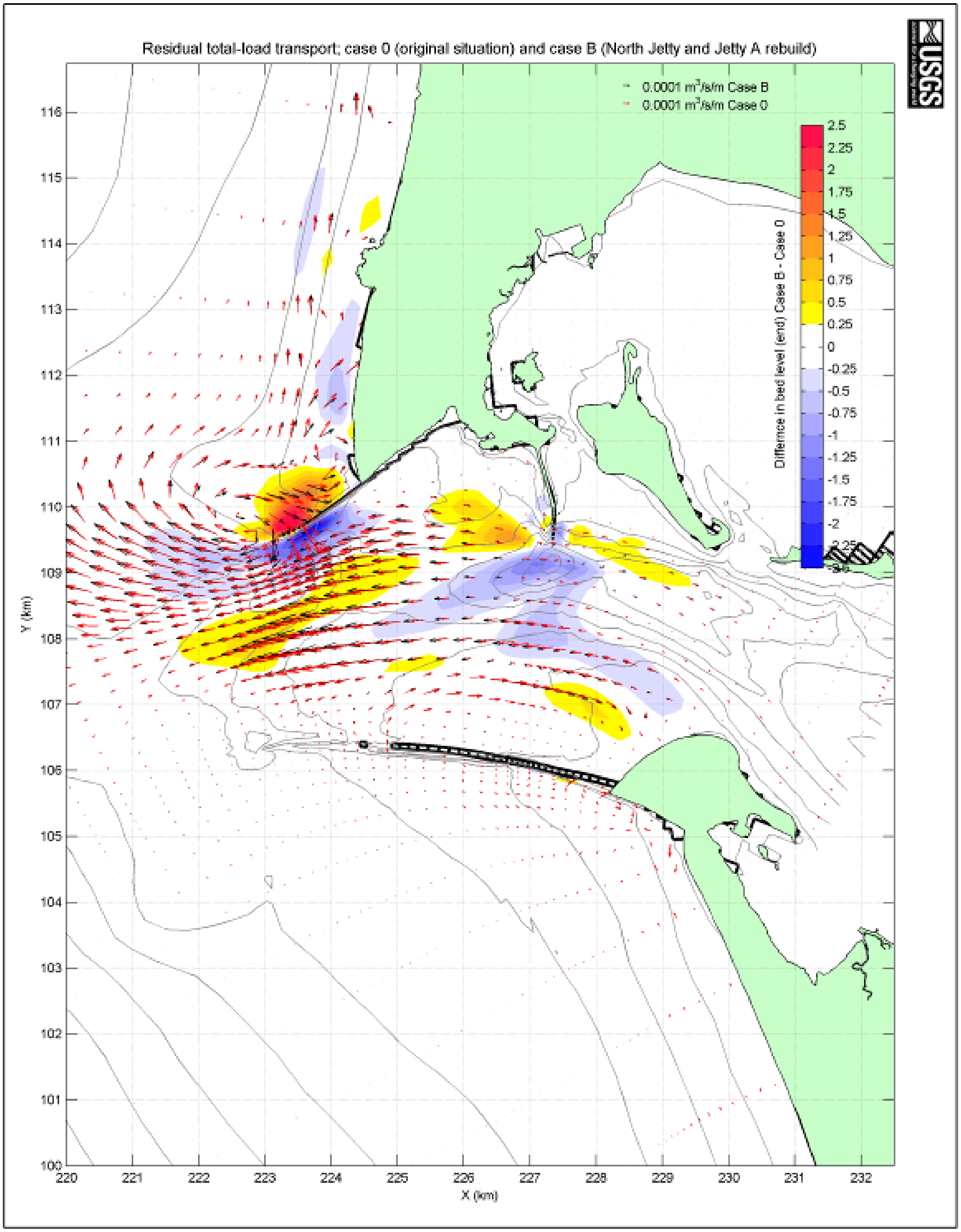


Figure 60. Difference in Bed Level (meters) for October/November Time Window



6.12. Wetland and Waters Mitigation

The Corps has proposed mitigation for impacts to 404 waters of the US under the Clean Water Act. These actions would complement Conservation Measures recommended by NMFS for the benefit of listed and candidate salmonid species as well as other native and listed species found in the lower Columbia River ecosystem. The Corps is also required to provide mitigation for wetland impacts. The Corps has identified specific wetland mitigation opportunities and would develop detailed plans and specifications for these areas, as well as proposals for mitigation to 404 waters. These mitigation requirements would be determined by the Corps and coordinated with the Services and State resource agencies in order to obtain legally required compliance documents using the AMT.

As described in the proposed action, the Corps has developed a mitigation plan to offset impacts to wetland and waters with a suite of potential actions and to offset impacts to shallow-water habitats. In the long term, implementation of mitigation along with upland revegetation would increase the overall square footage of wetlands and improve uplands, potentially also improving wetland-stream hydrologic functions in the Columbia River estuary. Mitigation for impacts to low saltwater marsh habitat would improve resting and rearing habitat access for juvenile fish, as well as improved and increased instream and riparian and estuarine functions; for example, creation of intertidal and mudflat habitat, restoration of hydrologic regimes, and improvement of riparian and canopy cover. These actions would mitigate for impacted habitats and functions, which are being affected in the immediate vicinity of the jetties.

Actions could also improve estuarine productivity lower in the Columbia River system for a wide range of species in the mitigation areas. Re-establishment of native plant communities and improvement of estuarine functions would improve water quality function, habitat complexity, and trophic inputs. Reintroduction of a greater range of flows and more natural tidal regimes to current uplands would also improve the likelihood of re-establishing native intertidal species. Re-establishing hydrologic and tidal regimes increases the opportunity to develop edge networks, dendritic channels, and mud flat habitats for use by listed species. Increased benthic habitat could also improve food web productivity.

This mitigation also complements the recovery plan in the estuary module (NMFS 2007c), as actions being proposed by the Corps address threats identified in the recovery plan, and specifically relate to Columbia River Estuary (CRE) management actions. Depending on final plan selection, mitigation may specifically address the following CRE actions: 1 (riparian protection and restoration); 4 (restoring flow regimes via improved/restored tributary hydrologic connectivity); 5 (replenishment of littoral cell via beneficial use of dredged materials); or; 9 (protection of remaining high-quality off-channel habitat from degradation). Several of these CREs were also in the higher rankings for benefits with implementation, and higher percentages for Survival Improvement Targets (NMFS 2007c).

Therefore, the Corps expects mitigation actions to have either direct or indirect long-term beneficial rather than adverse effects to most aquatic species, including listed species and their designated critical habitat in the action area. In the short-term, temporary disturbance and increased suspended sediment may result in higher turbidity during in-water construction at restoration sites. This is not likely to occur during upland planting. However, these actions would be limited in duration and intensity, as BMPs to reduce and avoid pollutant runoff described in the proposed action would also be applicable to actions at the mitigation sites. Suspended sediments from in-water work would be monitored per State Water Quality Certification conditions, and appropriate BMPs to minimize turbidity will also be implemented to ensure levels do not reach a duration or intensity that would harm species.

For invasive species removal, the Corps proposes to use no herbicides within 100 feet of the Columbia River or associated water bodies, and therefore, does not expect increased pollutant loads or effects on instream or riparian function. Short-term noise disturbances are likely to attenuate near the source and project locations are likely to be much further away from habitat used by marine mammals. These acoustic effects will likely be minimal and discountable.

Temporally, implementation of different components of mitigation projects could occur throughout the year. It would likely be possible to complete associated in-water work during the appropriate in-water work windows that protect listed species at the mitigation sites. Concurrent with initial impacts to wetlands, construction would likely occur in one or two seasons with subsequent monitoring. Temporally, this limits the repetition of disturbance activities associated with the construction of these projects. Short-term effects to water quality may occur on a daily basis, but would be limited and similar to those describe in the Water Quality effects discussion.

6.13. Effects on Fish and Wildlife

6.13.1. Anadromous and Resident Fish Species

On March 18, 2011, The Corps received a Biological Opinion from NMFS indicating that the Corps' proposed actions were not likely to adversely affect any listed species, with the exception of eulachon, humpback whales, and Stellar sea lions (2010/06104). For these species, NMFS determined that Corps' actions were not likely to jeopardize the existence of the species. NMFS also concluded that Corps actions were not likely to adversely modify any of the current or proposed critical habitats. There was a Conservation Recommendation to carry out actions to reverse threats to species survival identified in the Columbia River Estuary ESA Recovery Plan Module for Salmon and Steelhead. The Corps also provided a conference report for critical habitat that NMFS proposed for leatherback turtles, eulachon, and Lower Columbia River coho salmon. The Corps will request NMFS adopts its conference report when this habitat becomes designated. The Corps will also request an Incidental Harassment Authorization of Stellar sea lions, humpback whales, California sea lions, and harbor seals prior to the start of construction.

On February 23, 2011 the Corps received a Letter of Concurrence from USFW regarding potential effects to species under their jurisdiction (13420-2011-I-0082). The Corps determined its actions would have no effect on listed species, with the exception of bull trout, marbled murrelets, and snowy plover. The Corps concluded that its actions were not likely to adversely affect these species or their critical habitat. The USFW concurred with the Corps' determination. USFW also included four Conservation Recommendations to protect and improve snowy plover habitat and manage attractant waste derived from construction actions.

In the Corps Biological Assessment, the following possible effects of the proposed action on anadromous and resident fish species and their critical habitat were evaluated to determine their significance. These included:

- Temporary and permanent interruption/alteration of adult and juvenile migration pathways.
- Temporary and/or permanent loss of shallow-water habitat.

- Juvenile predator attraction to the jetty substrate and habitat type.
- Temporary disruption and displacement from piling installation and barge offloading traffic.
- Temporary loss of benthic organisms.
- Temporary displacement from dredging and rock placement activities.
- Temporary water quality impacts from construction activities, dredging, rock placement, and potential spills.
- Temporary and permanent negligible changes to salinity, velocity, and bed morphology.

Adult salmonids that could be in the vicinity of the proposed action are highly mobile and in the process of upstream migration. Adults are not expected to spend extended amounts of time in the vicinity of the jetties and are able to avoid areas of disturbance. No adverse permanent disturbances to habitat that adult salmonids use in the MCR area are expected to result from the proposed action. The potential impacts discussed below primarily pertain to juvenile salmonids in the vicinity of the MCR jetties during their out-migration from the estuary to the ocean primarily in spring and fall.

To avoid and minimize impacts to listed salmonids, the States established an in-water work window to prevent disruption of spawning activities and ensure project actions occur when fish are least likely to be present. The MCR in-water work window is from November 1 to February 28. However, adverse wave and inclement winter weather conditions at the MCR often preclude safe working conditions during the in-water work window; thus, it is unlikely that barge offload structures and other project elements could be built during this time. Crew safety and construction feasibility may require project actions to occur during fair weather months outside of the in-water work window.

Rock Placement. Rock placement is not expected to cause mortality to adult or juvenile anadromous and resident fish. Fish could be displaced during rock placement by disturbance from rocks entering the water. Some benthic habitat will be permanently lost due to rock placement. Adjacent benthic areas will suffer relatively minor and temporary effects due to settling of suspended sediments. Because much of the rock will be placed above MLLW on existing relic rock, most benthic habitat should not be adversely affected. Because the jetties are in a high energy environment and existing habitat near the structures is relatively unproductive, this habitat loss is considered negligible.

Jetties and Causeways. Juvenile salmonids, especially sub-yearling Chinook salmon, out-migrate in close proximity to the North Jetty, and may out-migrate in close proximity to the South Jetty as well. The length of the North Jetty forces fish that are bound for waters near the surf zone along Benson Beach farther offshore. They swim a farther distance and are potentially exposed to increased risks from predation before reaching preferred shallow-water nearshore habitat. However, the PNNL (2005) acoustic tagging studies have indicated that the areas immediately adjacent to the jetties are not shown to demonstrate the highest peaks for juvenile migration, which tend to occur closer to the navigation channels in the vicinity of the jetties. Further, the duration of exposure to these structures is relatively limited, as juveniles spend only a short residence time in the MCR vicinity, ranging from hours to days during the. With rehabilitation of the North Jetty, it is expected that Benson Beach will halt its recession and resume accretion, which over time will lessen the distance that sub-yearling juvenile Chinook salmon must swim to reach preferred nearshore waters. Deposition of sand upstream of existing spurs has been shown on the channel side of the South Jetty. It is expected that juvenile salmonids would utilize rebuilt portions of the jetties. It is possible that juvenile salmonid outmigration occurs in close proximity to the South Jetty as it does at the North Jetty. Only off-loading facilities on the channel side with elevations at or above MLLW are expected to be capable of altering outmigration routes by forcing juvenile salmonids away from the shallower waters along the jetty proper and into deeper waters as they swim around offloading facilities, particularly the one near Parking Area D on the Clatsop Spit.

Effects to juvenile salmonids could result from predator attraction to the rock structure and disruption to migration pathways as a result of the presence of off-loading facilities. Piscivorous fish capable of preying on juvenile salmonids could recruit to rebuilt portions of the jetties, piles for barge offloading facilities, and temporary causeways. It is when juvenile salmonids are near these locations that they would be susceptible to predation from piscivorous fish. The addition of rock to the jetties and the presence of piles and causeways may increase perching opportunities for piscivorous birds, especially cormorants and brown pelicans. However, pile caps will reduce this likelihood, and perching opportunities for cormorant and pelican use are not expected to increase in a measurable manner. Also because rocks are already abundant at the MCR, no increases in pinnipeds, capable of preying on adult salmonids, would occur because of the presence of additional rock.

<u>Barge Offloading Facilities and Dredging</u>. Barge offloading facilities are a potential method of delivery for stone and other construction materials. If barge offloading facilities are used, this would create the largest impacts to 404 waters of the US and associated aquatic habitat. Therefore, the associated fill acreages and volumes represent the worst-case scenario for spatial and temporal effects. Pilings will be constructed out of untreated wood or steel. The presence of the barge facilities would not likely cause disturbance to salmonids in the vicinity, except for the coming and going of barges that could induce movement in fish. The construction and eventual removal of these facilities, including dredging and pile driving, would temporarily disturb fish. Because of the soft substrates, it is expected that vibratory drivers can be used effectively to install piles. The impacts from pile driving would be intermittent and would not be expected to adversely affect fish.

Material to be dredged for barge offloading facilities is primarily sand with little or no fines. Disposal of dredged material is expected to occur primarily at previously approved or designated in-water disposal sites. A clamshell dredge will be used for most dredging. Fish would likely be forced into moving to other nearby suitable habitat during dredging. There also would be a loss of benthic invertebrates in areas dredged, but only negligible losses to food resources for juvenile salmonids and aquatic species would be expected to result.

If all four offloading facilities were utilized simultaneously, this would result in a dredged area of approximately 16 acres. Within an estimated 3-mile proximately of the MCR jetties, about 19, 575 acres of shallow water habitat (anything -20 ft or shallower) exists. Therefore, as with stone placement, this results in a habitat conversion of less than one percent. Furthermore, it is more likely that only one or two facilities would be needed per year, which makes the relative percent of habitat conversion even smaller. Though there will be loss of benthic invertebrates in areas dredged, only negligible losses to food resources of juvenile salmonids or sturgeon are expected to result. Because eulachon feed on plankton, their foraging habitat will not be affected. Some sandy, shallow-water inter-tidal habitat will be converted to deeper inter- and sub-tidal habitat. Consequently, these conversions and disturbances could result in a possible conversion of biological communities with changes in depth and light penetration. The extent is expected to be minimal and recolonization is expected to be rapid. These effects are unlikely to measurably impact food resources or foraging behavior of juveniles or adults.

<u>Potential Spills</u>. Operation of heavy equipment requires use of fuel and lubricants that would kill or injure aquatic organisms if spilled into the water. The contractor will provide a spill prevention plan to include measures to minimize the potential for spills and to respond quickly should spills occur.

Due to preventative and response measures required, it is unlikely that spills would adversely affect aquatic resources because of their low chance of occurrence.

Turbidity. Placement of rock and dredging/pile driving for barge offloading facilities will be conducted and are not likely to require measures to minimize turbidity. Placement of clean fill and pile installation in sandy substrate is not anticipated to create deleterious turbidity plumes. Increased turbidity from construction activities will be intermittent over the projected 8-year construction timeframe, but individual, localized increases should be of limited extent and duration. These turbidity increases would likely not result in a reduction in feeding rates and growth, physiological stress, and increased mortality of juvenile and adult salmonids and other fish because of rapid dissipation of turbidity in the high-energy MCR environment and the mobility of fish. Movement from turbid areas and behavioral avoidance of turbid areas by fish would likely result. Sediment suspension is not thought to be an issue with respect to aquatic resource impacts because the sediments that would be suspended are mostly clean sand, which settles quickly. In-water work also requires turbidity monitoring be conducted in accordance with conditions in the Oregon and Washington Section 401 Water Quality Certifications to ensure the proposed action maintains compliance with water quality standards that are protective of fish and other aquatic resources (see Section 5.5.14).

System Effects - Permanent Changes to Velocity, Salinity, Bed Morphology. Modeling results show that no appreciable permanent changes to velocity, salinity, and bed morphology at the MCR would be expected from implementation of the proposed action. Any negligible changes to water velocities resulting from the proposed action would not likely adversely alter aquatic habitat or affect the organisms that use the MCR area.

Salmonid Critical Habitat. Increases in suspended sediment and resultant turbidity from driving piles and/or placement of jetty stones may impact aquatic habitat. The increases in suspended sediment and turbidity will generally be limited to the construction areas along the jetty bases and will be intermittent over the projected 8-year construction timeframe. No contaminated material would be suspended because sediment is nearly pure sand. The course-grained characteristic of the sand will cause it to settle relatively quickly.

Rock placement will occur for jetty repair and stabilization and for construction of barge offloading facilities. Alteration of bottom habitat would occur from dredging, which will create temporary disturbance and greater depths that could affect the composition of benthic communities. These effects are inconsequential, as the character of the area is naturally dynamic and prone to extreme energy conditions, and benthic organisms are adapted for such conditions and usually rapidly recolonize. Alteration of bottom habitat by pile driving, placing additional rock to expand the base of the jetties should not adversely affect aquatic habitat. The MCR is an active migration corridor and it is unlikely that salmon are feeding to any extent in the area. Measurable effects on salmon feeding habitats are not expected.

The permanent removal or conversion of some shallow water, nearshore sandy habitat likely used by juvenile salmonids for migrating, foraging, or rearing habitat would result from previously described rock placement for turnouts, set-up pads, causeways and stone docks for offloading facilities. In addition, some shallow water, nearshore sandy habitat likely used as migrating, foraging, or rearing habitat by juvenile salmonids would be unavailable for the projected 8-year construction timeframe Some causeway structures would be removed upon project completion and others will remain.

In-water habitats, both shallow intertidal and deeper subtidal areas would also be affected by the project. Habitat conversions and temporal disturbance would occur from maintenance dredging and placement of jetty cross-sections, turnouts, crane set-up pads, barge offloading facilities, and causeways. There would also be permanent lagoon fill at the North Jetty root and temporary lagoon fill lasting more than a year at the South Jetty. Without drawing a distinction between depths, *original* initial acreage estimates of maximum potential footprint for all in-water impacts included: North Jetty ~11.75, South Jetty ~21.2, and Jetty A ~7.23. This came to an approximated total of ~40.18 acres of potential in-water conversions. These estimates were included in the Biological Assessments that are under Consultation because they are considered the worst case scenario for analysis of potential impacts. However, now under the current revisions of the proposed action, these estimates would likely be closer to approximately 32.82 total acres of in-water footprint, with estimates being closer to 12.38, 13.84, and 6.62 acres of impact possible at each jetty respectively. The larger estimates included a reflection of estimates for previously evaluated alternatives, including the proposed Trestle Bay fill and the expanded prism of the North Jetty, which are no longer part of the selected plan.

Shallow-water habitat is especially important to several species in the estuary; therefore, specific initial estimates were also calculated regarding shallow-water habitat (shallow here defined as -20-ft or -23-ft below MLLW). About 21 acres (out of the ~33 mentioned above) of area at these depths will be affected by, maintenance dredging, and construction of the causeways and barge offloading facilities, and about 12 acres will be impacted by lagoon fill. However, this shallow-water footprint estimate does NOT including any expansion of the jetty's existing footprint. For this analysis, there was no distinction drawn between periodically exposed intertidal habitat and shallow-water sandflat habitat. As with wetland estimates, these approximations would be updated and may be reduced as project designs are refined and as additional analyses and surveys are completed to quantify changes in jetty and dune cross sections.

Consequently, these conversions and disturbances could result in disturbance of benthic invertebrates and a possible conversion of biological communities. Within an estimated 3-mile proximity of the MCR jetties, about 19, 575 acres of shallow water habitat (anything -20 ft or shallower) exists, of which 33 acres represents a difference of much less than 1 %. Therefore, these effects of habitat conversion are expected to be minimal, and unlikely to appreciably impact food resources or foraging behavior of juvenile or adult salmonids. Spawning does not occur in the areas of habitat conversion, so effects from the proposed action would not impact spawning substrate or behavior.

<u>Green Sturgeon</u>. The federally listed green sturgeon (southern DPS) occurs in the Columbia River estuary. Its distribution and habitat use in the estuary is not well known, though the area was recently listed as critical habitat (74 FR 52300). Green sturgeon would be expected to occur in the more tranquil estuary proper to a greater extent than in the vicinity of the MCR jetties. Though sandlance provide one food source for the green sturgeon, the proposed project is not expected to have any considerable impact on this supply. Given the existing relic rock substrate resulting from the current jetty structures, it is unlikely that the area in the vicinity of the jetty repairs provides much suitable habitat for sandlance. Therefore placements of the jetty stone on top of or near the existing footprint will not likely result in any measurable impact to the green sturgeon's food availability. There is a slightly higher likelihood of affecting sandlance habitat in the vicinity of the proposed barge off-loading sites, but these impacts are also anticipated to be negligible relative to the habitat available, and new ephemeral shallow-water habitat will likely be created as sand is accreted behind the repaired jetty structures. During construction, rock placement and dredging (turbidity) could disturb green sturgeon in the area. Some sand habitat in close proximity to the jetties that

green sturgeon could potentially use would be permanently removed by placement of rock for off-loading facilities, jetty and stabilization stone.

The Corps and USGS have recently been working on a green sturgeon study in the Coos and Columbia River estuaries. Though results are preliminary and sample sizes are relatively small, acoustic receivers detected green sturgeon presence several times off the tip of Jetty A, near the North Jetty, and in the area of Social Security beach off the Clatsop Spit (USGS Preliminary 2009-2010 data). Information about specific use in the action area is still under development, but activities at Jetty A and North Jetty could cause some avoidance behavior by green sturgeon present during construction.

<u>Eulachon</u>. Impacts to federally listed eulachon are anticipated to be temporary and minimal. Eulachon occur in nearshore ocean waters and to 1,000 feet in depth, except for the brief spawning runs into their natal (birth) streams. After leaving estuarine rearing areas, juvenile eulachon move from shallow nearshore areas to deeper areas over the continental shelf. Larvae and young juveniles become widely distributed in coastal waters and are found mostly at depths up to about 49 feet. Though substrate likely to be impacted by dredge and fill activities may be similar to eulachon spawning habitat, the likely timing for work in late summer/early fall are outside of the typical eulachon spawning season. Further, eulachon are planktonic feeders, so minimal losses of benthic invertebrates would not affect their foraging behaviors. Finally, the Biological Review Team further identified dredging activities as low to moderate threats for eulachon (NOAA 2009).

<u>Bull Trout</u>. Federally listed bull trout are known to have occurred in the Columbia River historically but now appear to occur only incidentally in the lower river. Water temperature and lack of spawning substrate likely limits their use at the MCR to migratory passage. Only sporadic records of bull trout in the Columbia River downstream of Bonneville Dam or passing through the dam have been documented dating to 1941. The proposed action will occur in the area designated as bull trout critical habitat, mostly serving as a migratory corridor. For these reasons, the proposed action is not likely to adversely affect bull trout.

<u>Pacific Lamprey</u>. Pacific lampreys are likely present in the vicinity of the MCR as juveniles out-migrate from February to June, adults return to freshwater from July to October. Depending on the available construction window, either end of the age distribution may be present during project activities. However, the project is not anticipated to impact their food sources or habitat, as the jetty system is not expected to discernibly alter the current distribution of predator or prey species, and the rocky substrate may provide some resting habitat on which lampreys could attach.

<u>Resident Fish Species</u>. The proposed action will directly affect species such as English sole, sand sole and starry flounder from the permanent loss of sandy bottom habitat preferred by these species from jetty construction. Impacts to groundfish habitat are likely to be minimal because the jetties do not provide highly productive rocky habitat due to low benthic productivity, unstable bottoms, and high current/wave action in the jetty areas. There may be a long term, intermittent impact from disturbance to some groundfish species that use the jetty habitat over the projected 8-year construction timeframe. Effects on groundfish migratory habitat are likely to be negligible since disturbed areas will be small relative to the amount of available migratory habitat at the MCR. It is unlikely that disturbing this small amount of migratory habitat would impact the population levels of groundfish. Groundfish species should quickly recolonize the jetty areas once construction for a particular jetty is completed.

Essential Fish Habitat (EFH). The Columbia River estuary and the Pacific Ocean are designated as EFH for various groundfish and coastal pelagic and salmon species. The proposed action will directly affect EFH for Chinook salmon, coho salmon, English sole, sand sole and starry flounder from the spatially limited, small amount of permanent loss of sandy bottom habitat due to jetty construction. Short-term disturbances to EFH would result for lingcod, English sole, sand sole, starry flounder, black rockfish, brown rockfish, China rockfish, copper rockfish, and quillback rockfish. However, the addition of rock would increase EFH for lingcod, black rockfish, brown rockfish, China rockfish, copper rockfish, and quillback rockfish. These effects are not expected to be detectable at a species or population scale. An EFH assessment under the Magnuson-Stevens Act was provided as part of the Biological Assessment submitted to the NMFS for the proposed action. In the subsequent Biological Opinion, no additional Conservation Measures were proposed.

6.13.2. Macrophytes and Invertebrates

The mobile sand community at the MCR provides habitat for invertebrate species such as polychaetes, clams, amphipods, and crabs. This is a high-energy zone and generally less productive than other areas of the estuary. The jetties provide rocky intertidal and subtidal habitat. Dominant macrophytes include brown and green seaweeds and sea lettuce that are attached to the jetty rocks. Invertebrate species include sponges, hydroids, sea anemones, crabs, tubeworms, limpets, and mussels that live on the rocks or in crevices. There would be some loss of invertebrates with construction; however, those species occupying rocky habitats would colonize newly placed rock. No permanent, adverse effects to macrophyte and invertebrate populations are expected.

6.13.3. Dungeness Crab

Crabbing occurs in the river between the jetties. Extensive use by crabs occurs on sandy bottom areas on the south side of the North Jetty and to a lesser extent on the north side of the South Jetty. Crabs move out of the estuary in large numbers (as 1+ aged crabs) along the northern part of the channel (south side of the North Jetty) in the fall and move into the estuary as megalops in the spring. Megalops enter the estuary passively by current mainly along the north side of the entrance (on the south side of the North Jetty) where current is strongest and salinity highest. No adverse impacts to adult and juvenile Dungeness crabs would be expected from the proposed action because modeling shows no appreciable permanent changes to velocity, salinity, and bed morphology at the MCR. Disposal actions could smother crabs and other benthic invertebrates at the disposal site. However, this is not expected to discernibly affect the population or species. Further evaluation of disposal effects on crabs was conducted when the disposal sites were designated.

6.13.4. Marine Mammals and Sea Turtles

Whales. Federally listed whales that could occur in the vicinity of the vicinity of the MCR project include blue, fin, sei, sperm, humpback, and southern resident killer whales. These species are migratory in the vicinity of the MCR, generally are not found close to shore, and are highly mobile. Moreover, MCR is likely not the preferred habitat for these species, they are unlikely to feed in the vicinity of the jetties, and jetty rehabilitation work would have inconsequential impacts on their prey base. The proposed action is not expected to adversely affect these whale species.

Turtles. Federally listed marine turtles that could occur in the vicinity of the MCR project include leatherback, loggerhead, green, and olive Ridley sea turtles. These turtle species are migratory in the vicinity of the MCR, are generally are not found close to shore, and are highly mobile. In 2010 the

NMFS proposed a revised critical habitat designation for leatherback turtles that includes the vicinity of the MCR project (75 FR 319). The MCR is likely not the preferred habitat for any of these marine turtle species because the area is not located within a migration corridor, they are unlikely to feed in the vicinity of the MCR jetties, and jetty repair/rehabilitation work will likely have inconsequential impacts on their prey base. Consequently, the proposed action is not expected to adversely affect any federally listed turtle species.

Sea Lions. The South Jetty is an important year-round, non-breeding haulout site for federally listed Steller sea lions. Based on data recorded by ODFW between 1995 and 2004, monthly averages number of Steller sea lions at the South Jetty ranged from 168 to 1106 animals (Corps 2007). They primarily use the concrete block structure that has become an island with the erosion of the rubble mound structure landward. This concrete block structure is the farthest ocean-ward, above-water portion of the South Jetty. Steller sea lions are not known to use the North Jetty or Jetty A. Their use of the South Jetty is concentrated more in the winter months and is least during the May-July breeding season when adults disperse to rookeries. Stabilization of the jetty head and placing jetty rock near the head will disturb Steller sea lions by forcing them to move off haul out areas; however, they will be able to haul out elsewhere in the vicinity. Prey resources for sea lions are not expected to be affected. The proposed action is not likely to adversely affect Steller sea lions.

6.13.5. Terrestrial Wildlife, Plants, and Seabirds

The proposed action is not expected to measurably affect terrestrial wildlife and seabird species. These species could readily avoid the construction areas, any impacts to shallow intertidal habitat would be small relative to the availability of adjacent foraging habitat, and the short temporal loss may be replaced with some accreted habitat that is formed behind the repaired jetty structures. This habitat will likely be ephemeral and will not provide a long-lasting benefit. At the jetty structures, wave and current action likely limits seabird and shorebird use of these areas.

Common loon, Clark’s grebe, western grebe, horned grebe, red-necked grebe, Brandt’s cormorant, bufflehead, rhinoceros auklet, Cassin’s auklet, tufted puffin, black oystercatcher, harlequin duck, fork-tailed storm petrel, and peregrine falcon are species of concern in the states of Oregon and/or Washington (Oregon Natural Heritage Program 2004; WDFW 2005) and could occur in the vicinity of the MCR. The proposed action is not expected to markedly affect these species because they could readily avoid the construction areas.

Pelagic and Brandt’s cormorants nest on the cliffs of Cape Disappointment (Corps 1999). Three species of terns occur in the Columbia River or over nearshore waters. Caspian terns are present from April to September and have established a large colony on East Sand Island within the estuary. Common and arctic terns occur off the Oregon and Washington coasts from April to September (Corps 1999) principally during migration. Shorebirds found on coastal beaches at the MCR and estuarine flats include sanderlings and various species of sandpipers, dunlins, and plovers. Various species of gulls are common in the vicinity of the MCR. Shearwaters, auklets, murres, fulmars, phalaropes, and kittiwakes are occasionally noted in the vicinity of the MCR but more commonly offshore. Again, the proposed action is not expected to measurably affect these species because they could readily avoid the construction areas, and impacts to shallow intertidal habitat is minimal relative to the availability of adjacent foraging habitat, and the short temporal loss is likely to be replaced with accreted habitat that is captured and formed behind the new and repaired structures. Furthermore, wave and current action at the jetty features likely limits shorebird use of these areas.

It is unlikely that bald eagles would be impacted by the proposed action because they can readily avoid the construction areas while foraging. The Cape Disappointment bald eagle pair nests in close proximity to roads through the park, but use of haul roads is less of a concern for nesting bald eagles because they appear to be acclimated to traffic and noise.

ESA-listed species the short-tailed albatross and Columbian white-tailed deer are not expected in the vicinity of the MCR; therefore the proposed action would have no effect on these species. Also, no Oregon silverspot butterfly populations are known to occur in the project area, and the project is not anticipated to have any effect on their preferred habitat types.

Brown pelicans are likely to be in the vicinity during construction, though they were delisted in 2009. Though there is a possibility of minimal disturbance, considering their acclimation to human activity at the MCR and the availability of nearby suitable habitat, the proposed actions could temporarily affect brown pelicans, but likely not to a level that causes harm.

Due to the minimal likelihood that species would be present, that they would encounter any elements of the proposed action, or that actions would occur in or measurably affect any portion of their critical habitat, the Corps determined that the proposed action would have no effect on the following federally listed species: short-tailed albatross, northern spotted owl, Columbian white-tailed deer, Oregon silverspot butterfly, Nelson's Checker-mallow, and streaked horned lark (see Section 2.2.2).

Marbled murrelets are expected to occur in the general vicinity of the MCR, specifically on the Columbia River bar and nearshore waters (see Section 2.2.2). Their numbers are anticipated to be low throughout the general project area. Cape Disappointment State Park is located about 1.6 miles northeast of the North Jetty at Benson Beach and contains suitable habitat for marbled murrelet nesting. While nesting has not been documented in this area, birds have been noted in flight during the nesting season. Periodic minor disturbance may occur to marbled murrelets due to noise generated from trucks on haul roads through Washington State Parks property adjacent to possible nesting habitat, although all truck traffic would occur only during daylight hours. The following measures would be employed during the marbled murrelet nesting season (April 1 to September 15) to reduce impacts from noise to nesting murrelets:

1. Trucks will only be allowed to use roads through Cape Disappointment during daylight hours.
2. Trucks will not unnecessarily stop along the roads through Cape Disappointment.
3. Trucks will be prohibited from using compression brakes (jake brakes) on roads through Cape Disappointment.

No adverse impacts on feeding by marbled murrelets would be expected from implementation of the proposed action because modeling shows no appreciable permanent changes to velocity, salinity, and bed morphology at the MCR. Because the proposed action is located approximately 1.6 miles from potential nesting areas, periodic disturbance may occur to marbled murrelets in project vicinity because of noise generated from construction and from trucks on the haul roads through Washington State Parks property. Conservation measures will further avoid and minimize disturbance to marbled murrelets.

Western snowy plovers historically occurred in the vicinity of Clatsop Spit although no breeding or wintering plovers have been reported from these beaches in recent years (see Section 2.2.2). This evidence was supported by a survey completed by the USFWS and Corps representatives in May 2010 when no plovers were observed. However, two birds were sighted in recent surveys (Blackstone 2012). Benson Beach and Clatsop Spit are not designated as critical habitat, although a

Habitat Conservation Plan (HCP) has been developed for Clatsop Spit by OPRD. Most of the land-based construction activities would occur above the MHHW levels in the near and immediate vicinity of the jetties. Thus, this limits the geographical extent of the disturbance effects from construction clearing, and reduces the likelihood that actions would occur in foraging areas preferred by snowy plover. According to USFWS, European beachgrass reduces the amount of open, sandy habitat, contributes to steepened beaches, and increases habitat for predators. These conditions are problematic at the Spit, and may actually be improved by the proposed foredune augmentation, clearing for stockpiling and construction staging, and eventual replanting of native dune plants.

A draft Habitat Conservation Plan (HCP) for western snowy plovers was prepared (Jones and Stokes 2007 and 2009) and included restoration activities at various locations along the Oregon Coast including Clatsop Spit. The Snowy Plover Management Area identified on Clatsop Spit included 0.62 mile of beach along the Columbia River within the park and is located north of the South Jetty. This area is owned by the Corps and leased by the OPRD. The OPRD manages the natural resources, facilities, and visitors within the leased area. Activities that OPRD are interested in include predator management, symbolic fencing, public outreach and education, habitat restoration and maintenance (which could include grading of vegetated areas), and monitoring. On December 17, 2010, the Corps joined the USFWS, other federal agencies, and the State of Oregon in signing a statewide HCP for snowy plovers. The area proposed for construction, storage, and staging is mostly outside of the area on Clatsop Spit identified in the HCP. Thus, the proposed action is not likely to adversely affect snowy plovers. The Corps would be implementing best management practices (BMPs) that are in alignment with its efforts under the HCP.

As discussed in Section 5, the Corps is investigating opportunities to create western snowy plover nesting habitat on Clatsop Spit within Fort Stevens State Park. As staging areas could be attractive to plovers, the Corps would consider creation of habitat after use of the Spit for rock storage is completed to avoid potential limitations to rock storage and transport on the Spit if plovers begin to nest in staging areas. The Corps would also consider options to create plover habitat concurrently with rock storage if it is certain that plover use of the created habitats and beaches would not interfere with the Corps' ability to use Clatsop Spit throughout the life of the project. This habitat area would be implemented with the intention to create more preferable nesting habitat such that plover are lured away from the potential attractive nuisance of the cleared staging areas. In other words, the Corps would be creating bare sand habitat that would attract birds away from construction site impacts. Habitat maintenance each year after creation would be required to preserve functional habitat. The Corps would maintain these sites during construction, but after project completion maintenance would not be the responsibility of the Corps. The Corps has had initial discussions with the USFWS and OPRD regarding snowy plover habitat creation.

6.14. Cultural and Historic Resources

Section 106 of the National Historic Preservation Act (NHPA) requires that federally assisted or federally permitted projects account for the potential effects on sites, districts, buildings, structures, or objects that are included in or eligible for inclusion in the National Register of Historic Places (Register). The preferred alternative is being conducted in an area that is highly erosive and has previously been disturbed by jetty construction. Jetty site evaluations concluded that shipwrecks or remnants of shipwrecks do not occur at the jetty locations. Although the MCR jetties are currently not listed on the National Register of Historic Places, nomination of the structures is planned. Documentation of the structures will be coordinated with the State Historic Preservation Offices. The North and South Jetties are eligible for listing on the Register because they are associated with important historical events and thus meet Criterion A under the National Register criteria. Section

106 documentation of the current condition of the jetty trestle remnants was conducted in 2006 for the repair work. Both the North and South jetties are eligible for the National Register of Historic Places because they are important historically. However, they do not retain original materials of workmanship as they have been repaired many times, but they do retain their original alignments. Much of the area around each jetty is composed of accreted material from littoral drift with little or no potential for historic properties. Previous cultural resources surveys provide coverage over portions of the project footprints and adjacent areas, though much of this selected action will be conducted in an area that is highly erosive and has previously been disturbed by jetty construction and prior dredging. The rehabilitation and repair work; the staging/work, and mitigation areas are on landforms created in historic times from accretion or dredged material disposal after the jetties were constructed. Work in these areas has little chance of impacting historic resources, though there is the possibility of encountering shipwreck remains. There are no known historic properties recorded within the immediate project footprint other than the jetties and associated trestle remains. The South Jetty and trestle remains are not contributing elements to Fort Stevens (OR-CLT-1), which was officially listed on the Register in 1971, and the North Jetty and trestle remains are not contributory to the Cape Disappointment (formerly Fort Canby State Park) Historic District.

Interim repair work done in 2005 and 2006 on the Washington side was coordinated with the State Historic Preservation Office; a no adverse effect determination was supported for this interim repair after remnants of the original trestle were documented by a historic architecture study in an area adjacent to the jetty rock structure in a planned staging area where trestle remnants would be impacted. Much of the area around each jetty is composed of accreted material from littoral drift with little or no potential for historic properties. The Corps determined that the undertaking would have *no effect* on historic properties since the action would not affect the criteria that make the jetties eligible for the National Register of Historic Places and the Washington and Oregon State Historic Preservation Offices (SHPO) have concurred.

6.15. Socio-economic Resources

Construction vehicles hauling jetty rock would have an intermittent affect on local traffic patterns in the Long Beach/Ilwaco area (North Jetty/Jetty A) and in Warrenton/Hammond area (South Jetty), depending on whether barge or truck transport is used for jetty rock. The approximate number of trucks or barges to be used for rock transport is shown below. This revised schedule is much reduced relative to the earlier prediction of a schedule extending out to year 2033.

- Construction Year 2013 (South Jetty Dune Augmentation): 2000 trucks (not likely to come in by barge)
- Construction Year 2014 (North Jetty Lagoon Fill and Critical Maintenance): 2500 trucks for lagoon fill; 1500 trucks 8 barges for North Jetty stone.
- Construction Year 2016 (North Jetty): 2900 trucks or 13 barges.
- Construction Year 2017 (North Jetty): 970 trucks or 5 barges.
- Construction Year 2017 (South Jetty): 3000 trucks or 14 barges.
- Construction Year 2018 (South Jetty): 2970 trucks or 14 barges.
- Construction Year 2019 (South Jetty): 2640 trucks or 12 barges.
- Construction Year 2020 (South Jetty): 2980 trucks or 13 barges.

Construction of the proposed action would have minor adverse impacts to recreationists at Cape Disappointment State Park and Fort Stevens State Park, both those participating in water-sports and beach activities near the jetties, and those using the jetty structures for fishing and crabbing. Heavy equipment using park roads and parking lots will delay or inconvenience park visitors and water sport and beach recreationists. Park visitors and recreationists are likely to be disturbed by construction noise. A number of restrictions would be in place near the construction zones at each jetty to protect park visitors, water sport and beach recreationists, and the public. For public safety reasons, the Corps discourages use of the jetty structures themselves, and this policy would remain in force throughout the construction period. Along the South Jetty where surfing occurs, there may be some exclusion areas near the jetty structure and during dune augmentation and portions of jetty repair. However, the bulk of vessel traffic will occur on the channel side of the jetty and repairs will be in the immediate vicinity of the structure, so the minimal and short-term effects on surfing are likely to be negligible. Some park roads and parking lots would likely be closed at times during construction. Razor clam beds in the vicinity of the jetties may be temporarily closed during construction activities, but are not expected to be negatively impacted. Access to the jetties and nearby beaches would also be closed periodically at different times during construction of the individual jetties, which would also impact water sport and beach recreationists and anglers using the immediate vicinity. However, large portions of the parks and beaches will remain open and accessible to the public, and the bulk of the construction activities are likely to be seasonally concentrated. The long-term reduction in the levels of recreational activity could also affect the local economy of the Long Beach peninsula and the Warrenton/Hammond area, which are highly dependent on tourism. However, navigation traffic transiting the MCR, including recreational vessels and cruise ships that dock at Astoria, Oregon, would not be affected during construction. Overall, the recreation and local economy impacts during construction of the proposed action are expected to be minor. Therefore, the Corps is not proposing mitigation for recreational impacts, nor is the Corps proposing to construct additional beach access points. The potential environmental impacts of creating additional beach access points outweigh the inconvenience and reduced access caused by seasonal construction activities.

After construction, rehabilitation of the MCR jetty system would have a long-term, positive effect on navigation and vessel safety, including recreation vessels and cruise ships. Maintenance of the shoreline at Clatsop Spit and Benson Beach is expected, which preserves these areas for recreational opportunities mentioned above. The proposed action would have no effect on utilities and public services in the area. The MCR is the gateway to the Columbia-Snake River system, accommodating commercial navigation traffic with an approximate annual value of $20 billion dollars a year. The proposed action would have a long-term, positive effect on maintaining this vital transportation link and associated economy for the states of Oregon, Washington, Idaho and Montana, as well as for the Nation as a whole.

6.16. Cumulative Effects

Cumulative effects are defined as, “The impact on the environment which results from the incremental impact of an action when added to other past, present, and reasonably foreseeable future actions regardless of what agency (federal or non-federal) or person undertakes such other actions” (Code of Federal Regulations Title 40, Section 1508.7). Cumulative impacts can result from individually minor, but collectively significant actions taking place over a period of time. The past actions that have occurred in and near the MCR jetties are identified below. Together, these actions have resulted in the existing conditions in the vicinity of the MCR jetties (see Section 2).

- European settlement and associated modifications in the vicinity of the MCR.
- Residential, commercial, and industrial development that occurred in upland areas.
- Original construction of the MCR jetty system and subsequent rehabilitation and repairs.
- Development and recreational use of Fort Stevens and Cape Disappointment State Parks.
- Operation and maintenance of the Columbia River federal navigation channel including navigational structures, periodic dredging and disposal, surveying, etc.
- Designation and use of dredge material disposal sites. Several active and historic disposal sites occur in the vicinity of the MCR. A North Jetty site was established in 1999 to allow placement of dredged material along the jetty toe to protect it from excessive waves and current scour. Its use is limited to disposal of MCR dredged material. From 1999-2008, about 4.4 mcy of dredged material was placed in this site. The shallow water ocean disposal site (SWS) was designated in 2005 by USEPA and lies about 2 miles offshore from the MCR. The SWS is used for disposal of material dredged from the MCR and is of strategic importance to the region; its continual use has supplemented Peacock Spit with sand, sustained the littoral sediment budget north of the MCR, protected the North Jetty from scour and wave attack, and stabilized the MCR inlet. There is a deep water ocean disposal site further offshore from the MCR and a proposed dredge material disposal site near the South Jetty.
- Disposal of dredged material (marine sand) at Benson Beach.
- Deepening of the Columbia River federal navigation channel.

The reasonably foreseeable future actions under consideration in this analysis are identified below. The listing includes relevant foreseeable actions in and near the MCR including those by the Corps, other federal agencies, state and local agencies, and private/commercial entities.

- Mitigation associated with the proposed action.
- Operation and maintenance of the federal navigation channel for authorized project purposes.
- Protection and restoration of existing natural areas and potential acquisition, restoration and protection of natural areas in the vicinity of the MCR by federal, state, and local agencies.
- Operation and maintenance of existing recreational facilities in Fort Stevens and Cape Disappointment State Parks.
- Continued use and development in upland areas for residential, commercial and industrial use in proportion to future increases in population throughout the area.
- Water quality improvements with implementation of more stringent non-point source pollution standards, such as total maximum daily loads (TMDLs).
- The Corps has recently proposed designation of three dredge disposal areas that would provide potential benefit in restoring a sediment budget to the littoral cells in the vicinity of MCR. These sites include: South Jetty Nearshore site (subtidal), Benson Beach Intertidal site, and the North Head Nearshore site (subtidal). As with the existing North Jetty 404 Site, these additional sites could also help to alleviate some to the scour occurring at the jetty structures.

  The proposed sites are somewhat removed from the immediate geographic vicinity of the jetty Major Rehabilitation proposed actions. These beneficial use sites could also help rebuild the sand shoals at the North and South Jetty foundations. However, it is uncertain in what priority, frequency, and timeframe these new disposal sites would be implemented. Currently, the South Jetty Nearshore site is top priority, followed by Benson Beach, and then the North Head site. The specifics for these sites have been described and evaluated in the Corps' April 2012 *Draft EA for Proposed Nearshore Disposal Locations at the Mouth of the Columbia River Federal Navigation Project, Oregon and Washington*.

The potential cumulative effects associated with the proposed Major Rehabilitation actions were evaluated with respect to each of the resource evaluation categories in this Environmental Assessment. For the proposed action, water quality impacts (suspended sediment and turbidity increases) are expected to be temporary and localized, and BMPs would further reduce effects. Water quality impacts from the proposed action are not expected to be cumulatively significant. Stricter controls placed on foreseeable future projects would reduce short-term, adverse impacts and are anticipated to provide a long-term, cumulative benefit to the water quality in the vicinity of the MCR.

Future development, construction activities, and other foreseeable future projects, in combination with population growth, would produce changes in the amount of impervious surfaces and associated runoff in the vicinity of the MCR. However, all projects are required to adhere to local, state, and federal stormwater control regulations and best management practices that are designed to limit surface water inputs.

Biological resources include fish and wildlife, vegetation, wetlands, federal threatened and endangered species, other protected species, and natural resources management. While historic development in the vicinity of the MCR has caused losses of aquatic and riparian habitats, especially in the lower Columbia River and estuary with resulting adverse impacts to fish and wildlife resources, these actions occurred in a regulatory landscape that is very different from that which exists today. While future development will likely have localized impacts on these resources, under the current regulatory regime these resources are unlikely to suffer significant losses. Moreover, initiatives by federal, state, and local agencies and groups would operate to mitigate the unavoidable environmental impacts of any future development. In addition, there are a number of actions that are ongoing or planned that would provide a cumulative, long-term improvement to aquatic resources and habitat, especially for ESA-listed salmonid species, including the implementation of the Conservation Recommendations and Reasonable and Prudent Alternatives specified in the 2008 NMFS Federal Columbia River Power System Biological Opinion and more stringent non-point source pollution standards. Any future federal actions would require additional evaluation under the National Environmental Policy Act at the time of their development.

In the long term, mitigation associated with the proposed action would provide the benefits previously described, including an increase in the overall square footage of wetlands and improve uplands, potentially also improving wetland-stream hydrologic functions in the Columbia River estuary.

A long-term reduction in the levels of recreational activities near the MCR jetties would occur during the proposed action and future activities. This reduction in recreation activity could also affect the local economy of the Long Beach peninsula and the Warrenton/Hammond area, which are highly dependent on tourism. These recreation and local economy impacts are not expected to be significant. The proposed action and future activities are not expected to cause a cumulative, adverse change to population or other indicators of social well being, and should not result in a disproportionately high or adverse effect on minority populations or low-income populations. No cultural and historic resources are expected to be impacted by the proposed action. Reasonably foreseeable future actions will be subject to review and approval by State Historic Preservation Officer.

The proposed action would facilitate effective maintenance of the Columbia River navigation channel, as it would improve and restore the function of the MCR jetty system. The jetty system helps reduce shoaling in the main channel and directs and concentrates currents in order to preserve sufficient depths in the main channel. While operations and maintenance dredging would continue at the MCR, the proposed action is intended to reduce the migration of littoral drift into the channel; upon completion, this may reduce the volumes and frequency of future operation and maintenance dredging at the MCR. Another benefit of reducing littoral drift into the MCR is the preservation of Benson Beach and Clatsop Spit. The dredge disposal at Benson Beach and the other existing SWS, North Jetty 404 site, and proposed North Head beneficial use sites may complement the proposed infill actions that are intended to protect the North Jetty root. Similarly, this may also be the case if new disposal sites are implemented at both the South Jetty Nearshore and Intertidal sites near the South Jetty trunk, root, and dune augmentation areas. Shoreline preservation could be complemented by the infill activities, dredge disposal, and further stabilization and augmentation efforts at the spit.

In conclusion, this cumulative effects analysis considered the effects of implementing the proposed action in association with past, present, and reasonably foreseeable future Corps' and other parties' actions in and near the MCR. The potential cumulative effects associated with the proposed action were evaluated with respect to each resource evaluation category and no cumulatively significant, adverse effects were identified. In addition, there are a number of actions that are ongoing or planned that would provide a cumulative, long-term improvement to aquatic and wildlife resources and habitat.

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7. COORDINATION

An agency coordination meeting was held on May 25, 2006 for the purpose of introducing the project to several agencies that will be involved with review of environmental documents. Staff from the USACE Portland District presented the current state of environmental review and engineering modeling to the NMFS, USFWS, WDOE, ODEQ, and Oregon Department of Land Conservation and Development.

On April 13, 2007 the USACE met with the U.S. Geological Survey (USGS) and Portland State University regarding numerical modeling in support of the MCR rehabilitation project. Also in 2007, four resource agency meetings and presentations were held regarding the MCR project on April 27, May 30, July 11, and September 5. A public information meeting was held in Astoria, Oregon on July 31, 2006. After a presentation about the MCR jetty rehabilitation project, the public was invited to ask questions and talk to USACE staff about the project. In addition, the USACE Portland District established a web site to keep the public informed about the repair/rehabilitation of the MCR jetties located at https://www.nwp.usace.army.mil/issues/jetty/home.asp.

An initial draft EA was distributed for a 30-day public review in June 2006. Six comment letters were received based on the June 2006 EA. Since the current range of alternatives and project description changed, comments received on the June 2006 EA may no longer be relevant to the current proposed alternatives. A summary of these comments is provided below.

- Interested in how rehabilitation would impact siltation in side channels and in Baker Bay and effects to coastal erosion.
- Need to analyze/mitigate losses to crab nursery habitat.
- Loss of sand from coastlines (primarily Benson Beach) needs to be analyzed/mitigated. Interested in sand placement on Benson Beach.
- Focus on Environmental Impact Statement (EIS) and evaluate all projects in the MCR vicinity cumulatively in a comprehensive context (dredging, dam regulation, disposal, etc).
- Purpose should be to get goods to market not rehabilitate the jetties. Alternative should consider other options besides shipping.
- Jetty A's purpose should be discussed; noted that channel has moved north.
- Evaluate how existing spur groins have performed.
- Affected environment should extend to Grays Harbor.
- Role of near-jetty disposal should be evaluated in greater detail.
- The degree to which waves have changed should be evaluated with respect to jetty design.
- Discuss project impacts to Clatsop Spit and Peacock Spit and sediment budget to littoral cell.
- Sand placement alternatives should be considered to address jetty foundation shoal erosion.
- The draft EA (2006) was put out for public review too early and has deprived the public its opportunity to comment.
- Should report current rates of erosion at Peacock Spit.
- Supports rehabilitation of the MCR jetties citing navigation safety and economic benefits.
- Interested in how rehabilitation of Jetty A would affect base of North Jetty and channel entrance to Port of Ilwaco with respect to sand accumulation.
- Supports studying/planning and rehabilitating the MCR jetties citing the international/economic importance of shipping.
- Recommend that rehabilitation be accomplished from land-based work sites to minimize amount of dredging.

- Recommend that dredged material resulting from project be used to create snowy plover habitat at base of South Jetty by covering beach grass. Interested in reviewing planting plan.
- Interested in type of wetlands to be impacted at North Jetty and location of disposal site.
- The wetlands behind North Jetty should be categorized using the Washington State wetland rating system for western Washington to assist in determining appropriate mitigation.
- Interested in potential impacts/mitigation to wetland north of the North Jetty access road from filling behind the North Jetty (the area is considered Conservancy Shorelands under Pacific County Shoreline Management Plan).
- Best management practices should be in place to prevent adverse impacts to wetlands from construction traffic.
- Interested in alternative routes to beach, and viewing area during construction.
- Assess impacts of barge offloading facility creation and haul routes when known.
- Interested in interactions with other planned activities about the MCR including Benson Beach project.
- Modeling should consider impacts from sediment transport/deposition at Benson Beach and whether build-out would affect ability to do the Benson Beach project.

Due to changes in the project description, a revised draft EA was prepared. The revised 2010 draft EA (*Revised Draft Environmental Assessment Columbia River at the Mouth, Oregon and Washington Rehabilitation of the Jetty System at the Mouth of the Columbia River, January 2010*) was informed by and revised to reflect and address the above comments, as appropriate. The revised draft EA was issued for a 30-day public review period in January 2010. The revised draft EA was provided to federal and state agencies, organizations and groups, and various property owners and interested publics. In addition, a public information meeting was held in Astoria, Oregon on February 3, 2010. After a presentation by the Corps about the MCR jetty rehabilitation project, the public was invited to ask questions and talk to USACE staff about the project. Another public information meeting to describe likely construction techniques was also held on June, 4, 2010, at Fort Vancouver, WA to solicit input from potential construction contractors and to provide additional information regarding the feasibility of the Major Rehabilitation and Repair approach.

A summary of the comments received on the January 2010 revised draft EA is provided below, followed by the Corps' response and subsequent changes, as appropriate, to both the final 2011 EA posted in May 2011, (*Final Environmental Assessment Columbia River at the Mouth, Oregon and Washington Rehabilitation of the Jetty System at the Mouth of the Columbia River* and *Finding of No Significant Impact, May 31, 2011)* (2011 final EA) as well as this 2012 revision.

1. Confederated Tribes of the Grand Ronde, email dated January 21, 2010.
    a. Requested any reviews related to the National Historic Preservation Act.
        i. No change to EA text. This will be done as part of the actions described in the Compliance section.
2. Clatsop County Transportation and Development Services, letter dated January 21, 2010.
    a. Project will affect the safety and operations of Ridge Road to be used to access the South Jetty project area; request meeting to discuss requirements for road's use.
        i. No change to EA text. This will occur later during development of the Detailed Design Report and Plans and Specifications prior to construction.
3. Oregon State Historic Preservation Office, letter (no date).
    a. Project will have no effect on any known cultural resources; no further archaeological research is needed unless cultural material is discovered during construction.

            i. No change to EA text. This will help inform part of the National Historic Preservation Act actions described in the Compliance section.

4. Columbia River Crab Fisherman's Association, letter dated February 1, 2010.
    a. Agree with findings of report/no action is unacceptable; EA and Finding of No Significant Impact (FONSI) are appropriate.
        i. No change to EA text.
    b. Just adding stone to jetties will not solve entire foundation problem, direct sand supplementation of the sand foundation is needed to stabilize jetties over coming decades.
        i. No change to EA text. Engineering staff has evaluated and designed the project as described in the EA to address the perceived problems and causes, including consideration of spur groins to accrete sand and protect the jetties' foundations.
    c. Lengthen Jetty A to full length will help stabilize natural northern migration of shipping channel and help somewhat with increasing erosion on Sand Island.
        i. No change to EA text. Engineering staff has evaluated and designed the project to address the perceived problems and causes as described in the EA, including capping or stabilization of the head of Jetty A at its current length to avoid further head loss.
    d. Routine direct placement of sand near root of jetties and north along Benson Beach will be required and must be part of the long-range stabilization plan. Consider a permanent pipe with frequent outlets for length of jetties to distribute sediment on both sides of jetties to supplement sand foundation. Consider permanent pipeline to supplement Benson Beach.
        i. No change to EA text. Engineering staff has evaluated and designed the project to address the perceived problems and causes as described in the EA, including lagoon fill and consideration of spur groins to address protection of the jetty foundation. Benson Beach littoral drift replenishment is being conducted under a separate project.
    e. In general, the Columbia River Crab Fisherman's Association supports the project.
        i. No change to EA text.
5. Public Commenter, email dated February 12, 2010.
    a. Previous jetties repairs have required a great deal of truck traffic in SW Washington; transport rock this time via barge. State is in a budget crisis cannot afford to repair roads; barges are more energy efficient and would keep roads from being compromised.
        i. As described in Section 5.5.3, the feasibility of several transportation options have been considered, and a combination of approaches may be implemented.
6. Public Commenter, letter dated January 15, 2010.
    a. During design, consider how construction will affect the surf break.
        i. No change to EA text. Wave climate and currents were modeled and considered for their impacts to the function and integrity of the jetty structures for maintaining navigation. Understanding wave formation for recreational uses was not one of the project purposes evaluated.
    b. Locations of spur groins not clearly shown in the EA.
        i. Locations of spurs were clearly shown on the proposed action figure for each jetty. They are no longer proposed in this 2012 preferred alternative.
    c. The EA does not adequately address impact to socio-economics of Warrenton; revise text (Sections 2.4.3 and 6.8) to acknowledge other activities like water sports (surfing, kayaking,

kite boarding), clam digging, and beach activities such as walking, running, dog exercise, etc.

    i. Text of EA was revised as suggested.

  d. There needs to be public access to beach immediately south of South Jetty; prohibiting access by not allowing climbing over jetty rocks is not a solution. Public beach access should be maintained during construction. Letter provides two ways to address this: (1) contractor can retain some parking at Lot C and provide safe pedestrian access through construction zone; or (2) contractor can build new or temporary parking lot/path to the beach south of jetty.

    i. As described in the Socio-economic sections of the EA, for safety reasons, the Corps prohibits climbing on jetty rocks, and to maintain safety will also have certain portions of the park closed where there is construction, equipment, or staging activities. Though there may be intermittent closures in certain areas, there are likely to be portions of the beach that remain open and unaffected. The Corps will be coordinating with the Park and construction staff to maintain the safety of park visitors.

  e. Post-construction establish a permanent, safe public access from the parking area to the beach.

    i. No change to EA text. The purpose of this project is to maintain the jetties and does not include construction of additional beach access points.

  f. The EA should address construction safety for surfers and other water sport enthusiasts; contractor to delineate safety zones when working in or around the water using buoys or other types of notification; provide signs or displays warning surfers when in-water work is underway.

    i. No change to the EA text. This is mentioned in Section 6.15

7. Chadbourne + Doss Architects, email dated February 4, 2010.

  a. Spends time at South Jetty and sees opportunity for interpretive center or thoughtful installation to help communicate purpose of the jetty and efforts of Corps.

    i. No change in the EA text. This does not fit with the purpose and need of the project.

8. Public Commenter, letter dated January 17, 2010.

  a. Provides information and photos of Japanese approach to sea walls and breaker barriers.

    i. No change in the EA text. Concrete armor units similar to those shared by the commenter are already under consideration for use at the jetty heads.

9. JP&M Mining, email dated January 20, 2010.

  a. Attending meeting in Astoria on February 3, wants any existing surveys on North and South jetties and information on previous quarries used.

    i. Request was forwarded to the geotechnical engineer, and a quarry list has been provided in the EA.

  b. Putting together a business plan that may include revamping a coastal port.

    i. No change in the EA text.

  c. Jetty rehab excellent way to use local workers and improve infrastructure in coastal communities.

    i. No change in the EA text.

10. Public Commenter, letter dated February 2, 2010.

   a. Provided two historical references to be added to history of MCR jetties section.
      i. These were added to reference section.
   b. Draft EA overemphasizes use of quarried armor stones; other approaches like reinforced concrete armor units and structural solutions using reinforced concrete elements should also be given emphasis in decision-making process.

11. More information was added to EA about physical model (Section 4.1.2.3). Concrete armor units are under consideration for use at the jetty heads. PND Engineers, letter dated February 12, 2010.
    a. Provided information on OPEN CELL jetty structures.
       i. No change in the EA text. Information was forwarded to the coastal engineers.
12. Northwest Environmental Advocates, letter dated February 12, 2010.
    a. USACE must prepare an EIS that complies with the purpose of NEPA.
       i. No change to the EA text. With the release of the Draft EA for solicitation of public comments, through its evaluation of impacts and alternative, and through meeting its other compliance obligations, the Corps has also been complying with its NEPA obligations. At the conclusion of the Final EA, the Corps will make its determination as to whether or not an EIS or a FONSI will be completed.
    b. Information required for public disclosure has been omitted from draft EA (disposal of dredged materials, costs and benefit-to-cost ratio for the project, meaningful discussion of impacts, etc).
       i. EA text has been revised for dredged material disposal, alternative selection, and impact discussions.
    c. Draft EA segregates connected actions; the jetties, maintenance of the MCR and Columbia River navigation channel, and dredged material disposal sites are connected actions.
       i. No change to text in the EA. The purpose and need described in the proposed action is limited to repair and rehabilitation of the existing jetty system.
    d. Biological Assessments for the Services not completed prior to public review of draft EA.
       i. The EA text has been edited to reflect updated evaluations and information, including in the ESA Compliance section. Biological Assessments have been completed, and a Biological Opinion and Letter of Concurrence have been obtained from the Services prior to completion of the final EA.
    e. Inadequate information on future conditions that will degrade the jetties, e.g., wave height changes, climate change.
       i. Text was added to the EA in section 6.11 describing hydrologic and hydraulic processes and modeling that was conducted during evaluation and design of the jetty alternatives.
    f. Draft EA does not address the impacts of filling the Trestle Bay area with cobble.
       i. As described in the alternatives discussion for the South Jetty, this alternative component has been removed as part of the selected or preferred plan. Text was added to Section 6 to discuss impacts from fill at the foredune augmentation.
    g. Draft EA does not adequately analyze alternatives.
       i. Changes to the text were made for describing the selection of alternatives.
    h. Draft EA does not contain a detailed mitigation plan.

      i. The wetland impacts and mitigation sections have been revised to reflect mitigation plans.

   i. Draft EA fails to identify/analyze cumulative impacts of past, current and future actions; as with previous EIS or EAs for MCR and Channel Deepening projects, including deepwater site, there is no evaluation of baseline conditions and cumulative changes to issues such as salinity, ocean plume, risk of oil spills, changes in shipping, habitat loss, impacts on salmonids, and sedimentation processes.
      i. The Cumulative Effects section has been revised. The No Action and Baseline conditions, impacts, and hydrology and hydraulics have also been described.
   j. Draft EA does not discuss how littoral cell and other Corps actions, such as hydrosystem operation and dredging and disposal of dredged materials, have affected sedimentation in the littoral cell and how continued maintenance of existing jetty length will continue to affect sedimentation processes.
      i. Text was added to the EA in section 6.11 describing hydrologic and hydraulic processes and modeling that was conducted during evaluation and design of the jetty alternatives.
   k. Draft EA does not address possible effects of filling the dunes at South Jetty root/Trestle Bay.
      i. As described in the alternatives discussion for the South Jetty, the Trestle Bay fill alternative component has been removed as part of the selected or preferred plan. Text was added to Section 6 to discuss impacts from fill at the foredune augmentation.
   l. Action area should encompass the entirety of the littoral cell.
      i. The affected environment and possible environmental consequences were both described, as were effects to hydraulics and hydrology in the project vicinity.
   m. Project timing and schedule not clear – draft EA does not state how long repairs should last; timing of project is described as lasting 50 years but project actions take place in 2045 and 2069.
      i. More information has been added to EA under Construction Scheduling, and also in the description of alternatives and proposed actions. The construction schedule has also been revised in this EA and the previous draft and final EAs. Even with repairs and rehabilitation earlier in the project life, the model predicts that future repairs could be required given storm and wave climate at the jetties. This has been described in the No Action section.
   n. A supplemental EIS for the MCR is required to address impacts of jetty rehabilitation project.
      i. No changes were made to the EA text. The Corps disagrees and has determined a separate EA for jetty repairs and rehabilitation is an appropriate path for complying with NEPA requirements.
   o. Independent peer review is required by the Water Resources Development Act of 2007.
      i. No change to EA text. The 90% Major Rehabilitation Report, of which the draft EA was a part, has completed independent external peer review (IEPR).

13. United States Fish and Wildlife Service, letter received February 23, 2010.
   a. Requests disposal of dredged material be used to cover European beach grass.

    i. These actions would be evaluated during construction implementation and would also be vetted through the AMT.

b. Requests heavy equipment to remove European beach grass and to restore and enhance snowy plover nesting habitat in concert with the draft Habitat Conservation Plan and Oregon Parks and Recreation Department (OPRD).
    i. Habitat preferred by snowy plover will be created adjacent to the staging areas in order to reduce the potentially attractive nuisance created by the cleared staging area.
c. Requests habitat improvements in coordination with OPRD for rock storage via creation of habitat areas for snowy plover that do not interfere with use of the Spit.
    i. Habitat preferred by snowy plover will be created adjacent to the staging areas in order to reduce the potentially attractive nuisance created by the cleared staging area.

This 2012 revised final EA updates and corrects the 2011 final EA by updating the alternative plans considered and the Preferred Alternative actions proposed for the North Jetty, South Jetty and Jetty A. This has resulted in smaller project and environmental footprints than proposed in the 2006 draft EA, the 2010 draft EA and the 2011 EA. It also updates the Cumulative Effects section with the addition of the Corps' proposed designation of additional nearshore disposal sites. The 2011 and 2012 EAs were also informed by and revised to reflect and address the above public notice comments, as appropriate. After the previous 30-day public review period and receipt of comments from federal and state agencies, organizations and groups, and various property owners and interested publics, public concerns identified in comments were addressed. A determination would be made as to whether or not an Environmental Impact Statement (EIS) is necessary. The determination would be made in a Record of Decision or Finding of No Significant Impact (FONSI).

Besides these official public information meetings and distribution of the EA, the Corps has also had multiple meetings with various regulatory agencies to ensure regular coordination throughout project development. As mentioned in the overview of the Preferred Alternative, the Corps has also proposed formation of a modified interagency Adaptive Management Team to keep resource agency partners apprised of any potential project changes or challenges during implementation.

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8. COMPLIANCE WITH LAWS AND REGULATIONS

8.1. Clean Air Act

This Act established a comprehensive program for improving and maintaining air quality throughout the United States. Its goals are achieved through permitting of stationary sources, restricting the emission of toxic substances from stationary and mobile sources, and establishing National Ambient Air Quality Standards. Title IV of the Act includes provisions for complying with noise pollution standards. Section 118 (42 U.S.C. 7418) of the Clean Air Act specifies that each department, agency, and instrumentality of the executive, legislative, and judicial branches of the Federal Government (1) having jurisdiction over any property or facility or (2) engaged in any activity resulting, or which may result, in the discharge of air pollutants, shall be subject to, and comply with, all Federal, State, interstate, and local requirements respecting the control and abatement of air pollution in the same manner, and to the same extent as any non-governmental entity. Corps activities resulting in the discharge of air pollutants must conform to National Ambient Air Quality Standards (NAAQS) and State Implementation Plans (SIP), unless the activity is explicitly exempted by EPA regulations10.

Repair and rehabilitation of the MCR jetty system is anticipated to remain in compliance with the Clean Air Act and the State Implementation Plan. This is not a transportation project, it will not qualify as a major stationary source of emissions of criteria pollutants, and the project does not appear to be located in a non-attainment area for limited air quality.

There would be an intermittent but long-term reduction in air quality during construction of the proposed action due to emissions from construction equipment. Any emissions that do occur during and after construction from motor vehicles or facility functions are expected to be de *minimus* and will be from activities of a similar scope and operation to those of the original facility. There also would be an intermittent but long-term increase in noise levels from construction equipment. Efforts to avoid and minimize these effects have been considered when comparing and evaluating construction methods. Use of vibratory hammers will minimize some of the noise impacts during piling placement. It is also possible barging rocks verses overland trucking would result in reduced truck traffic and lower project emissions. These effects will be evaluated while taking into consideration other environmental factors during final selection of construction methods.

8.2. Marine Protection, Research, and Sanctuaries Act

Prior to dredging and disposal activities, the Corps will request authorization to use one of the designated Section 102 sites for disposal of dredged materials. This will include a request for concurrence that the Corps' proposed Annual Use Plan is in compliance with the Site Monitoring and Management Plan. The proposed transportation of dredged material for placement or disposal in ocean waters will be further evaluated to determine that the proposed disposal will not unreasonably degrade or endanger human health, welfare, or amenities or the marine environment, ecological systems, or economic potentialities. In making this determination, the criteria established by the Administrator, EPA pursuant to section 102(a) of the Ocean Disposal Act will be applied. In addition, based upon an evaluation of the potential effect which the failure to utilize this ocean disposal site will have on navigation, economic and industrial development, and foreign and domestic commerce of the United States, an independent determination will be made regarding the need to dispose of the dredged material in ocean waters, other possible methods of disposal, and other appropriate locations.

8.3. Clean Water Act

Effects to water quality and effects from discharges and disposal into navigable waters, including 404 wetlands and waters including mitigation have been described in the pertinent sections of this EA. This Act also requires 401 Water Quality Certification from state or interstate water control agencies which certify that a proposed water resources project is in compliance with established federal and state effluent limitations and water quality standards. The proposed action is expected to be in compliance with the Act. A Section 404(b) (1) Evaluation has been prepared for the proposed action. The Section 404(b) (1) Evaluation and any additional necessary information will be submitted to the ODEQ and the WDOE. These agencies will be responsible for project review and issuance of the 401 Water Quality Certificates which will likely include terms and conditions to ameliorate impacts from the proposed action, including BMPs and turbidity monitoring requirements. The Corp will obtain these State 401 Water Quality Certifications prior to any inwater work or wetland fill. In addition, a National Pollutant Discharge Elimination System permit will be required from the USEPA and obtained prior to disturbance and work performed on federal lands in Washington, and the Corps intends to use the construction general permit after development of an appropriate Stormwater Pollution Prevention Plan. The Corps has a general 1200-CA permit (#14926) through the ODEQ that, though expired, has been administratively extended indefinitely by ODEQ and remains in effect. The Corps intends to maintain compliance with its terms and conditions, including development of an Erosion and Sediment Control Plan prior to disturbance and work performed on federal, state, and local lands in the Oregon State.

8.4. Coastal Zone Management Act

This Act requires federal agencies to comply with the federal consistency requirement of the Coastal Zone Management Act. This activity will be coordinated with the Oregon Department of Land Conservation and Development and the WDOE. A consistency determination will be prepared and concurrence received from both States prior to construction.

8.5. Endangered Species Act

In accordance with Section 7(a) (2) of this Act, federally funded, constructed, permitted, or licensed projects must take into consideration impacts to federally listed or proposed threatened or endangered species. Information on federally listed species and designated critical habitat is presented in this EA. Biological Assessments (BAs) were prepared for the proposed action to address federally listed species under the jurisdiction of the NMFS and USFWS. The BAs were provided to the respective agencies for review and consultation.

On March 18, 2011, The Corps received a Biological Opinion from NMFS indicating that the Corps' proposed actions were not likely to adversely affect any listed species, with the exception of eulachon, humpback whales, and Stellar sea lions (2010/06104). For these species, NMFS determined that Corps' actions were not likely to jeopardize the existence of the species. NMFS also concluded that Corps actions were not likely to adversely modify any of the current or proposed critical habitats. There was a Conservation Recommendation to carry out actions to reverse threats to species survival identified in the Columbia River Estuary ESA Recovery Plan Module for Salmon and Steelhead. The Corps also provided a conference report for critical habitat that NMFS proposed for leatherback turtles, eulachon, and Lower Columbia River coho salmon. The Corps will request NMFS adopts its conference report when this habitat becomes designated. Prior to construction, the

Corps will also request an Incidental Harassment Authorization of Stellar sea lions, humpback whales, California sea lions, and harbor seals.

On February 23, 2011 the Corps received a Letter of Concurrence from USFW regarding potential effects to species under their jurisdiction (13420-2011-I-0082). The Corps' determined its actions would have no effect on listed species, with the exception of bull trout, marbled murrelets, and snowy plover. The Corps concluded that its actions were not likely to adversely affect these species or their critical habitat. The USFW concurred with the Corps' determination. USFW also included four Conservation Recommendations to protect and improve snowy plover habitat and manage attractant waste derived from construction actions.

Mitigation components have been included in the proposed action by the Corps. These actions complement the Corps' affirmative commitment to fulfill responsibility to assist with conservation and recovery of ESA-listed salmonids.

8.6. Fish and Wildlife Coordination Act

This Act states that federal agencies involved in water resource development are to consult with the USFWS concerning proposed actions or plans. The proposed action has been coordinated with the USFWS in accordance with the Act. The Corps has also been in regular coordination with ODFW and WDFW regarding plan selection and development of wetland and waters mitigation projects.

8.7. Magnuson-Stevens Fishery Conservation and Management Act

The Sustainable Fisheries Act of 1996 amended the Magnuson-Stevens Act establishing requirements for essential fish habitat (EFH) for commercially important fish. Pursuant to the Magnuson-Stevens Act, an EFH consultation is necessary for the proposed action at the MCR jetties. Essential fish habitat is defined by the Act as "those waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity." The estuary and the Pacific Ocean off the MCR are designated as EFH for various groundfish and coastal pelagic and salmon species. The proposed action will directly affect EFH for Chinook salmon, coho salmon, English sole, sand sole, and starry flounder from the permanent loss of sandy bottom habitat from jetty construction. Short-term disturbances to EFH would result for lingcod, English sole, sand sole, starry flounder, black rockfish, brown rockfish, China rockfish, copper rockfish, and quillback rockfish. However, the addition of rock would increase EFH for lingcod, black rockfish, brown rockfish, China rockfish, copper rockfish, and quillback rockfish. An EFH assessment under the Magnuson-Stevens Act was provided as part of the Biological Assessment submitted to the NMFS for the proposed action. In the subsequent Biological Opinion, no additional Conservation Measures were proposed.

8.8. Marine Mammal Protection Act

This Act prohibits the take or harassment of marine mammals. It is possible that the proposed action could result in harassment of the federally listed Steller sea lion with construction at the existing above-water portion of the head of the South Jetty. They can be present at any time of the year. Impacts to this species were evaluated and are described in this EA. Impacts were further evaluated as part of the Biological Assessment submitted to the NMFS for the proposed action. The Biological Opinion from NMFS indicated Corps actions would NOT jeopardize the survival of the species.

Prior to construction activities, an incidental harassment authorization (IHA) for marine mammals at the South Jetty will be obtained from the NMFS. The Corps anticipates that the new IHA permit will entail requirements similar to those in the previous permit for repair of the South Jetty. The Corps also proposed Conservation Measures as previously described.

8.9. Migratory Bird Treaty Act and Migratory Bird Conservation Act

These acts require that migratory birds not be harmed or harassed. Under the Migratory Bird Treaty Act, "migratory birds" essentially include all birds native to the U.S. and the Act pertains to any time of the year, not just during migration. The Migratory Bird Conservation Act aims to protect game birds. Impacts of construction at the jetties and the hauling of rock to the jetties could displace birds by causing flushing, altering flight patterns, or causing other behavioral changes, but it is not expected that effects would rise to the level of harm or harassment.

8.10. National Historic Preservation Act

Section 106 of this Act requires that federally assisted or federally permitted projects account for the potential effects on sites, districts, buildings, structures, or objects that are included in or eligible for inclusion in the National Register of Historic Places. This project is being conducted in an area that is highly erosive and has previously been disturbed by jetty construction and prior dredging. There are no known historic properties recorded within the immediate project footprint other than the jetties and associated trestle remains. The proposed action has been coordinated with the Washington and Oregon State Historic Preservation Offices (SHPO) in order to obtain their comments on this Section 106 action in accordance with the Act. Letters were sent to WA Department of Antiquities and Historic Preservation on April 16, 2012, and to Oregon State Historic Preservation Office on April 16, 2012. The Corps anticipated concurrence from the respective State Historic Preservation Officers of Washington and Oregon if monitoring is conducted during excavations and the usual inadvertent discovery protocols followed. The Oregon and Washington SHPOs have concurred that the undertaking would have no effect on historic properties as the action would not affect the criteria that make the structures eligible, essentially, importance in historic events and alignment. Original workmanship and materials have all changed over a century of repairs and the alignment and configuration remain essentially the same. The Corps also coordinated with the Grande Ronde Tribe in accordance with Section 106 of the NHPA, and the Grande Ronde Tribe indicated they have no concerns in regards to this project's effects to properties on or eligible to the Register.

8.11. Native American Graves Protection and Repatriation Act

This Act provides for the protection of Native American (and Native Hawaiian) cultural items, established ownership and control of Native American cultural items, human remains, and associated funerary objects to Native Americans. It also establishes requirements for the treatment of Native American human remains and sacred or cultural objects found on federal land. This Act also provides for the protection, inventory, and repatriation of Native American cultural items, human remains, and associated funerary objects. There are no recorded historic properties within the immediate project area and the probability of locating human remains in this area is low. However, if human remains are discovered during construction, the Corps and/or the Contractor will be responsible for following all requirements of the Act.

8.12. Environmental Justice

Executive Order 12898 requires federal agencies to consider and minimize potential impacts on subsistence, low-income, or minority communities. The goal is to ensure that no person or group of people should shoulder a disproportionate share of the negative environmental impacts resulting from the execution of domestic and foreign policy programs. The proposed action is not expected to disproportionately affect low income and/or minority populations and is in compliance with Executive Order 12898.

8.13. Executive Order 11988, Floodplain Management

The proposed action would not further encourage development in, or negatively alter any floodplain areas. Executive Order 11988 regarding Floodplain Management was signed May, 24, 1977. The order requires that Federal agencies recognize the value of floodplains and consider the public benefits from their restoration and preservation. The objective is to avoid long and short-term adverse impacts to the base floodplain (100-year flood interval), and to avoid direct and indirect support of development in the base floodplain when there is a practicable alternative. Though the jetties are located in the floodplain on accreted land at the Clatsop Spit and Benson Beach, the floodplain in which they are located is relatively recently created and is at the mouth of the Columbia River. Therefore, these areas do not provide much floodplain storage or peak attenuation capacity. Furthermore, there are no other practicable alternative locations to conduct repairs or their associated construction activities, as the jetties are in a fixed location which is water and location dependent to maintain navigation. Additionally, the construction activities and fill will not be affecting floodplain areas that that have any private property, and there are few structures within the vicinity of the State Park lands and action area. The location of the State Park also precludes additional development in the vicinity of the jetties. Finally, the Corps does not expect any loss of beneficial values in the floodplain, and will be conducting some mitigation and restoration actions that will improve wetland function and dune stabilization. In order to inform the public of the proposed action, a draft EA was widely distributed and public comments were solicited. None of the commentators remarked on concerns for floodplain issues.

8.14. Executive Order 11990, Protection of Wetlands

Wetlands near the North and South Jetties and Jetty A will be filled for the proposed action. Plans for filling wetlands and the associated subsequent mitigation has been documented here and has been documented through the Section 404 (b) (1) evaluation that has also been prepared for the proposed action.

8.15. Prime and Unique Farmlands

No prime or unique farmlands will be affected by the proposed actions.

8.16. Comprehensive Environmental Response, Compensation, and Liability Act and Resource Conservation and Recovery Act

There is no indication that any hazardous, toxic, and radioactive wastes are in the vicinity of the MCR jetties. Any presence of these types of wastes would be responded to within the requirements of the law and Corps' regulations and guidelines.

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FINDING OF NO SIGNIFICANT IMPACT

For

REHABILITATION OF THE JETTY SYSTEM AT THE MOUTH OF THE COLUMBIA RIVER, OREGON AND WASHINGTON

I find that the selected course of action to maintain a resilient jetty system at the mouth of the Columbia River (MCR) will not significantly affect the quality of the human environment, and an Environmental Impact Statement is not required. The selected course of action in this Finding of No Significant Impact (FONSI) is the *Preferred Alternative* as summarized below and analyzed in the *Revised Final Environmental Assessment, Columbia River at the Mouth, Oregon and Washington, Rehabilitation of the Jetty System at the Mouth of the Columbia River* (U.S. Army Corps of Engineers, June 2012), otherwise known as the revised final EA. This revised final EA and FONSI list all of the important considerations of the proposed project and their environmental impacts, and the 2012 revised final EA is incorporated herein and provides a basis for the following information and conclusions. These impacts, both individually and cumulatively, are NOT SIGNIFICANT as *significant* is defined by National Environmental Policy Act (NEPA) and case law.

Introduction and Background Information

Features of the MCR navigation project were authorized by the River and Harbor Acts of 1884, 1905, and 1954. The navigation project consists of a 0.5 mile wide navigation channel extending for about 6 miles through a jettied entrance between the Columbia River and Pacific Ocean. The North Jetty and Jetty A are located in Pacific County, Washington, near the cities of Ilwaco and Long Beach on the Long Beach Peninsula. The South Jetty is located in Clatsop County, Oregon near the cities of Warrenton/Hammond and Astoria.

The MCR is the ocean gateway for maritime navigation to and from the Columbia-Snake River navigation system. The MCR jetties serve as the opening point to the larger Columbia/Snake River navigation system, carrying about 40 million tons of cargo on an annual basis, with an estimated value of $20 billion. The MCR jetty system is in a state of structural decay. Continued deterioration, ongoing storm activity and the continued loss of sand shoal material — the foundation of each of the three MCR jetties — has positioned the jetty system for a potential series of frequent, costly emergency repairs. Consequently, substantial repairs to the MCR jetties are necessary to maintain the location of the entrance and for the continued safe entry of ships into the Columbia River federal navigation channel. Actions identified in the June 2012 *MCR Jetty System Major Rehabilitation Evaluation Report* and proposed at the North and South Jetties and Jetty A will begin to address these issues. The revised 2012 EA provides a comprehensive analysis for all actions proposed at the MCR, including actions for the South Jetty dune augmentation, actions at the North Jetty described in the *North Jetty Major Maintenance Report* (MMR), May 2011, and actions described in the *MCR Jetty System Major Rehabilitation Evaluation Report*. All of these actions are described in the revised EA along with an evaluation of their cumulative effects.

In June 2006, the Corps issued a draft EA (*Draft Environmental Assessment, Columbia River at the Mouth, Oregon and Washington, Rehabilitation of the Jetty System at the Mouth of the Columbia River, June 2006*) for public review and comment. This 2006 draft EA identified a preferred alternative for major rehabilitation and repairs including rebuilding the jetty lengths, adding spur groins, and capping the head at each of the jetties. In January 2010, the Corps issued a revised draft EA (*Revised Draft Environmental Assessment Columbia River at the Mouth, Oregon and Washington Rehabilitation of the Jetty System at the Mouth of the Columbia River, January 2010*) for public review and comment, which superseded the 2006 draft EA. The preferred alternative included a smaller-scaled project without the rebuilt lengths and included head-capping, spur groins, and repair and rehabilitation actions at the jetties. The 2010 revised draft EA also included the following actions: South Jetty foredune augmentation at the jetty root near the neck of Clatsop Spit; fill of the lagoon at the North Jetty; and critical repairs to Stations 86-99 of the North Jetty.

After public review of the 2010 draft EA, the Corps modified the preferred alternative for the North Jetty, South Jetty, and Jetty A. The modification also included avoidance of fill in Trestle Bay. These combined modifications avoided and minimized some of the formerly identified environmental impacts by reducing the final structure and construction footprints necessary to achieve a resilient jetty system at the MCR. The 2010 draft EA was finalized in May 2011, *Final Environmental Assessment Columbia River at the Mouth, Oregon and Washington Rehabilitation of the Jetty System at the Mouth of the Columbia River* and *Finding of No Significant Impact, May 31, 2011* (2011 final EA). In addition to avoiding fill in Trestle Bay, the preferred alternative in the 2011 final EA included: spur groin and head-capping features at all jetties; scheduled repairs as the South Jetty; North Jetty lagoon fill; dune augmentation at Clatsop spit; immediate rehabilitation at Jetty A; and a proposed schedule of activities in a 20-year period. The Corps signed a FONSI in 2011 for a subset of the preferred alternative described in the 2011 final EA, which included the following: critical repairs at the North Jetty, North Jetty lagoon fill; and the dune augmentation at Clatsop spit. This FONSI replaces the 2011 FONSI.

The 2012 revised EA updates the 2011 final EA. It makes the clarification that the No Action Alternative is not the same as the Base Condition; since the Base Condition includes some action (these were the selected course of action in the 2011 FONSI).

The cumulative effects evaluation has been updated in the revised final EA to incorporate the Corps' proposal to designate nearshore dredge disposal sites at the MCR (see the April 24, 2012 Public Notice for: *Nearshore Disposal Locations at the Mouth of Columbia River Federal Navigation Project Pacific County, Washington Clatsop County, Oregon*).

The Selected Course of Action

The preferred alternative is composed of four categories: (1) engineered designs elements and features of the physical structures for each jetty ; (2) construction measures and implementation activities for all actions; (3) proposed Clean Water Act (CWA) 404 mitigation actions for impacts to wetlands and waters of the US; and (4) proposed establishment of and coordination with an Adaptive Management Team (AMT) composed of representatives from the Corps and Federal and State resource management agencies.

The selected course of action will have a smaller footprint than described in the 2006 and 2010 draft EAs and the previous 2011 final EA. This selected action is based on current modeling which eliminates the immediate need for spur groins and larger head-capping features. The key elements of this selected course of action include the following to maintain the MCR navigation project over the next 8 years:

- South Jetty foredune augmentation at Clatsop Spit
- North Jetty lagoon fill
- ***North Jetty***:
    - Critical repairs as described in the 2011 final and the 2012 revised final EAs
    - Scheduled repairs
    - Stabilizing the jetty length but no head capping
- ***South Jetty***:

- Interim repairs
- Monitor intensely
- Understand more work may be required in the future

- *Jetty A*:
  - Scheduled repairs
  - Stabilizing the jetty length but no head capping.

The Corps identified these actions to protect the rubble-mound structures at the MCR over the next 8 years. Because these jetties are built on sand, are subject to extreme physical environmental conditions, and have been established for over 125 years, they would require work and repair beyond the 8-year period. Throughout and at the end of 8-years, via inspections and monitoring, the Corps would need to continue assessment of any potential necessary future maintenance, rehabilitation, or reconstruction.

The construction schedule begins in 2013 with the South Jetty dune augmentation, and then lagoon fill and culvert replacement is scheduled in 2014, with stone placement for critical interim repairs to begin in 2014. The overall schedule for all actions is expected to last for about 8 years, concluding in year 2020 depending on the project's funding stream. Design elements and structural features of the preferred alternative for each jetty include the following:

- North Jetty – The Corps will conduct scheduled repairs addressing the existing loss of jetty cross section and to minimize future cross-section instability. The cross-section repairs are primarily above mean lower low water (MLLW), with a majority of stone placement likely not to extend beyond -5 feet below MLLW. The jetty head will be stabilized with large stone. Shore-side improvements include lagoon fill, repairs between Station 86-99, and culvert replacement accomplished under the base-condition scenario. These actions are designed to stop the current ongoing erosion of the jetty root.

- South Jetty – Interim repair actions will be conducted as described in the Base Condition in the revised final EA. The cross-section repairs are primarily above MLLW, with a majority of stone placement not likely to extend beyond -5 feet below MLLW. Augmentation of the dune at the western shoreline extending south from the jetty root is described and included to prevent the degradation of the jetty root and prevent the potential breaching of the foredune.

- Jetty A – The Corps will conduct scheduled repairs addressing the existing loss of jetty cross-section and to minimize future cross-section instability. The cross-section repairs are primarily above mean lower low water (MLLW), with a majority of stone placement not likely to extend beyond -5 feet below MLLW. The jetty head will be stabilized in its current location with large armor stone.

Construction measures and implementation activities for all three jetties include the following:

- Storage and staging areas for rock stockpiles and all associated construction and placement activities such as roadways, parking areas, turn-outs, crane set-up pads, haul roads, weigh stations, yard area for sorting and staging actions, and other ancillary activities.
- Stone delivery from identified quarries either by barge or by truck. Possible transit routes have been identified in the revised final EA. This also includes construction and use of permanent barge offloading facilities and causeways with installation and removal of associated piles and dolphins.
- Stone placement either from land or water, which includes the construction, repair, and maintenance of a haul road on the jetty itself, crane set-up pads, and turnouts on jetty road.

- Regular dredging and disposal of infill at offloading facilities with frequency dependent on a combination of evolving conditions at the site and expected construction scheduling and delivery. Disposal of infill will occur at existing approved in-water sites.

The selected course of action, including the duration of the construction activities, remain within the scope of effects previously evaluated in the 2011 Biological Opinion (May 18, 2011, *Endangered Species Act Biological Opinion and Conference Report and Magnuson-Stevens Fishery Conservation and Management Act Essential Fish Habitat Consultation for the Major Rehabilitation of the Jetty System at the Mouth of the Columbia River* – NMFS No 2010/06104, and; February 23,2011, *Major Rehabilitation of the Jetty System at the Mouth of the Columbia River Navigation Channel, Clatsop County, Oregon and Pacific County, WA* – USFWS # 13420-2011-I-0082).

In addition, the Corps has identified specific and potential mitigation for impacts to CWA 404 wetlands and waters of the US. Wetland mitigation opportunities have been identified adjacent to the impacted wetlands at the North Jetty. Wetland mitigation for Jetty A would also be implemented at the North Jetty because space is unavailable at Jetty A. Mitigation for wetland impacts at the South Jetty would occur within the State Park but southwest of the impact area in a location south of Trestle Bay. The mitigation for the impacted wetlands would be creation of wetlands of similar type and function. Specific mitigation for impacts to waters other than wetlands has not been determined, but a suite of potential projects and examples has been identified. Depending on further development of both the project and potential mitigation alternatives and commensurate with final impacts, a specific mitigation project or combination of projects would be selected and constructed concurrently. Mitigation will provide environmental benefits to offset impacts as portions of the proposed action are completed over time. This EA has identified and quantified the maximum amount of impacts and mitigation likely under the Preferred Alternative, and further details and selection of specific appropriate mitigation actions for waters other than wetlands will be refined as the project moves forward. Depending on the method of project implementation, commensurate mitigation could also be reduced if impacts are avoided. Generally, possible mitigation measures could include but are not limited to an individual project or a combination of projects and actions such as the following list.

- Excavation and creation of tidal channel and wetlands to restore and improve hydrologic functions including water quality, flood storage, and salmonid refugia.
- Culvert and tide gate replacements or retrofits to restore or improve fish passage and access to important spawning, rearing, and resting habitat.
- Beneficial uses of dredged material from MCR hopper dredge to replenish littoral cells.
- Invasive species removal and control and revegetation of native plants to restore ecological and food web functions that benefit fisheries.

Mitigation meets compliance obligations under the Clean Water Act and would be commensurate with impacts from construction activities. It also complements Corps obligations to protect and restore critical habitat for ESA listed species.

Due to the construction duration over 8 years, an Adaptive Management Team (AMT) will be established. This forum will: provide an opportunity for periodic evaluation; facilitate continued coordination; and allow the Corps to inform agency partners should unforeseen changes arise. Results regarding marine mammal and fish monitoring, wetland mitigation and habitat improvement monitoring, and water quality monitoring will be made available to the AMT to fulfill reporting requirements and address any unexpected field observations. Results of jetty monitoring surveys will also inform the AMT of schedule and design refinements that become necessary as the proposed action evolves over time. Final selection and design of the mitigation proposal would be determined by the Corps and would be vetted through this forum to facilitate obtaining final environmental clearance documents for this component of the MCR proposed action.

Environmental Effects

__Physical Characteristics__. The preferred alternative enables the jetty structures to continue protecting the MCR inlet, adjacent morphology, shore lands, and side channels from becoming destabilized by waves and currents. Various modeling described in the revised final EA has indicated that the preferred alternative will have no calculable effect on nearshore or shore lands beyond 1-2 miles north or south of the MCR inlet. Stabilizing the jetty heads will stop the migration of littoral sediment into the federal navigation channel. Because jetty lengths will be about the same as existing conditions, a negative impact on the sediment budget in the littoral cell or on Clatsop and Peacock Spits is not be expected. Likewise, there will be little to no changes to salinity or plume conditions.

__Anadromous and Resident Fish__. Several listed anadromous species occur in the vicinity of the MCR, including salmonids, steelhead, eulachon, and green sturgeon. Proposed actions may have some adverse effects on these species, but they are not expected to be measurable at the population or species scale. Protection of water quality via best management practices, the use of a vibratory hammer, and the avoidance and minimization of wetland impacts are all components of the selected action that reduce the extent and intensity of any effects. Possible effects of the preferred alternative on anadromous and resident fish species include:

- Temporary and permanent interruption/alteration of adult and juvenile migration pathways.
- Temporary and/or permanent loss of shallow-water habitat.
- Juvenile predator attraction to the jetty substrate and habitat type.
- Temporary disruption and displacement from piling installation and barge offloading traffic.
- Temporary loss of benthic organisms.
- Temporary displacement from dredging and rock placement activities.
- Temporary water quality impacts from construction activities and potential spills.
- Temporary increase in turbidity.
- Temporary and permanent immeasurable changes to salinity, velocity, and bed morphology.

In accordance with Section 7(a) (2) of the Endangered Species Act, federally-funded, constructed, permitted, or licensed projects must take into consideration impacts to federally listed or proposed threatened or endangered species. Information on federally listed species and designated critical habitat is presented in the final revised EA. The Corps prepared Biological Assessments (BAs) covering the preferred alternative as described in the 2011 final EA to address federally listed species under the jurisdiction of both the National Marine Fisheries Service (NMFS) and the U.S. Fish and Wildlife Service (USFWS), and these BAs considered a larger project footprint and longer construction schedule than the revised 2012 preferred alternative. The BAs were provided to the respective agencies for review and consultation.

On March 18, 2011, The Corps received a Biological Opinion from NMFS indicating that the Corps' previously preferred alternative was not likely to adversely affect any listed species, with the exception of eulachon, humpback whales, and Stellar sea lions (2010/06104). For these species, NMFS determined that Corps' actions were not likely to jeopardize the existence of the species. NMFS also concluded that Corps actions were not likely to adversely modify any of the current or proposed critical habitats. There was a Conservation Recommendation to carry out actions to reverse threats to species survival identified in the NMFS 2011 *Columbia River Estuary ESA Recovery Plan Module for Salmon and Steelhead,* (NMFS Northwest Region. Portland, OR, January. Prepared for NMFS by the Lower Columbia River

Estuary Partnership (contractor) and PC Trask & Associates, Inc., subcontractor)... The Corps also provided a conference report for critical habitat that NMFS proposed for leatherback turtles, eulachon, and Lower Columbia River coho salmon. The Corps will request NMFS adopts its conference report when this critical habitat becomes designated. The Corps also will request an Incidental Harassment Authorization of Stellar sea lions, humpback whales, California sea lions, and harbor seals prior to the start of construction.

On February 23, 2011 the Corps received a Letter of Concurrence from USFWS regarding potential effects to species under their jurisdiction (13420-2011-I-0082). The Corps determined its actions would have no effect on listed species, with the exception of bull trout, marbled murrelets, and snowy plover. The Corps concluded that its actions were not likely to adversely affect these species or their critical habitat. The USFWS concurred with the Corps' determination. USFWS also included four Conservation Recommendations to protect and improve snowy plover habitat and manage attractant waste derived from construction actions.

In the Biological Assessments, the Corps considered the following actions and effects: rock placement; spur groins, jetties and causeways, barge offloading facilities and dredging; water quality and turbidity; system effects; and aquatic habitat.

Essential Fish Habitat (EFH). The preferred alternative will directly affect EFH for Chinook salmon, coho salmon, English sole, sand sole and starry flounder from the spatially limited, small amount of permanent loss of sandy bottom habitat from jetty construction. Short-term disturbances to EFH will result for lingcod, English sole, sand sole, starry flounder, black rockfish, brown rockfish, China rockfish, copper rockfish, and quillback rockfish. The addition of rock would increase EFH for lingcod, black rockfish, brown rockfish, China rockfish, copper rockfish, and quillback rockfish. These effects are not expected to be measureable at a species or population scale. An EFH assessment under the Magnuson-Stevens Act was provided as part of the Biological Assessment submitted to the NMFS for the preferred alternative. Although NMFS did identify minor adverse effects on EFH associated with the preferred alternative, in the subsequent Biological Opinion, no additional EFH Conservation Measures were recommended.

Marine Mammals and Sea Turtles. Six ESA-listed whale species and four sea turtle species could occur in the vicinity of the MCR. All of these species are migratory, generally are not found close to shore, and are highly mobile. Moreover, the MCR is not preferred habitat for these species, they are unlikely to feed in the vicinity of the jetties, and jetty work will have inconsequential impacts on their prey base. Acoustic effects from pile installation will be damped by the use of vibratory hammers, and will be temporary and intermittent. The impacts are expected to attenuate to near background levels near the source. Therefore, sound levels are not expected to reach levels harmful to species. The preferred alternative is not expected to measurably affect these whale and sea turtle species such that there will be an adverse effect to the population or species.

The South Jetty is a non-breeding haul-out site for Steller sea lions. They primarily use the concrete block structure at the jetty head. Their use of the jetty is concentrated in the winter months and is least used during the May-July breeding season. Stabilizing the jetty head and placing jetty rock near the head will disturb Steller sea lions by forcing them to move off haul out areas; however, they will be able to haul out elsewhere in the vicinity. Prey resources for sea lions are not expected to be affected. Conservation measures to avoid and minimize impacts to sea lions also have been proposed. Prior to construction activities, an incidental harassment authorization (IHA) for marine mammals at the South Jetty will be obtained from the NMFS. The Corps anticipates that the new IHA permit will entail requirements similar to those in the previous permit for repair of the South Jetty. Effects to Steller sea lions are not expected to be measureable.

Macrophytes and Invertebrates. The mobile sand community at the MCR provides habitat for invertebrate species such as polychaetes, clams, amphipods, and crabs. This is a high-energy zone and generally less productive than other areas of the estuary. The jetties provide rocky intertidal and subtidal habitat. Dominant macrophytes include brown and green seaweeds and sea lettuce that are attached to the jetty rocks. Invertebrate species include sponges, hydroids, sea anemones, crabs, tubeworms, limpets, and mussels that live on the rocks or in crevices. There will be some loss of invertebrates with construction; however, those species occupying rocky habitats will colonize newly placed rock. No permanent adverse effects to macrophyte and invertebrate populations are expected.

Dungeness Crab. Crabs are known to occur on sandy bottom areas on the south side of the North Jetty and to a lesser extent on the north side of the South Jetty. Crabs move out of the estuary in large numbers along the northern part of the channel (south side of North Jetty) in the fall and move into the estuary as megalops in the spring. Megalops enter the estuary passively by current mainly along the north side of the entrance (on the south side of North Jetty) where current is strongest and salinity highest. No adverse impacts to adult and juvenile Dungeness crabs will be expected from the preferred alternative because modeling shows no appreciable permanent changes to velocity, salinity, and bed morphology at the MCR. The inconsequential changes to water velocities from adding spur groins also will not adversely alter the migration paths of young crabs moving in or out of the estuary (though they are no longer proposed).

Terrestrial Wildlife, Seabirds, and Plants. The preferred alternative is not expected to measurably affect terrestrial wildlife and seabird species. These species could readily avoid the construction areas, any impacts to shallow intertidal habitat will be small relative to the availability of adjacent foraging habitat, and the short temporal loss is likely to be replaced with some ephemeral accreted habitat that is formed behind the repaired jetty structures.

ESA-listed Species Under USFW Jurisdiction. There are several listed species that could occur in the counties where the preferred alternative is located: short-tailed albatross, northern spotted owl, Columbian white-tailed deer, Oregon silverspot butterfly, and Nelson's checker-mallow. There is small likelihood that these species will be present in the project vicinity or encounter any elements of the preferred alternative, or that the action will occur in or measurably affect any portion of their critical habitat. Therefore, effects to these species are highly unlikely.

Periodic minor disturbance could occur to marbled murrelets from noise generated from trucks on haul roads. The following measures will be employed during the murrelet nesting season (April 1 to September 15) to reduce potential impacts from noise: trucks will only be allowed to use roads through Cape Disappointment during daylight hours; trucks will not unnecessarily stop along the park roads; and trucks will be prohibited from using compression brakes (jake brakes). These measures will reduce and limit the duration and extent of exposure to acoustic effects. Consequently, the preferred alternative will not adversely affect marbled murrelets at a level to the population or species.

Western snowy plovers have occurred in the vicinity of Clatsop Spit although no breeding or wintering plovers have been reported in recent years. Two birds were sighted in the 2012 surveys. A Habitat Conservation Plan (HCP) for snowy plovers was developed for Clatsop Spit by the Oregon Parks and Recreation Department (OPRD). The area proposed for construction, storage, and staging is mostly outside the area on Clatsop Spit identified in HCP. The Corps is currently investigating opportunities to create western snowy plover nesting habitat on Clatsop Spit within Fort Stevens State Park. As staging areas could be attractive to plovers, the Corps would consider creation of 10 -20 acres of habitat during or after use of the Spit for rock storage is completed. This habitat would be created with the intent to avoid potential limitations to rock storage and transport on the Spit if plovers begin to nest in construction areas.

The options to create plover habitat concurrently with rock storage is preferable if it plover use of the created habitats and beaches would not interfere with the Corps' ability to use Clatsop Spit throughout the life of the project. This scenario would instead provide preferable alternative habitat away from the potential attractive nuisance of open sands that the construction disturbance would create. In other words, the Corps would be creating bare sand habitat that would attract birds away from construction site impacts. Habitat maintenance each year after creation would be required to provide functional habitat. The Corps would maintain these sites during construction, but after project completion maintenance would not be the responsibility of the Corps. The Corps has had initial discussions with OPRD regarding plover habitat creation and has signed a Memorandum of Agreement with the OPRD, USFWS, and other agencies regarding management of snowy plovers at Clatsop Spit and on other Corps lands. The Corps would be implementing best management practices (BMPs) that are in alignment with its efforts under the HCP. Consequently, the preferred alternative is not expected to have negative effects to snowy plovers that are measurable at a population or species level.

On February 23, 2011 the Corps received a Letter of Concurrence from USFWS regarding effects to species under their jurisdiction (13420-2011-I-0082). The Corps' determined its actions will have no effect on listed species, with the exception of bull trout, marbled murrelets, and snowy plover. The Corps concluded that its actions were not likely to adversely affect these species or their critical habitat. The USFWS concurred with the Corps' determination. USFWS also included four Conservation Recommendations to protect and improve snowy plover habitat and manage attractant waste derived from construction actions.

Fill and Removal Impacts on CWA 404 Wetlands and Waters.
The process used to determine mitigation was to first maximize avoidance of the impacts. However, some impacts to wetlands and waters remained unavoidable. Mitigation for unavoidable impacts was then based on the extent and quality of the habitat affected.

As mentioned initially, the actions evaluated in the 2012 EA and this FONSI include South Jetty dune augmentation, actions at the North Jetty described in the *North Jetty Major Maintenance Report* (MMR), May 2011, and actions described in the Major Rehabilitation Report (MRR) (*MCR Jetty System Major Rehabilitation Evaluation Report*, June 2012). Though these actions will be funded as separate projects, they were analyzed together. The following mitigation is required as a result of their associated cumulative effects. The breakdown of effects from fill are indicated in the table below and then described in further detail.

Area Affected	Impacted Acreage	Mitigation Acreage	Comment
North Jetty			
Wetland	1.14	2.28	Base Condition: MMR
404 Waters Lagoon	8.02	12.03	Base Condition: MMR
Other 404 Waters	4.36	6.54	
South Jetty			
Wetlands	2.65	5.30	
404 Waters	13.84	20.76	
Jetty A			
Wetlands	0.91	1.82	
404 Waters	6.60	9.90	

Impacts associated with wetlands had a known and quantified footprint and were the same under all the construction alternatives. Specific wetland mitigation sites and methods were identified and developed. The exact extent of impacts to 404 waters of the US remained unknown because they were contingent upon the delivery method of the rock which would be determined during contract bidding. Therefore, the extent of mitigation for impacts to 404 waters remained uncertain and variable based on the mode of stone delivery and placement. Impacts would be greater if the contractor chooses to use offloading facilities; hence, the maximum potential effects were evaluated in the 2012 EA (and in the BAs). Because of this, maximum mitigation requirements were also assumed for 404 waters. Mitigation requirements would be further coordinated with the AMT and may be reduced if offloading facilities are not constructed.

Wetland Fill. In accordance with *Executive Order 11990, Protection of Wetlands* and Section 404 of the Clean Water Act, the Corps closely evaluated the proposed construction staging and stockpile areas and their wetland impacts. Official wetland delineations have been completed for all three jetties. The selected action has been and will continue to be developed during design and construction to avoid and minimize the project's ecological impacts to habitats and species. However, there will be unavoidable effects to wetlands and shallow-water habitat that will be filled and converted as a result of the project. After avoidance and minimization measures, the following effects were unavoidable.

North Jetty: All wetlands south of the North Jetty Access Road will be impacted and filled in order to reduce processes eroding and undermining the jetty root, to which the lagoon also contributes. Additionally, a few small wetlands north of the roadway will be impacted in order to provide the necessary space for adequate rock storage (enough for 2 years-worth of rock placement) and efficient construction, staging, and access areas. There will also be some wetland impacts during replacement of the damaged culvert crossing under the North Jetty Access Road. After avoidance and minimization measures, including implementation of an 80-foot (ft) buffer around conserved wetlands north of the roadway and a 200-ft shoreline buffer beyond the Highest High Tide, unavoidable total wetland impacts are estimated to total about 1.14 acres out of the 31 acres identified for construction actions, and impacts to other waters of the U.S. via the lagoon are estimated to total about 8.02 acres.

These wetlands all will be mitigated onsite, in an area north of the North Jetty Access Road adjacent to the conserved wetland fringe that extends further north. At a 2:1 mitigation ratio, this equals about 2.28 acres of wetland mitigation, plus the required buffer. This amount of upland area is available immediately adjacent to the impact area, and wetland creation via excavation to appropriate depths, appropriate native plantings, invasive species removal, and buffer requirements will offset impacts to wetland within the same vicinity in which they are proposed. This 2:1 ratio also aligns with mitigation requirements in Washington (WA) that were developed in partnership with WA Department of Ecology (WADOE), the Environmental Protection Agency (EPA), and the Corps. According to this guidance, estuarine ratios are developed on a case-by-case basis. Given the ample rainfall and close proximity to higher functioning wetlands, the likelihood of successful wetland establishment further supports the proposed amount of wetland mitigation.

Jetty A: A total of about 0.91 acre of wetland at Jetty A also will be filled due to rock storage and construction staging activities. Unfortunately, these wetlands cannot be avoided, but impacts to adjacent waters of the U.S. will be minimized by implementing a 100-ft buffer beyond the Highest High Tide elevation, which is consistent with the setbacks required for lands designated by Pacific County as "Conservancy".

Because of onsite space constraints and site conditions, these wetlands will be mitigated in the same vicinity as the mitigation area identified at the North Jetty, north of the North Jetty Access Road. At a 2:1 mitigation ratio, this equals about 1.82 acres of wetland mitigation, plus the required buffer. These requirements were determined as described for the North Jetty and align with WADOE guidance (2006). Wetland creation will occur in conjunction with and in addition to the area and process described for mitigation at the North Jetty. Reduced disturbance coupled with improved potential hydrology and adjacent functioning wetlands at North Jetty compared to at Jetty A make the success of wetland creations more likely at the location at the North Jetty compared to any creation at Jetty A. The total mitigation acreage at the North Jetty is 4.1 acres, and this area is available at the North Jetty mitigation site.

South Jetty: In order to acquire the 44 acres needed for staging and rock stockpiles, 2.65 acres of unavoidable wetland impacts will occur at the South Jetty. However, by slightly revising locations, maintaining hydrologic connections at wetland crossings, and by maintaining a 50-ft wetland, shoreline, and riparian buffer for preserved areas whenever possible, these impacts have been greatly reduced and minimized relative to initial conservative impact estimates. This includes limiting the roads required to cross wetlands to a 20-ft width and requiring culverts to maintain hydrologic connectivity at crossings. In addition to wetlands, about 3.5 of the existing 5.2 acres of other waters of the US will be impacted in the form of fill in a lagoon area adjacent to and along the jetty. There will be a road and crossing over these waters, which will include culverts in order to maintain flows into and out of the marsh wetland complex. The 40-ft wide causeway/jetty access roadway will be constructed immediately adjacent to the jetty in order to minimize interference with and impacts to the inlet of the marsh complex.

These wetlands will be mitigated near the impact site in an area identified in Trestle Bay near the channel entrance to Swash Lake. At a 2:1 mitigation ratio, this equals about 5.3 acres of wetland mitigation. Anecdotally, it is thought that the uplands in this area are the result of previous historic fill from the dredging the adjacent channel, so that excavation of uplands would result in restoration of wetland that are likely to be intertidal. There is also a former Oregon Department of Transportation (ODOT) mitigation site that the Corps' selection action likely will abut. This is an appropriate mitigation site because it is within the same sub-watershed Hydrologic Unit Code (HUC) 7 and per the Oregon Rapid Wetland Assessment Protocol (ORWAP) scoring and Cowardin classification, the adjacent areas have wetland types similar to those being impacted.

The Corps anticipates that effects from wetland impacts and lagoon fill will be immeasurable on river functions, as the wetlands are not within the channel prism of the Columbia River. Although these wetlands are connected hydrologically to the Columbia River, wetland fill impacts likely will not negatively alter groundwater-stream exchange or hyporheic flow because the wetlands are on accreted land that has formed on stabilized sand shoals behind the jetties. Wetland hydrology is mostly elevation and rainfall dependent, and fill impacts will be relatively minimal relative to the Columbia channel. Culverts will be installed to maintain wetland hydrology and connectivity with permanent replacement at the North Jetty and where temporary construction roadways cross wetlands. In addition, mitigation opportunities have been identified and include wetland excavation, additional native revegetation and plantings, invasive species removal, or other actions as appropriate. Final mitigation plans for wetland impacts will be developed by the Corps and vetted through the AMT.

A further evaluation of effects of the preferred alternative on wetlands and other waters of the U.S. can be found in the 2012 EA and the 404 (b) (1) analysis, which is incorporated in the 2012 revised final EA. Based on the above considerations, the Corps has determined that there is no practical alternative to the proposed construction in wetlands, and the preferred alternative includes all practicable measures to minimize harm to wetlands and waters that may result from such use.

Fill and Removal Impacts on CWA 404 Waters of the US. In-water habitats (below MHHW), both shallow intertidal and deeper subtidal areas, will also be affected by the project. These waters are considered "waters of the US" as defined by the Clean Water Act.

Barge offloading facilities are a potential method of delivery for stone and other construction materials. If barge offloading facilities are used, this would create the largest impacts to 404 waters of the US and associated aquatic habitat. Therefore, the associated fill acreages and volumes represent the worst-case scenario for spatial and temporal effects. Habitat conversions and impact to 404 waters will occur from maintenance dredging and stone placement for the jetty cross-section repairs and head stabilization, turnouts, crane set-up pads, barge offloading facilities, and causeways (but no longer from spur groins, as they no longer components of the selected action). There also will be permanent lagoon fill at the North Jetty root and temporary fill at the South Jetty lagoon. Alteration of bottom habitat would occur from dredging, which would create temporary disturbance and greater depths that could affect the composition of benthic communities. These effects are anticipated to be minimal, as the character of the area is naturally dynamic and prone to extreme energy conditions, and benthic organisms are adapted for such conditions and usually rapidly recolonize.

Permanent removal and conversion of some shallow-water, nearshore sandy habitat likely used by juvenile salmonids for migrating, foraging, or rearing will result from rock placement for repairs, and some habitat also will be unavailable for the 8-year construction duration due to the development of turnouts, set-up pads, causeways and stone docks for barge offloading facilities along the North Jetty, Jetty A, the South Jetty, and at the east end of Clatsop Spit near the South Jetty adjacent to Parking Area D (spur groins were evaluated as well, but no longer proposed). Some causeway structures will be removed upon project completion, and others will remain.

The calculated extents that follow were strictly based on the area of habitat that was converted. They did not include value or functional assignments regarding the importance of the conversion; whether it was a beneficial, neutral, or detrimental effect to specific species; or if conversions created unforeseen, indirect far-field effects. For example, acreage of conversion for shallow sandy sub-tidal habitat to rocky sub-tidal habitat was calculated in the same manner as conversion from shallow intertidal habitat to shallow sub-tidal habitat. Without drawing a distinction between depths or tidal elevations, initial acreage estimates for all in-water impacts and habitat conversions were estimated at a total of approximately (~) 32.84 acres and include:

- <u>North Jetty</u> ~12.38 acres (8.02 acres for lagoon fill; 0.63 acre for barge offloading facilities, crane set-up pads, and turnouts; 3.73 acres for dredging at offloading facility; [without previously proposed 1.55 acres for spur groins])
- <u>South Jetty</u> ~13.84 acres (3.5 acres for lagoon fill; 0.4 acre for crane set-up pads, and turnouts; 1.56 acres for barge offloading facilities; 8.38 acres for dredging at offloading facilities [without previously proposed 1.1 acres for spur groins])
- <u>Jetty A</u> ~7.82 acres (1.2 acres of cross-section fill; 2.89 acres for barge offloading facility and causeway; 3.73 acres for dredging at offloading facility [without previously proposed 0.61 acre for spur groins])

Shallow-water habitat is especially important to several species in the estuary; therefore, specific initial estimates were also calculated regarding shallow-water habitat (shallow here defined as -20-ft or -23-ft below MLLW). About 21 acres of area at these depths will be affected by maintenance dredging and construction of the causeways and barge offloading facilities. About 12 acres would be affected by lagoon fill. However, these shallow-water footprints are very small as a relative percentage of the ~19,575 acres of shallow-water habitat available within a 3-mile proximity to the MCR.

Because of these impacts, the Corps has proposed mitigation actions at a ratio of 1.5:1 to offset temporal and spatial impacts to 404 waters and associated aquatic resources. This ratio was determined with input from the resource agencies considering several factors including: beneficial use listings that involve species with EFH and critical habitat designations in the impacted areas, the duration of the construction period, the number of different CWA beneficial uses in the area impacted by the project, and the temporal and spatial extent of the actions. These actions are not proposed to directly mitigate or compensate for any project-related impacts to ESA-listed species but will mitigate for effects to CWA 404 waters of the US. However, the 404 mitigation actions would also complement but are not driven by Conservation Recommendations in the NMFS BiOp for recovery of ESA-listed salmonid habitats and ecosystem functions and processes.

Mitigation features would be commensurate with impacts and would be designed to create or improve aquatic habitat. In-kind mitigation opportunities for impacts to 404 waters were investigated specifically tidal marsh, swamp, and shallow water and flats habitat. Though a specific site or action has yet to be determined for mitigation of impacts to waters other than wetlands, if possible fish access to these mitigation features would be an important consideration.

A list of possible mitigation features has been identified and one or a combination of actions would be selected for further development and implementation in order to offset actions affecting 404 waters. Selection would occur by the Corps after coordinating with the AMT. Supplementary compliance documentation may be necessary and work is anticipated to be completed concurrent with jetty repair actions.

Uplands Disturbance and Re-stabilization:
Rock storage and staging areas would impact both wetlands as well as uplands. Best Management Practices (BMP) to reduce the environmental footprint and to avoid, and minimize impacts have been incorporated and would be implemented, including appropriately locating staging sites, implementing stormwater management plans, and stabilizing the site during and after construction. Post-construction upland re-stabilization to meet CWA National Pollution Discharge Elimination System (NPDES) requirements would include re-establishing native grasses, shrubs, and trees where appropriate; controlling and removing invasive species like scotch broom and European beach grass in the project vicinity; and re-grading/tilling the area to restore pre-project natural contours. The Oregon Parks and Recreation Department (OPRD) has requested that the Corps utilize the State Forester as one resource for determining optimal revegetation plans.

Upland Replanting - (1:1) NPDES site stabilization

- North Jetty total acres: 28.7
- South Jetty total acres: 18.7-28.7 (Depending on snowy plover habitat creation)
- Jetty A total acres: 12
- Approximate total acres of stabilization: 69.4

On Clatsop Spit, there is a unique opportunity to partner with USFWS and OPRD regarding creation and management of snowy plover habitat. The OPRD (2010) developed a HCP to manage snowy plover habitat. There may be locations in the vicinity and away from projected construction and staging areas to convert upland habitat to snowy plover habitat via invasive species removal, tilling, and application of shell hash. Operation and maintenance during the project via regular tilling and shell hash distribution could possibly be coordinated between the agencies through a Memorandum of Agreement (MOA) or similar avenue. This scenario would also provide preferable alternative habitat away from the potential attractive nuisance of open sands that the construction disturbance would create. The Corps currently has a signed MOA indicating it will cooperate with OPRD in the implementation of the snowy plover management plan under development.

Cultural and Historic Resources. Section 106 of the National Historic Preservation Act (NHPA) requires that federally assisted or federally permitted projects account for the potential effects on sites, districts, buildings, structures, or objects that are included in or eligible for inclusion in the National Register of Historic Places (Register). The selected action will be conducted in an area that is highly erosive and has previously been disturbed by jetty construction and prior dredging. The North and South Jetties are eligible for listing on the Register because they are associated with important historical events and thus meet Criterion A under the National Register criteria. The Corps plans to nominate these structures to the Register. There are no known historic properties recorded within the immediate project footprint other than the jetties and associated trestle remains. The South Jetty and trestle remains are not contributing elements to Fort Stevens (OR-CLT-1), which was officially listed on the Register in 1971, and the North Jetty and trestle remains are not contributory to the Cape Disappointment (formerly Fort Canby State Park) Historic District. The jetties do not retain original materials of workmanship as they have been repaired many times, but they do retain their original alignments. Much of the area around each jetty is composed of accreted material from littoral drift with little or no potential for historic properties. Previous cultural resources surveys provide coverage over portions of the project footprints and adjacent areas, though much of this selected action will be conducted in an area that is highly erosive and has previously been disturbed by jetty construction and prior dredging. The rehabilitation and repair work; the staging/work, and mitigation areas are on landforms created in historic times from accretion or dredged material disposal after the jetties were constructed. Work in these areas has little chance of impacting historic resources, though there is the possibility of encountering shipwreck remains.

The Corps coordinated with the Grande Ronde Tribe in accordance with Section 106 of the NHPA, and the Grande Ronde Tribe indicated they have no concerns in regards to this project's effects to properties on or eligible to the Register. The Corps determined that the selected course of action will result in a determination of *no adverse effect* under Section 106 of the National Historic Preservation Act. Letters were sent to WA Department of Antiquities and Historic Preservation (DAHP) on April 16, 2012, and to Oregon State Historic Preservation Office (SHPO) on April 16, 2012. Preliminary consultations indicated that the jetties will be found eligible to the Register. The Corps anticipated concurrence from the respective State Historic Preservation Officers of Washington and Oregon if monitoring was conducted during excavations and the usual inadvertent discovery protocols followed. Subsequently, SHPO and DAHP have concurred that the undertaking would have no effect on historic properties as the action would not affect the criteria that make the structures eligible, essentially, importance in historic events and alignment.

Socioeconomic Resources. Construction vehicles hauling jetty rock will have an intermittent 8-year effect on local traffic patterns in the Long Beach/Ilwaco area and in Warrenton/Hammond area. The preferred alternative could have an adverse impact to recreationists at Cape Disappointment and Fort Stevens State Parks, those participating in water-sports and beach activities near the jetties, and those using the jetty structures for fishing and crabbing. A number of restrictions will be in place near the construction zones at each jetty to protect park visitors, water sport and beach recreationists, and the public. However, large portions of the park and beach will remain open and accessible to the public, and the bulk of the construction activities are likely to be seasonally concentrated. The long-term reduction in the levels of recreational activity could also affect the local economy of Long Beach peninsula and Warrenton/Hammond, which are highly dependent on tourism. However, these recreation and local economy impacts are not expected to reach levels of significance.

Furthermore, rehabilitation of the MCR jetty system is expected to have a long-term, positive effect on recreational vessel safety. Maintenance of the shoreline at Clatsop Spit and Benson Beach is also expected, which preserves these areas for recreational opportunities mentioned above. The selected action will have no effect on utilities and public services in the area.

The MCR is the gateway to the Columbia-Snake River system, accommodating commercial traffic with an approximate annual value of $20 billion dollars a year. The preferred alternative will have a long-term positive effect on maintaining this vital transportation link and associated economy for the states of Oregon, Washington, Idaho, and Montana, as well as for the nation as a whole.

Cumulative Effects. A cumulative effects analysis considered the effects of implementing the selected action in association with past, present, and reasonably foreseeable future actions in and near the MCR. The potential cumulative effects associated with the preferred alternative were evaluated with respect to each resource evaluation category, and no cumulatively measurable adverse effects were identified.

Public and Agency Input

The draft Environmental Assessments (EA) and public meetings in 2006 and 2010 served as the forum for public input. Comments received during the Public Notice postings of the EA were considered, and where applicable addressed and incorporated in the 2012 revised final EA.

Several public input opportunities occurred regarding this project. An agency coordination meeting was held on May 25, 2006, for the purpose of introducing the project to several agencies to be involved with review of environmental documents. Staff from the Corps' Portland District presented the current state of environmental review and engineering modeling to the NMFS, USFWS, WDOE, Oregon Department of Environmental Quality (ODEQ), and Oregon Department of Land Conservation and Development. The Corps conducted a public information meeting on the project in Astoria, Oregon in July 2006. After a presentation about the MCR jetty rehabilitation project, the public was invited to ask questions and talk to USACE staff about the project.

On April 13, 2007 the USACE met with the U.S. Geological Survey (USGS) and Portland State University regarding numerical modeling in support of the MCR rehabilitation project. Also in 2007, four resource agency meetings and presentations were held regarding the MCR project on April 27, May 30, July 11, and September 5. A public information meeting was held in Astoria, Oregon on July 31, 2006. In addition, the Corps Portland District established and currently maintains a web site to keep the public informed about the repair/rehabilitation of the MCR jetties located at https://www.nwp.usace.army.mil/issues/jetty/home.asp.

When a revised draft EA was prepared and was issued for a 30-day public and agency review period in January 2010, it was provided to federal and state agencies, organizations and groups, and various property owners and interested publics. The revised draft EA was revised to reflect and address the 2006 comments, as appropriate. Thirteen comment letters/emails were received in response to the 2010 revised draft EA. To date, most comments have been supportive of the project. Of these, two mentioned concern with traffic impacts; several had specific suggestions regarding design elements; and one had various concerns with NEPA and other compliance processes; all were addressed in the EA as appropriate. A public information meeting on the project also was held in Astoria, Oregon in February 3, 2010. After a presentation by the Corps about the MCR jetty rehabilitation project, the public was invited to ask questions and talk to USACE staff about the project. A public information meeting to describe likely construction techniques was also held on June, 4, 2010, at Fort Vancouver, WA to solicit input from potential construction contractors and to provide additional information regarding the feasibility of the Major Rehabilitation and Repair approach. A final EA was posted on the Corps' website in May 2011; that version is replaced by the revised 2012 EA. The 2012 revised final EA reflects the trend towards further reduction in the project footprint.

Besides official public information meetings and distribution of the EA, the Corps has also had multiple meetings with various regulatory agencies to ensure regular coordination throughout project development. As mentioned in the overview of the Preferred Alternative, the Corps has also proposed formation of a modified interagency Adaptive Management Team to keep resource agency partners apprised of any potential project changes or challenges during implementation.

Final Determination

The Corps is required to fulfill all statutory authorized project purposes and directions provided by the Congress in the project authorization documents. The MCR jetty system was authorized to improve and maintain navigation in the Columbia River and at its mouth. This also entails operations and maintenance activities as well as major maintenance and major rehabilitation at the jetties.

However, in fulfilling the authorization, the Corps is also required to take into account other applicable legal mandates. While acknowledging the impacts discussed in the EA and outlined above, the Corps is required by NEPA to make a determination of the significance of those impacts. A checklist of considerations that help in making the determination of whether impacts of a project rise to the level of "significantly affecting the human environment" is provided at 40 CFR 1508.27. Following is the checklist from (1) to (10):

1. *Impacts:* Beneficial impacts of this project are primarily related to maintaining safe and reliable navigation at the mouth. The repairs and Jetty A, South Jetty, and North Jetty including lagoon fill and the augmentation of the foredune at the South Jetty will ensure the navigational functionality of the structure, reduce the need for emergency dredging, and help to avoid a potential breach of the Clatsop Spit. Both beneficial and harmful environmental impacts are addressed in the 2012 revised final EA.
2. Public health and safety: Construction effects are considered short-term, localized, and temporary, and as such will have no significant adverse effects on public health and safety. Work area boundaries and proper signage will ensure public exclusion from construction zones. Once construction and repairs are completed, the resilience of the jetty structure and the maintenance of a reliable and safe navigation channel and entrance will be improved and maintained over the next 8 years. The presence of a maintained navigation system with functional jetty structures is a benefit to public health and safety, particularly those that involve vessel passage at the MCR.
3. Unique characteristics of geographical area: The construction sites will be located adjacent to both Fort Clatsop and Cape Disappointment State Parks. These parks are located on accreted land that has formed as a result of the jetties, and with jetty deterioration, their shorelines are also currently receding. Though there will be some interruption to visitors via altered traffic flows and reduced access to certain portions of the Parks during construction, this is not expected to rise to the level of adverse impacts because effects will be temporary, seasonally concentrated, and of limited geographic scope. Historic and cultural resources will be protected by project design. Riparian areas including wetlands, shorelines, and streams will be buffered where feasible, and mitigation will offset any unavoidable impacts. There will be no any measurable adverse effects to Essential Fish Habitat. There are no prime farmlands, wild and scenic rivers, wilderness, ecologically critical areas, or other unique natural features in the project area and therefore no effects on unique geographical characteristics.

4. Highly controversial effects on quality of human environment: The effects of the selected action on the environment have been analyzed and re-analyzed by the Corps and resource agencies such as NMFS and USFWS. The results of these analyses show that the project will have no highly controversial effects on the quality of the human environment in or near MCR or adjacent action areas. Further, a majority of the public comments received were positive regarding the anticipated effects from repairing and rehabilitating the jetty system. Any concerns expressed by commenters were addressed in the 2012 revised final EA. There is no known scientific controversy over the impacts of the project. The types of activities proposed have taken place previously in the same location and in similar areas, and the resulting effects are well-known and understood.
5. Highly uncertain or unique or unknown risks: There are no highly uncertain, unknown, or unique risks associated with implementing the selected course of action. Uncertainty and risk of jetty failure or a potential breach are actually expected to increase in the absence of the selected action. The repairs and all associated construction activities will be implemented using Best Management Practices and in accordance with all terms and conditions of the Biological Opinions received and Water Quality Certifications to be obtained by WADOE and ORDEQ. The preferred alternative is not expected to provide unique or uncertain risks beyond those addressed in the 2012 revised final EA.
6. Future Precedents: The Corps is authorized to maintain the Federal Navigation Channel (FNC) in the Columbia River and at its entrance. The preferred alternative described in the 2012 revised final EA for maintenance of the MCR do not set a precedent for future actions outside of those previously authorized by Congress. Safe and reliable navigation is a beneficial effect for navigational purposes and does not constitute an irrevocable or irretrievable step toward future changes in the scope, scale, orientation, or design of the current jetty system, nor in the current and historic method or approach to maintaining the navigational system at MCR. For these reasons, the selected action is not likely to establish a precedent for future actions that have not been previously taken as repair strategies at MCR or elsewhere in similar environments.
7. Significant Cumulative Impacts: The effects of this selected action were considered with past, present, and reasonably foreseeable actions within and adjacent to the project area. The 2012 revised final EA contains an effects analysis for each resource which discusses cumulative effects. None were found to be significant.
8. NRHP and Other Historical and Culturally Significant Places: The North and South Jetties are eligible for listing on the Register, and the Corps plans to nominate these structures. SHPO and DAHP have concurred that the undertaking would have no effect on historic properties as the action would not affect the criteria that make the structures eligible.
9. Endangered or Threatened Species or Habitat: Although there will be impacts as a result of the project, every effort has been made to minimize those impacts by incorporating conservation measures and best management practices for the repair and construction operations in order to minimize the project's footprint and described effects. Also, the selection of construction staging and storage areas was made to avoid and minimize impacts to 'waters of the United States' as required under the Clean Water Act. The Corps received a Biological Opinion from NMFS indicating that the Corps' original, larger-scaled suite of proposed actions was not likely to adversely affect any listed species, with the exception of eulachon, humpback whales, and Stellar sea lions (2010/06104). For these species, NMFS determined that Corps' actions were not likely to jeopardize the existence of the species. NMFS also concluded that Corps actions were not likely to adversely modify any of the

current critical habitats. There was a Conservation Recommendation to carry out actions to reverse threats to species survival identified in the *Columbia River Estuary ESA Recovery Plan Module for Salmon and Steelhead*. The Corps also provided a conference report for critical habitat that NMFS proposed for leatherback turtles, eulachon, and Lower Columbia River coho salmon. The Corps will request NMFS adopts its conference report when this habitat becomes designated. The Corps also will also request an Incidental Harassment Authorization of Stellar sea lions, humpback whales, California sea lions, and harbor seals prior to the start of construction.

On February 23, 2011 the Corps received a Letter of Concurrence from USFW regarding potential effects to species under their jurisdiction (13420-2011-I-0082). The Corps determined its actions will have no effect on listed species, with the exception of bull trout, marbled murrelets, and snowy plover. The Corps concluded that its actions were not likely to adversely affect these species or their critical habitat. The USFW concurred with the Corps' determination. USFWS also included four Conservation Recommendations to protect and improve snowy plover habitat and manage attractant waste derived from construction actions. The Corps would be implementing best management practices (BMPs) that are in alignment with these efforts as we;; as the Habitat Conservation Plan (HCP) that Oregon Parks and Recreation has developed for the Spit.

10. <u>Other Legal Requirements:</u> Discussion of compliance with applicable environmental laws or requirements is identified in 2012 revised final EA. This selected action will not violate any environmental laws and regulations.

Other Concerns and Factors:

No construction actions will begin until receipt of all applicable environmental clearance documents, including both State 401 Water Quality Certifications (WQCs) and States' concurrence with the Coastal Zone Management Act (CZMA) Consistency determinations. Construction is expected to begin at the earliest on the South Jetty foredune augmentation in 2013, depending on receipt of appropriations. Upon receipt of the Water Quality Certifications and CZMA Consistency concurrences, I will review all existing environmental documentation to determine if conditions have changed or whether existing documentation and clearances continue to adequately describe the effects of the selection and unless an EIS is deemed necessary, issue a revised FONSI.

Conclusion:

Based upon the revised final EA prepared that encompasses this project and contingent upon receipt of the above mentioned clearance documents, I have determined that the preferred alternative will not significantly affect the quality of the human environment and that an Environmental Impact Statement will not be prepared.

Date: 7/26/12

John W. Eisenhauer

John W. Eisenhauer, P.E.
Colonel, Corps of Engineers
District Commander

UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL MARINE FISHERIES SERVICE
Northwest Region
7600 Sand Point Way N.E., Bldg. 1
Seattle, WA 98115

Refer to NMFS No:
2010/06104

March 18, 2011

Joyce E. Casey
Chief, Environmental Resources Branch
U.S. Army Corps of Engineers, Portland District
P.O. Box 2946
Portland, Oregon 97208-2946

Re: Endangered Species Act Biological Opinion and Conference Report and Magnuson-Stevens Fishery Conservation and Management Act Essential Fish Habitat Consultation for the Major Rehabilitation of the Jetty System at the Mouth of the Columbia River.

Dear Ms. Casey:

The enclosed document contains a biological opinion (Opinion) and conference report prepared by the National Marine Fisheries Service (NMFS) pursuant to section 7(a)(2) of the Endangered Species Act (ESA) on the effects of the U.S. Army Corps of Engineers' proposed major rehabilitation of the jetty system at the mouth of the Columbia River. The Corps' authority for this action comes from the original authority for construction of the project granted by Senate Executive Document 13, 47th Congress, 2nd Session (5 July 1884), and subsequently renewed with authorizations related to construction, operation and maintenance of the Columbia River navigation channel. In this Opinion, NMFS concludes that the proposed action is not likely to jeopardize the continued existence of eulachon (*Thaleichthys pacificus*), Steller sea lions (*Eumetopias jubatus*), and humpback whales (*Megaptera novaeangliae*).

Furthermore, NMFS concluded that the proposed action may affect, but is not likely to adversely affect the following species:

- Fin whale (*Balaenoptera physalus*)
- Southern Resident killer whale (*Orcinus orca*)
- Sperm whale (*Physeter macrocephalus*)
- Sei whale (*B. borealis*)
- Blue whale (*B. musculus*)
- Leatherback sea turtle (*Dermochelys coriacea*)#
- Lower Columbia River (LCR) Chinook salmon (*O. tshawytscha*)*
- Upper Willamette River (UWR) Chinook salmon (*O. tshawytscha*)*
- Upper Columbia River (UCR) spring-run Chinook salmon (*O. tshawytscha*)*
- Snake River (SR) spring/summer-run Chinook salmon (*O. tshawytscha*)*
- SR fall-run Chinook salmon (*O. tshawytscha*)*
- Columbia River (CR) chum salmon (*O. keta*)*

- LCR coho salmon (*O. kisutch*)#
- Oregon Coast coho salmon (*O. kisutch*)
- Southern Oregon/Northern California Coasts coho salmon (*O. kisutch*)
- SR sockeye salmon (*O. nerka*)*
- LCR steelhead (*O. mykiss*)*
- UWR steelhead (*O. mykiss*)*
- Middle Columbia River steelhead (*O. mykiss*)*
- UCR steelhead (*O. mykiss*)*
- SR basin steelhead (*O. mykiss*)*
- Southern distinct population segment (DPS) green sturgeon (*Acipenser medirostris*)*

Additionally, NMFS concluded that the proposed action is not likely to adversely affect designated critical habitat for the above species or proposed critical habitat for eulachon, leatherback turtles, and LCR coho salmon.

The Corps also requested a conference report for critical habitat that NMFS proposed for leatherback turtles, LCR coho salmon, and eulachon. An action agency is not required to consult on proposed critical habitat unless its action is likely to destroy or adversely modify the proposed critical habitat. Nonetheless, NMFS encourages action agencies to complete a conference process to identify and resolve any conflicts that may arise between a proposed action and proposed critical habitat. Here, the effects of the proposed action on proposed critical habitat are likely to be similar to the effects on critical habitats that are already designated in the action area. Please note, however, that the Corps has a duty to reinitiate this consultation if NMFS designates these critical habitats before the action is completed and may comply with that duty by requesting that NMFS adopt the conference report as a final report or biological opinion.

The NMFS is not including an incidental take statement for eulachon as NMFS has not issued protective regulations for eulachon under section 4(d) of the ESA. Additionally, NMFS is not including an incidental take authorization for marine mammals at this time because the incidental take of marine mammals has not been authorized under section 101(a)(5) of the Marine Mammal Protection Act and/or its 1994 Amendments. Following issuance of such regulations or authorizations for marine mammals, NMFS may amend this biological opinion to include an incidental take statement for marine mammals, as appropriate.

This document also includes the results of our analysis of the action's likely effects on essential fish habitat (EFH) pursuant to section 305(b) of the Magnuson-Stevens Fishery Conservation and Management Act (MSA), and includes no conservation recommendations to avoid, minimize, or otherwise offset potential adverse effects on EFH, as NMFS determined that there are no conservation recommendations, in addition to those proposed by the Corps, that can be implemented that would avoid, minimize, or offset potential adverse effects. Therefore, no response is required.

In response to increased oversight of overall EFH program effectiveness by the Office of Management and Budget, NMFS established a quarterly reporting requirement to determine how many conservation recommendations are provided as part of each EFH consultation and how many are adopted by the action agency. Therefore, we request that in your statutory reply to the

EFH portion of this consultation, you clearly identify the number of conservation recommendations accepted, if applicable.

If you have questions regarding this consultation, please contact Robert Anderson, Fishery Biologist with the Oregon State Habitat Office, at 503.231.2226, or Zachary Radmer, Fishery Biologist with the Oregon State Habitat Office, at 503.872.2738. For questions about the marine mammal determinations contact Alison Agness of the Northwest Region, Protected Resources Division at 206.526.6152.

Sincerely,

William W. Stelle, Jr.
Regional Administrator

Endangered Species Act
Biological Opinion and Conference Report

and

Magnuson-Stevens Fishery Conservation and Management Act
Essential Fish Habitat Consultation

Major Rehabilitation of the Jetty System at the Mouth of the Columbia River
Sixth Field HUCs : Baker Bay-Columbia River – 1708000605; Necanicum River-Frontal Pacific Ocean – 1710020101; Youngs River-Frontal Columbia River – 1708000602; Long Beach-Frontal Pacific Ocean – 1710010607 and Wallacut River-Frontal Columbia River – 1708000604, Pacific and Clatsop Counties, Washington and Oregon.

Lead Action Agency: Army Corps of Engineers

Consultation Conducted By: National Marine Fisheries Service
Northwest Region

Date Issued: March 18, 2011

Issued by:
William W. Stelle, Jr.
Regional Administrator

NMFS No.: **2010/06104**

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INTRODUCTION

This document contains a biological opinion (Opinion) prepared by the National Marine Fisheries Service (NMFS) in accordance with section 7(b) of the Endangered Species Act of 1973, as amended (16 U.S.C. 1531, *et seq*.), and implementing regulations at 50 CFR 402.[1] It also contains essential fish habitat (EFH) conservation recommendations prepared by NMFS in accordance with section 305(b)(2) of the Magnuson-Stevens Fishery Conservation and Management Act (MSA) (16 U.S.C. 1801, *et seq*.) and implementing regulations at 50 CFR 600. The Opinion and EFH conservation recommendations are both in compliance with section 515 of the Treasury and General Government Appropriations Act of 2001 (Data Quality Act) (44 U.S.C. 3504 (d)(1) and 3516), and underwent pre-dissemination review. The administrative record for this consultation is on file at the Oregon State Habitat Office in Portland, Oregon.

The Corps maintains the jetty system and navigational channels at the mouth of the Columbia River (MCR) as appropriate based on necessity and appropriations.

Background and Consultation History

Project Authority

The present navigation channel and inlet configuration at the MCR is the result of continuous improvement and maintenance efforts that have been undertaken by the Corps, Portland District since 1885. Congress has authorized the improvement (actual construction) of the MCR for navigation through the following legislation. Senate Executive Document 13, 47th Congress, 2nd Session (5 July 1884) authorized the Corps to construct the South Jetty (first 4.5 miles) for the purpose of attaining a 30-foot channel across the bar at the MCR. House Document 94, 56th Congress, 1st Session (3 March 1905) authorized the Corps to extend the South Jetty (to 6.62 miles in length) and construct the North Jetty (2.35 miles long) for the purpose of attaining a 40-foot channel (0.5 mile wide) across the bar at the MCR. House Document 249, 83rd Congress, 2nd Session (3 September 1954) authorized a bar channel of 48 feet in depth and a spur jetty ("B") on the north shore of the inlet. Funds for Jetty "B" construction were not appropriated. Jetty A was constructed in 1939 under the authority of the Rivers and Harbors Act. Public Law 98-63 (30 July 1983) authorized the deepening of the northern most 2,000 feet of the MCR channel to a depth of 55 feet below mean lower low water (MLLW). The MCR Federal navigation project was originally authorized in 1884 before formulation of local sponsor cost sharing agreements; therefore, all costs of navigation maintenance and improvements at MCR are borne by the Federal government.

The authority for maintenance of the MCR jetties comes from the original authority for construction of the project and then with Corps' policies for the operations, maintenance, and management of a Corps' project (Chapter 11 of EP 1165-2-1).

[1] With respect to designated critical habitat, the following analysis relied only on the statutory provisions of the ESA, and not on the regulatory definition of "destruction or adverse modification" at 50 CFR 402.02.

Corps projects are maintained by regular operations and maintenance, major maintenance, and major rehabilitation. Major rehabilitation consists of either one or both of two mutually exclusive categories: reliability or efficiency improvements, as described below.

- Reliability. Rehabilitation of a major project feature that consists of structural work on a Corps-operated and maintained facility to improve reliability of an existing structure, the result of which will be a deferral of capital expenditures to replace the structure. Rehabilitation will be considered as an alternative when it can significantly extend the physical life of the feature (such as a jetty) and can be economically justified by a benefit/cost relationship. Each year the budget EC delineates the dollar limits and construction seasons (usually two construction seasons).
- Efficiency Improvements. This category will enhance operational efficiency of major project components. Operational efficiency will increase outputs beyond the original project design.

Thus, the authority for maintenance of the MCR jetties comes from the authorization documents for the project and/or the authority to operate and maintain the structures.

Consultation History

On April 2, 2004, NMFS issued a letter of concurrence on marine mammals and sea turtles to the Corps on the minor rehabilitation of the Columbia River North and South Jetties.

On July 29, 2004, NMFS issued an Opinion to the Corps on the minor rehabilitation of the Columbia River North and South Jetties for salmon and steelhead. In our 2004 Opinion, NMFS concluded that the proposed action was LAA Columbia River Basin salmon and steelhead. We also concluded that this action was NLAA Steller sea lions (this determination was amended on September 27, 2006). Our 2011 Opinion does not reach the same conclusion for Columbia River Basin salmon and steelhead because of new information, particularly information about species behavior at the MCR.

On November 30, 2005, the Corps reinitiated consultation on the rehabilitation of the Columbia River North and South Jetties project.

On June 2, 2005, NMFS issued an amendment to the July 29, 2004, Opinion, for salmon and steelhead.

On September 27, 2006, NMFS issued an amendment to the April 2, 2004, letter of concurrence, and issued the Corps an Opinion for Steller sea lions.

On April 18, 2007, NMFS issued an incidental harassment authorization (IHA) to the Corps for the Columbia River South Jetty.

On November 5, 2007, the Corps submitted a biological assessment (BA) to NMFS for the Columbia River Jetty System project. In February 2008, the Corps withdrew their request for consultation due to significant changes in the proposed action.

The Corps published a revised draft environmental assessment in April 2010 in which the Corps determined that a new proposed action with a smaller project footprint was the preferred alternative. The NMFS and the Corps resumed pre-consultation in June 2010. In August 2010, a site visit to view construction activities on the Tillamook North Jetty was conducted with NMFS and Corps representatives to observe and to compare construction activities and design elements associated with a similar, smaller-scale jetty rehabilitation project. From July 2010 to December 2010, NMFS and the Corps met regularly to discuss and describe the proposed action, related studies, jetty design model runs, and what information would be required for the BA and the Opinion. NMFS received the BA for the current proposed action on December 17, 2010.

On February 16, 2011, the Corps modified the proposed action such that no pile driving associated with this action will occur until on or after May 1 of each year. This change was made to prevent acoustic effects on Southern Resident killer whales that have been known to forage in the project vicinity in March or April.

The Corps determined in the December 17, 2010, BA that the proposed action is not likely to adversely affect (NLAA) the following species and/or designated (*) or proposed (#) critical habitats where applicable:

- Blue whale (*Balaenoptera musculus*)
- Fin whale (*B. physalus*)
- Southern Resident killer whale (*Orcinus orca*)
- Sperm whale (*Physeter macrocephalus*)
- Sei whale (*B. borealis*)
- Leatherback sea turtle (*Dermochelys coriacea*)(#)

NMFS concurs with the Corps' NLAA determination for the aforementioned whales and leatherback sea turtle, and proposed critical habitat for leatherback sea turtle as they are either very unpredictable in their occurrence in the action area or transitory when they do occur in the area, such that co-occurrence of the effects of the intermittent pile driving and the species is extremely unlikely.

The Corps determined in the December 17, 2010, BA that the proposed action is likely to adversely affect (LAA) the following species and/or designated (*) or proposed (#) critical habitats where applicable:

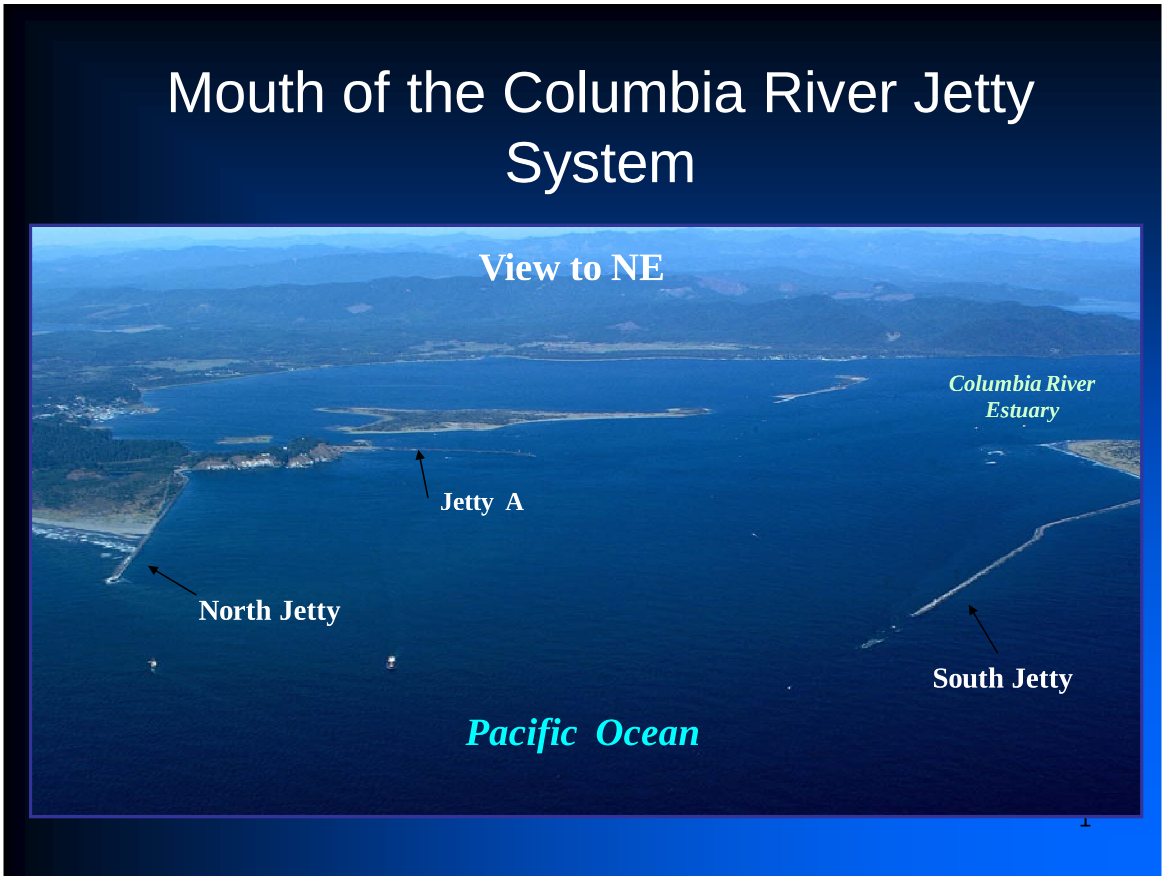
- Lower Columbia River (LCR) Chinook salmon (*O. tshawytscha*)*
- Upper Willamette River (UWR) Chinook salmon (*O. tshawytscha*)*
- Upper Columbia River (UCR) spring-run Chinook salmon (*O. tshawytscha*)*
- Snake River (SR) spring/summer-run Chinook salmon (*O. tshawytscha*)*
- SR fall-run Chinook salmon (*O. tshawytscha*)*
- Columbia River (CR) chum salmon (*O. keta*)*
- LCR coho salmon (*O. kisutch*)#
- Oregon Coast coho salmon (*O. kisutch*)
- Southern Oregon/Northern California Coasts coho salmon (*O. kisutch*)

- SR sockeye salmon (*O. nerka*)*
- LCR steelhead (*O. mykiss*)*
- UWR steelhead (*O. mykiss*)*
- Middle Columbia River steelhead (*O. mykiss*)*
- UCR steelhead (*O. mykiss*)*
- SR basin steelhead (*O. mykiss*)*
- Southern distinct population segment (DPS) green sturgeon (*Acipenser medirostris*)*
- Eulachon (*Thaleichthys pacificus*)#
- Steller sea lions (*Eumetopias jubatus*)
- Humpback whales (*Megaptera novaeangliae*)

The Corps stated in the BA that they will obtain an IHA permit from NMFS for incidental harassment of Steller sea lions, humpback whales, and non-federally listed California sea lions and harbor seals during the proposed action.

The Corps is proposing major repair and rehabilitation of the North Jetty, South Jetty, and Jetty A, all located at the MCR (Figure 1).

Figure 1. Mouth of the Columbia River Jetty System (Corps).



Project Background

The construction and repair history of the MCR jetties is summarized in Table 1.

Table 1. Construction and repair history for the MCR jetties.

1881: A pile dike was proposed to be built on the south side of the MCR to build up Clatsop spit and deepen the navigation channel.

1883: The Corps of Engineers stated that any structures placed in-river should not harm the river and should keep the channel open using the tide; therefore, the jetty should not obstruct the entry of the flood tide. Estimated depths of various jetty sections from the landward end were: 5,000 feet - less than +6 feet; 7,500 feet – +6 to +11 feet; 4,000 feet – +11 to +16 feet; and 7,500 feet – +16 to +21 feet. Jetty crest elevation was designed to be at a low water level because of wave violence that could harm a higher jetty. The logic was that a higher jetty could be built, if needed later, by placing more stone on the existing jetty.

1884: The improvement plan for MCR was approved by the Rivers and Harbors Act of July 5, 1884 to maintain a channel 30 feet deep at mean low tide by constructing a low-tide jetty, approximately 4.5 miles long, from near Fort Stevens on the South Cape to a point approximately 3 miles south of Cape Disappointment.

1886-1896: On-going construction on the South Jetty. A 115 feet long spur was also built landward of the jetty for shore protection. A 510 feet long sand-catch, consisting of heavy beach drift and loose brush, was built on the south side of landward end of the jetty to continue filling the old outlet of a lagoon at extreme end of Point Adams.

1903-1913: The South Jetty was extended. The crest elevation of the jetty was raised to 10 feet MLLW from stations 210+35 to 250+20, and rock placed from stations 250+20 to 375+52, elevation increasing in steps to 24 feet MLLW. Crest width is 25 feet. Seaward bend in the jetty is added and called the "knuckle."

1913-1917: The North Jetty was constructed from stations 0+00 to 122+00. Side slopes are 1 vertical by 1.5 horizontal (1:1.5) and crest width is 25 feet. Crest elevation varied from 15 to 32 feet.

1931-1936: The South Jetty was repaired from stations 175+00 to 257+68.7 (shoreline to knuckle), from stations 257+68.7 to 305+05 (knuckle to middle of outer segment), and from stations 305+05 to 353+05 (middle of outer segment to existing end) with 2.2 million tons of stone. The crest elevation was between 17 and 26 feet MLLW and the crest width was 24 feet. The jetty had been flattened to approximately low water level. A solid concrete terminal was constructed above low water level 3,900 feet shoreward of the original jetty end that was completed in 1913.

1936: A stone/asphalt cone-shaped terminal was constructed on the South Jetty from stations 340+30 to 344+30. The crest width was approximately 50 feet and the elevation varied from 23 to 26 feet.

1937-1939: The North Jetty was repaired from stations 68+35 to 110+35. The crest elevation was 26 feet and the crest width was 30 feet.

1939: Jetty A was constructed. Crest width was 10 feet from the root to station 53+00, and 20 feet thereafter. Jetty A was 30 feet wide. Four pile dikes were also constructed at Sand Island.

1940-1942: South Jetty was repaired from stations 332+00 to 343+30. A concrete terminal/stone foundation added. Crest elevation was 8-20 feet and crest width was between 50 and 75 feet.
1945-1952: Jetty A was repaired from stations 78+00 to 96+00, stations 92+35 to 95+35, stations 91+50 to 93+00, and stations 90+00 to 94+00. Crest elevation was 20 feet with a crest width between 20 and 40 feet.

1958: Jetty A was repaired from stations 41+00 to 79+00 to a crest elevation of 20 feet and crest width between 20 and 30 feet.

1961-1962: Jetty A was repaired from stations 50+00 to 90+50, with no repairs from Stations 68+00 to 76+50. Crest elevation was built with a 10% grade from 20 feet to 24 feet from stations 50+00 to 68+00. The crest elevation was raised to 24 feet from stations 76+50 to 90+50.

1961: South Jetty was repaired from stations 194+00 to 249+00 (current stationing). Crest elevation varied from 24 to 28 feet and crest width was 30 feet. Channel side slope 1:1.25 and ocean side slope 1:1.5. It was also repaired from stations 38+00 to 93+00 (old stationing). Elevation at station 38+00 is +24 feet was increased with a 0.5% grade up to +28 feet for the remainder of repair section. The repair centerline was located 13 feet north of the centerline of the original jetty design. The design crest width was 30 feet. The north slope was 1:1.25 and south slope was 1:1.5.

1962-1965: South Jetty was repaired from stations 249+00 to 314+05 (beyond knuckle). Crest elevation began at 28 feet and transitioned to 25 feet for most of section. Side slopes varied from 1:1.5 to 1:2 and crest width was 40 feet (this appears to be the furthest seaward intact portion of current jetty). Repairs were made from stations 93+00 to 157+50 (old stationing). The crest elevation was +28 feet at station 93+00, decreased to +25 feet at station 95+00, and then continued with this elevation to end of the repairs. The crest width was 40 feet and had a slope of 1:1.5 from stations 93+00 to 152+00. The slope transitioned to 1:2 from stations 152+00 to 154+00. The centerline of the repair was 15 feet south of the trestle centerline.

1965: The North Jetty was repaired from stations 89+47 to 109+67 with a crest elevation of 24 feet and crest width of 30 feet. Side slopes varied from 1:1.5 to 1:2.

1982: The South Jetty was repaired from stations 194+00 to 249+00 (segment before knuckle) so that the crest elevation varied from 22 to 25 feet MLLW. The crest width varied from 25-30 feet and the side slopes were 1:1.5. The crest elevation varied from +22 feet at station 38+00 to +25 feet at station 80+35 (old stationing). From stations 44+50 to 80+35, crest width is 30 feet and slope is 1:1.5. Crest elevation was +25 feet, width varied from 25-30 feet, and the side slope was 1:1.5.

2005: The North Jetty was repaired from stations 55+00 to 86+00. The crest elevation was built to +25 feet with a side slope of 1:1.5.

2006: The South Jetty was repaired from stations 223+00 to 245+00. The crest elevation was built +25 feet with a side slope of 1:2.

2007: The South Jetty was repaired from stations 255+00 to 285+00. The crest elevation was built to +25 feet with a side slope of 1:2.

Figure 1 shows the navigation channel and the three primary navigation structures, the North Jetty, South Jetty, and Jetty A. Those structures are shown in more detail in Figure 2. The North Jetty and Jetty A are located in Pacific County, Washington, near Ilwaco and Long Beach on the Long Beach Peninsula. The South Jetty is located in Clatsop County, Oregon near Warrenton/Hammond and Astoria.

Figure 2. Pictures of the MCR Jetties. Top left photo shows the South Jetty looking east. The remnant feature shown disconnected from the primary structure is the concrete monolith that was constructed in 1941. The top right photo shows Jetty A. The bottom photo illustrates the North Jetty and the shoreline north of the MCR.

South Jetty

Jetty A

North Jetty

Description of the Proposed Action

NMFS relied on the description of the proposed action (below), including all features identified to reduce adverse effects, to complete this consultation. To ensure that this biological opinion remains valid, NMFS requests that the action agency keep NMFS informed of any changes to the proposed action. For a complete description of the proposed action refer to the BA.

Along certain sections of each jetty, wave cast and erosional forces have flattened the jetty prism and left a bedding of relic stone with only some of the original jetty prism remaining. The Corps is proposing to perform modifications and repairs to the North and South Jetties and Jetty A at the MCR that would strengthen the jetty structures, extend their functional life, and maintain deep-draft navigation.

The proposed action is comprised of four categories that are applicable to each jetty:

1. Engineered designs elements and features of the physical structures.
2. Construction measures and implementation activities.
3. Proposed 7(a)(1) habitat improvement measures to improve habitat for the benefit of listed species.
4. Wetland mitigation actions to offset adverse effects of filling wetlands.
5. The proposed establishment of and coordination with an adaptive management team (AMT) comprised of staff and representatives from appropriate Federal and state agencies (including NMFS and the Corps).

Construction is proposed to continue for 20 years, with a 50-year operational lifetime for the MCR jetty system. An inherent level of uncertainty exists regarding dynamic environmental conditions around each of the Jetties. Because of this uncertainty, in all cases where areas, weights, and volumes (tons, acres, cubic yards, *etc.*) or other metrics are indicated, these are best professional estimates and may vary by greater or lesser amounts within a 20% range when final designs are completed. The estimated amounts represent the best professional judgment of the Corps as to what the range of variability will be in the design as on-the-ground conditions evolve over the 20-year construction schedule. The Corps currently maintains a jetty monitoring and surveying program that will further inform the timing and design of the proposed action. The information gathered at the Jetties will facilitate efficient completion of the project and whenever possible will avoid emergency repair scenarios.

1. Design elements and structural features specific to each jetty include the following:

- North Jetty – The North jetty will be repaired where cross-section has been lost, and engineering features designed to minimize future cross-section instability will be constructed. The cross-section repairs will be primarily above MLLW, with a majority of stone placement not likely to extend deeper than -5 feet MLLW. Four spur groins will be added and the jetty head (western-most section) will be capped with large stone to correct structural instability. Spur groins will be constructed primarily on existing relic stone. Head capping stone will be placed on relic stone as well as on jetty stone that is above MLLW. Shore-side improvements at the North jetty will include culvert replacements and the filling of lagoons. These improvement actions are designed to stop ongoing erosion of the jetty root.

- South Jetty – The South jetty will be repaired where cross-section has been lost, and engineering features designed to minimize future cross-section instability will be constructed. The cross-section repairs will be primarily above MLLW, with a majority of stone placement not likely to extend more than -5 feet MLLW. Five spur groins will be added and the jetty head (western-most section) capped with large stone to correct structural instability. Spur groins will be constructed primarily on existing relic stone. Head capping stone will be placed on relic stone as well as on jetty stone that is above MLLW. The dune at the western shoreline extending south from the jetty root will be augmented. The augmentation action is intended to prevent the degradation of the jetty root and prevent a potential breaching of the fore dune.

- Jetty A – Jetty A will be repaired where cross-section has been lost, and engineering features designed to minimize future cross-section instability will be constructed. The cross-section repairs will be primarily above MLLW, with a majority of stone placement not likely to extend more than -5 feet MLLW. Two spur groins will be added and the jetty head (southern most section) and will be capped with large stone to correct structural instability. The groins will be constructed primarily on existing relic stone. Head capping stone will be placed on relic stone as well as on jetty stone that is above MLLW. The repair is proposed to have a small cross-section, two spur groins, and a capped jetty head.

2. Construction for all three jetties is proposed to include the following:

- Storage and staging areas for rock stockpiles and all associated construction and placement activities such as roadways, parking areas, turn-outs, haul roads, weigh stations, and a yard area for sorting and staging actions.
- Stone delivery from identified quarries either by barge or by truck. Possible transit routes are identified below. Permanent barge offloading facilities and causeways will be constructed and operated as such. This part of the proposed action will include the installation and removal of piles and dolphins necessary for the offloading facilities.
- Stone placement either from land or water will require the construction, repair, and maintenance of a haul road on the jetty itself, crane set-up pads, and turnouts on the jetty road.
- Dredging and disposal of infill at offloading facilities, with a frequency dependent on a combination of the evolving conditions at the site and expected construction scheduling and stone delivery. Disposal will occur at existing approved in-water sites.

3. 7(a)(1) Habitat improvement projects. Proposed habitat improvement projects are likely to include one or more projects intended to benefit listed species, such as:

- Excavation and creation of intertidal wetlands to restore and improve wetland functions.
- Culvert and tide gate replacements or retrofits to restore or improve fish passage and access to significant spawning, rearing, and resting habitat.
- Dike breaches to restore brackish intertidal shallow-water habitat for fish benefits.
- Beneficial uses of dredged material from the MCR hopper dredge to replenish the Columbia River littoral cells.
- Invasive species removal and control and revegetation of native plants to restore ecological and food web functions that benefit fisheries.

These habitat improvement projects will require additional consultations, and the proposed AMT likely will be of assistance in this process. Furthermore, NMFS did not consider the beneficial effects of the habitat improvement projects in making our jeopardy/adverse modification determinations.

4. Clean Water Act Section 404 wetland mitigation projects.

The wetlands to be affected by the proposed action are isolated, non-fish bearing wetlands. The Corps will mitigate for all impacts to wetlands regulated under section 404 of the Clean Water Act. Estimates for wetland impacts are preliminary and may be reduced or increased when final delineations are completed.

5. Due to the long duration of the MCR jetty rehabilitation schedule, the Corps has proposed the formation of an AMT.

The Corps suggested annual meetings to discuss relevant design and construction challenges and modifications, technical data, and adaptive management practices as needed. The primary purpose of the proposed AMT and its implementation will be to ensure that construction, operation, and maintenance actions do not have impacts greater than those described in the BA and the Opinion. This process will also provide confirmation that any necessary construction or design refinements remain within the range and scope of effects described in the Opinion. The AMT will facilitate continued coordination and updating and allow the Corps to inform agency partners when unforeseen changes arise. Results regarding marine mammal and fish monitoring, wetland mitigation and habitat improvement monitoring, as well as water quality monitoring will also be made available to the AMT to fulfill reporting requirements and address any unexpected field observations. Results of jetty monitoring surveys will also inform the AMT of the changing repair schedule and design refinements that occur as the system evolves over time. This venue will provide greater transparency and allow opportunities for additional agency input. Final selection and design of the habitat improvement and wetland mitigation proposal will be vetted through the AMT to facilitate obtaining final environmental clearance documents for this component of the proposed action. Potential principal partners include federal (NMFS, U.S. Fish and Wildlife Service) and state (Washington, Oregon) resource management agencies.

Project Specifications

Repair and *rehabilitation* are two proposed approaches that specifically describe construction and stone placement actions for the cross-sections and engineered features along the trunks and roots of the Jetties. An economics and design model will be used to select the repair and rehabilitation schedule at the North and South Jetties. This model predicts a certain number of repair actions that will be needed to avoid a breaching scenario during the 20-year construction schedule and 50-year operational lifetime of the Jetties. This model and repair system is referred to as the scheduled repair approach. The scheduled repair approach prioritizes work on specific portions of the jetty so that sections in a greater degree of deterioration will be repaired with rock according to a programmed sequence developed as a result of regular jetty monitoring and inspections.

Repair is defined as adding limited amounts of stone to the trunk, head, and root features in order to restore the damaged cross-sections back to a standard repair template. The standard repair template will be described in more detail in the paragraphs below for each jetty. A repair action is generally triggered when the upper cross-sectional area falls below 30%-40% of its standard jetty template profile (*i.e.*, only 30% or 40% of the current jetty structure remains; 60%-70% of the previously existing prism is gone). For each repair action, the majority of stone placement will occur above MLLW. However, depending on conditions at specific jetty cross-sections, stone could extend more than -5 feet MLLW in order to restore that jetty section back to the standard repair template. Therefore, repair actions could be slightly greater or smaller, depending on the condition of the cross-section being repaired.

Rehabilitation is defined as adding new structures and/or placing rock along the cross-section of the entire root and trunk. For instance, the construction and placement sequence for immediate rehabilitation at Jetty A means stone placement activities are initiated at one end of the jetty and are completed continuously in succession without prioritization based on conditions at any particular jetty section. The proposed rehabilitation action on Jetty A is more robust than a repair action and includes a re-built cross-section along the entire length of the jetty. Sections in a greater state of deterioration may receive a relatively larger amount of rock compared to sections with less deterioration. The rehabilitation cross-section template is expanded slightly beyond the existing prism template. This involves stone placement that primarily fits within the existing footprint of the jetty structure or relic stone, but may extend slightly beyond the existing prism.

The following paragraphs use station numbers on each jetty to describe locations. These stations indicate lineal distance along the jetty relative to a fixed reference point (0+00) located at the landward-most point on the jetty root. Numbering begins at the reference point (0+00) and increases seaward such that each station number represents that distance in feet, multiplied by 100, plus the additional number of feet indicated after the station number. For instance, station 100+17 would be 10,017 feet seaward from the reference point. A summary of design parameters for the preferred plan at each jetty is shown in Table 2.

Table 2. Design parameters for the preferred plan at each jetty volumes, lengths and areas may vary by ± 20% upon final design.

North Jetty Scheduled Repair with Engineering Features

Jetty Crest Elevation	Estimated Stone Density	Total Repair Length	Jetty Crest Width	Jetty Sideslope		Jetty Head Station	Head Length	Spur Groin Sta.	Spur Groin Tons
				Channel	Ocean				
25' above MLLW	167 #/ft3	8,100'	30'	1v:1.5h	1v:1.5h	99+00 to 101+00	200'	Sta 50-C Sta 70-C Sta 80-O Sta 90-C	3,895 12,870 2,340 33,960

South Jetty Scheduled Repair with Engineering Features

Jetty Crest Elevation	Estimated Stone Density	Total Repair Length	Jetty Crest Width	Jetty Sideslope		Jetty Head Station	Head Length	Spur Groin Sta.	Spur Groin Tons
				Channel	Ocean				
25' above MLLW	167 #/ft3	15,800'	30'	1v:1.5h	1v:2h	311+00 to 313+00	200'	Sta 165-O Sta 210-C Sta 230-C Sta 265-C Sta 305-O	1,496 2,095 2,095 2,841 16,747

Jetty A Rehab with Engineering Features

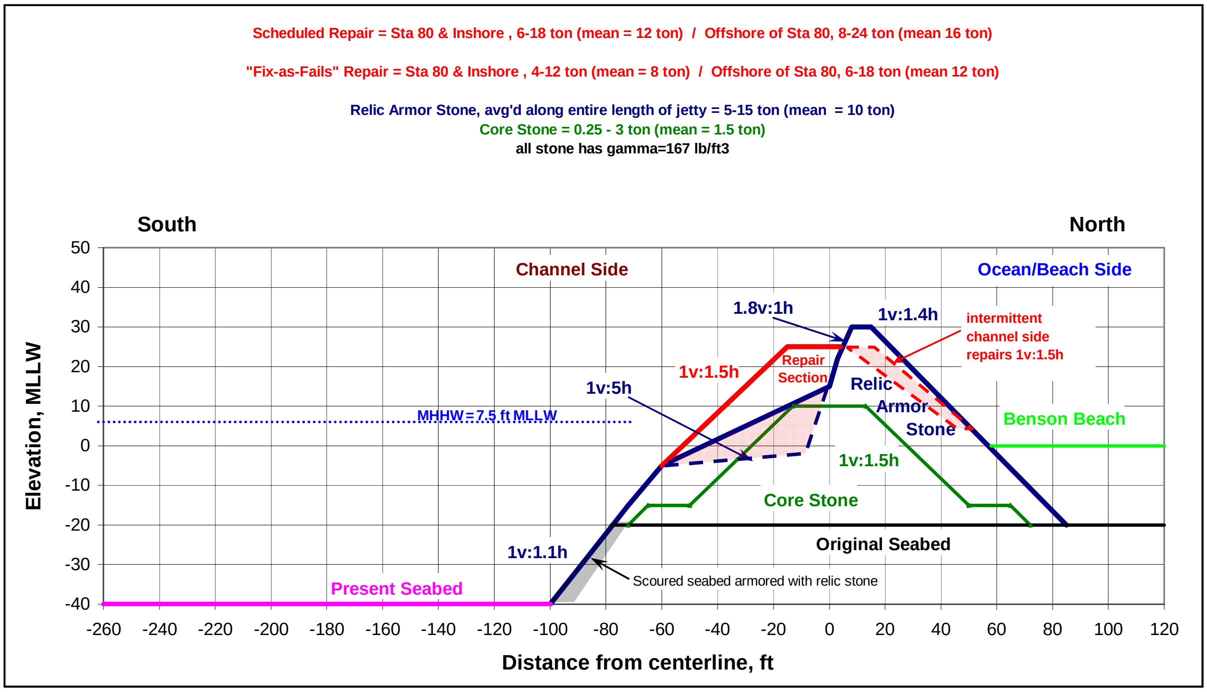
Jetty Crest Elevation	Estimated Stone Density	Total Repair Length	Jetty Crest Width	Jetty Sideslope		Jetty Head Station	Head Length	Spur Groin Sta.	Spur Groin Tons
				Estuary	Ocean				
20' above MLLW	167 #/ft3	5,300'	40'	1v:2h	1v:2h	91+00 to 93+00	200'	Sta 84-O Sta 90-E	12,272 12,272

MCR North Jetty

The proposed action for the North Jetty is scheduled repair and construction of engineered features (rehabilitation) including four spur groins and head capping, culvert replacement, and lagoon fill to stop erosion of the jetty root (Figures 3, 4, 5, and 6). The jetty head and foundation at the most exposed portion of jetty will be stabilized. Details are described below.

<u>North Jetty Trunk and Root.</u> The cross-section design from stations 20+00 to 99+00 will have a crest width of approximately 30 feet and will lie essentially within the existing jetty footprint based on the configuration of the original cross-section, previous repair cross-sections, and redistribution of jetty rock by wave action. Approximately 460,000 tons (~287,500 cubic yards [cy]) of new rock will be placed on relic armor stone, with the majority of stone placement occurring above MLLW. Approximately four repair events are predicted over the next 20 years. Each repair action is expected to cover a length range of up to 1,700 feet and include stone volumes in the range of 45,000 to 100,000 tons (~28,125 to 62,500 cy) per season.

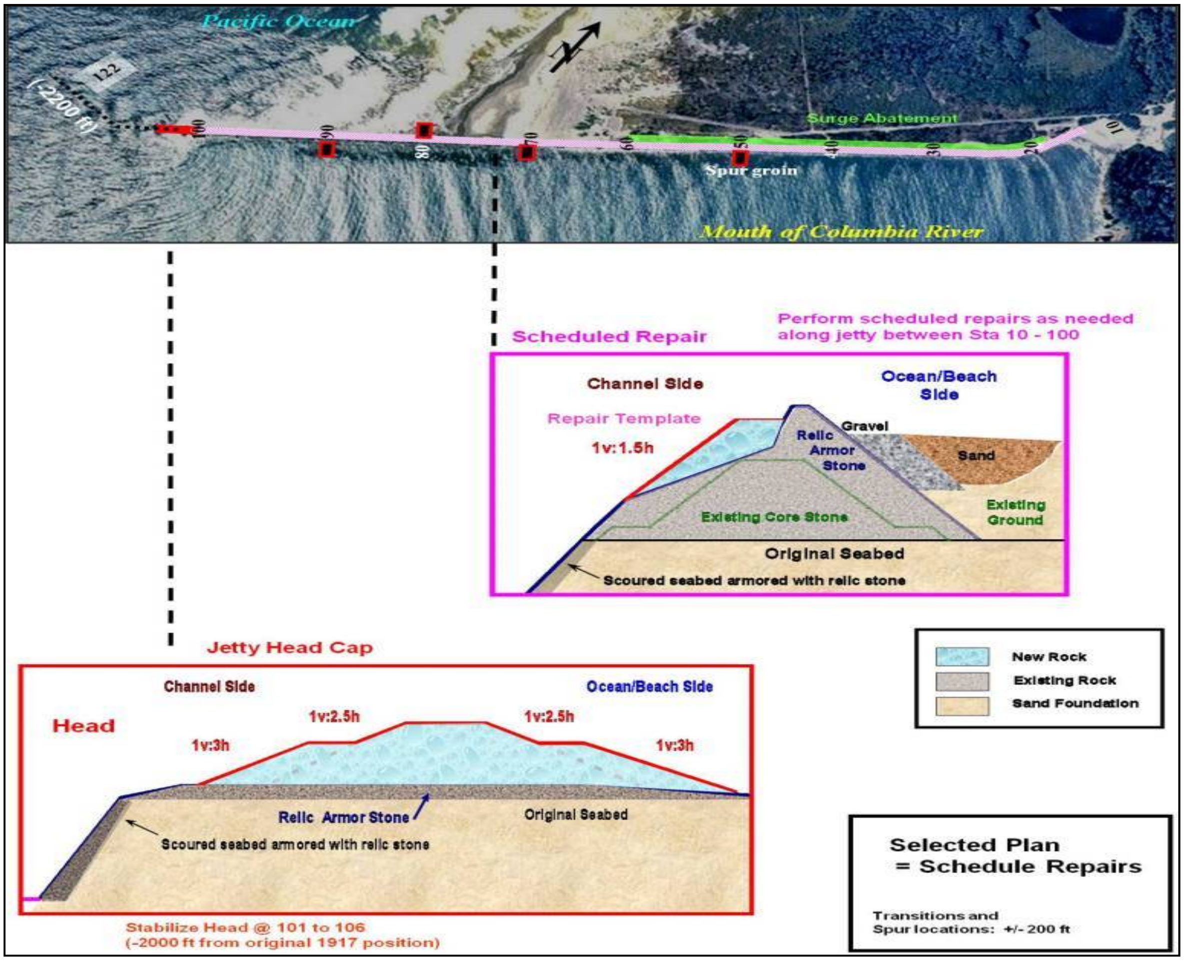
Figure 3. North Jetty cross-section for existing condition and scheduled repair template.



At the time of repair, it is likely that 60 to 70% of the standard jetty template cross-section will have been displaced. Therefore, each repair event will increase the degraded cross-section from 30 to 40% back to 100% of the desired standard cross-section template. This means the overall added rock will essentially triple what exists immediately prior to the time of repair. Jetty repairs will not increase the jetty prism or footprint beyond the scope and size of the historic structure, and would not include any modification that changes the character, scope, or size of the original structure design.

Described below is the quantity of rock that will be placed into each elevation zone per representative repair event. Approximately 21,550 cy of rock will be placed above mean higher high water (MHHW). This represents 58% of the overall stone placement on these portions of the jetty. Approximately 9,230 cy of rock will be placed between MHHW and MLLW. This represents 25% of the overall stone placement on these portions of the jetty. Approximately 6,675 cy of rock will be placed below MLLW. The footprint of the trunk and root of the North Jetty will remain on relic stone and within its current jetty dimensions.

Figure 4. Typical cross-sections of the trunk repair and cap rehabilitation. The approximate placement of spur groins is also indicated.



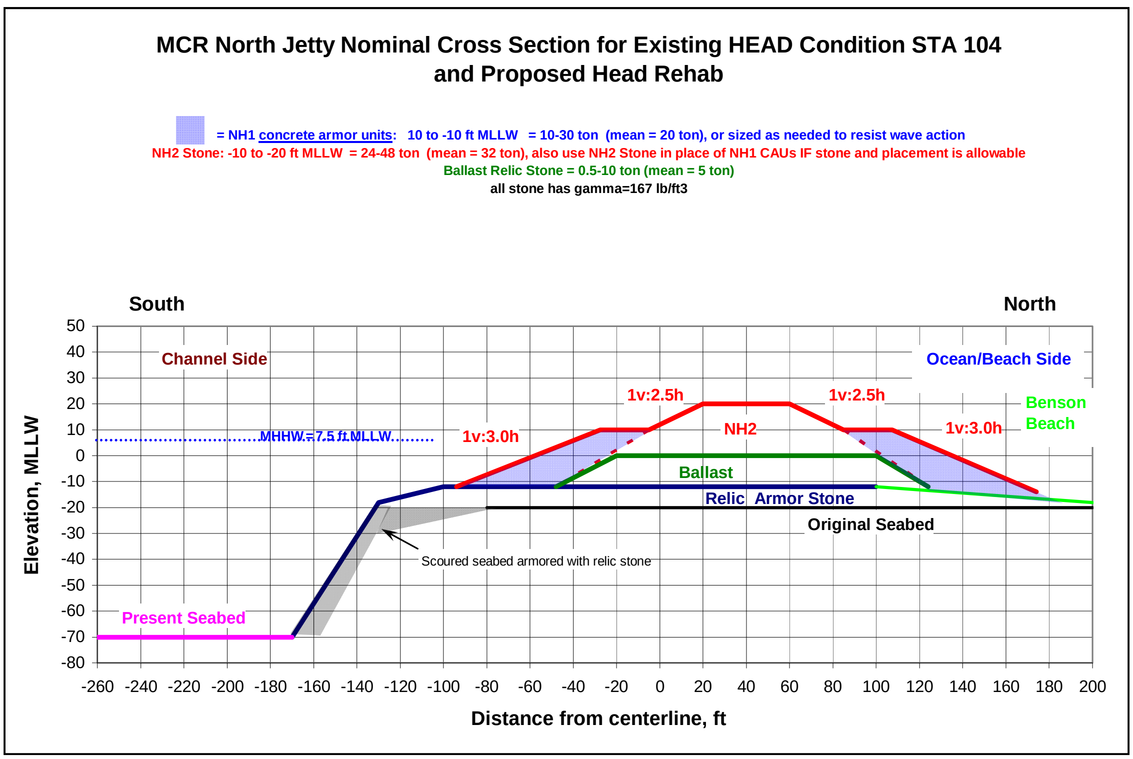
<u>North Jetty Head Capping.</u> An armor stone cap or concrete armor units (CAUs) will be placed on the head of the North Jetty to stop its deterioration (Figure 4, above, and Figure 5 and Table 3, below). Approximately 38,000 tons (~23,750 cy) of stone or functionally equivalent CAUs will be placed on the relic stone to cap the jetty head. Future physical modeling will refine head capping features.

Table 3. North Jetty head cap features.

Head Cap Features	North Jetty
Location of cap	stations 99 to 101
Timing of construction	2015
Approximate dimensions of cap: length x width x height (feet)	350 x 270 x 45 (2.17 acres)
Stone size	30 to 50 tons
Area affected (outside relic stone)	None
% of cap constructed on relic stone	100%
Construction method	Cranes set on the jetty

Stone placement for head capping has been divided into elevation zones. Approximately 13,425 cy of rock will be placed above MHHW. Approximately 6,490 cy of rock will be placed between MHHW and MLLW. This represents 24% of the overall stone placement on this portion of the North Jetty. Approximately 7,280 cy of rock will be placed below MLLW. This represents 27% of the overall stone placement on this portion of the North Jetty head. In all zones, all proposed stone placement will occur on existing base relic stone that formed the original jetty cross-section and was displaced and flattened by wave action, and does not include any modification that changes the character or increases the scope, or size of the original structure design. The footprint of the existing jetty mound on the flattened relic stone is approximately 1.37 acres, and the additional capping on the relic stone increases the width of the prism approximately 0.80 acres, for a total footprint of 2.17 acres, all of which will remain on the existing relic stone.

Figure 5. A more detailed representative cross-section of the North Jetty head cap.



MCR South Jetty

The proposed action for the South Jetty includes scheduled repairs addressing water structural instability mostly above MLLW, five spur groins, head capping, and the jetty shoreline near the root (Figures 6,7, and 8). Seven scheduled repair events over the next 20 years were predicted at the South Jetty.

South Jetty Trunk and Root. The cross-section design from stations 155+00 to 311+00 will have a crest width of approximately 30 feet and will lie essentially within the existing jetty footprint based on the configuration of the original cross-section, previous repair cross-sections, and redistribution of jetty rock by wave action (Figures 6 and 7). The majority of the stone will be placed above MLLW. Each repair action is expected to cover a length up to 2,100 feet and include stone volumes in the range of 30,000 to 118,000 tons per season (18,750 to 73,750 cy).

As with the North Jetty repair action, it is expected that 60 to 70% of the South Jetty's overall standard jetty template cross-section will have been displaced. Therefore, each repair event will increase the existing degraded cross-section from 30 to 40% back to 100% of the desired standard cross-section template. Jetty repairs will not result in an increase to the jetty prism or footprint beyond the scope and size of the historical structure, and would not include any modification that changes the character, scope, or size of the original structure design.

Approximately 37,640 cy of rock will be placed above MHHW per repair event. Approximately 10,420 cy of rock will be placed between MHHW and MLLW. This represents 19% of the overall stone placement on these portions of the South Jetty. Approximately 6,940 cy of rock will be placed below MLLW. This represents 13% of the overall stone placement on these portions of the South Jetty. Jetty repairs in all zones will occur on existing base relic stone that formed the original jetty cross-section. The footprint of the trunk and root of the South Jetty will remain within its current jetty dimensions and on relic stone.

Figure 6. Representative cross-sections of the South Jetty head cap rehabilitation and trunk repair. The approximate placement of spur groins is also included.

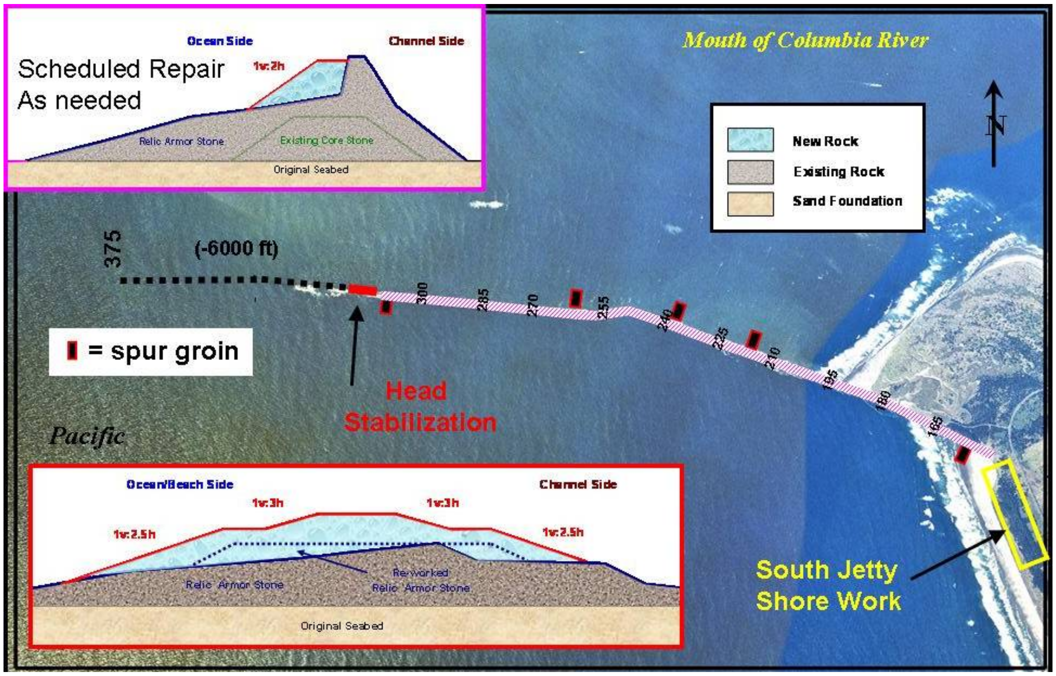
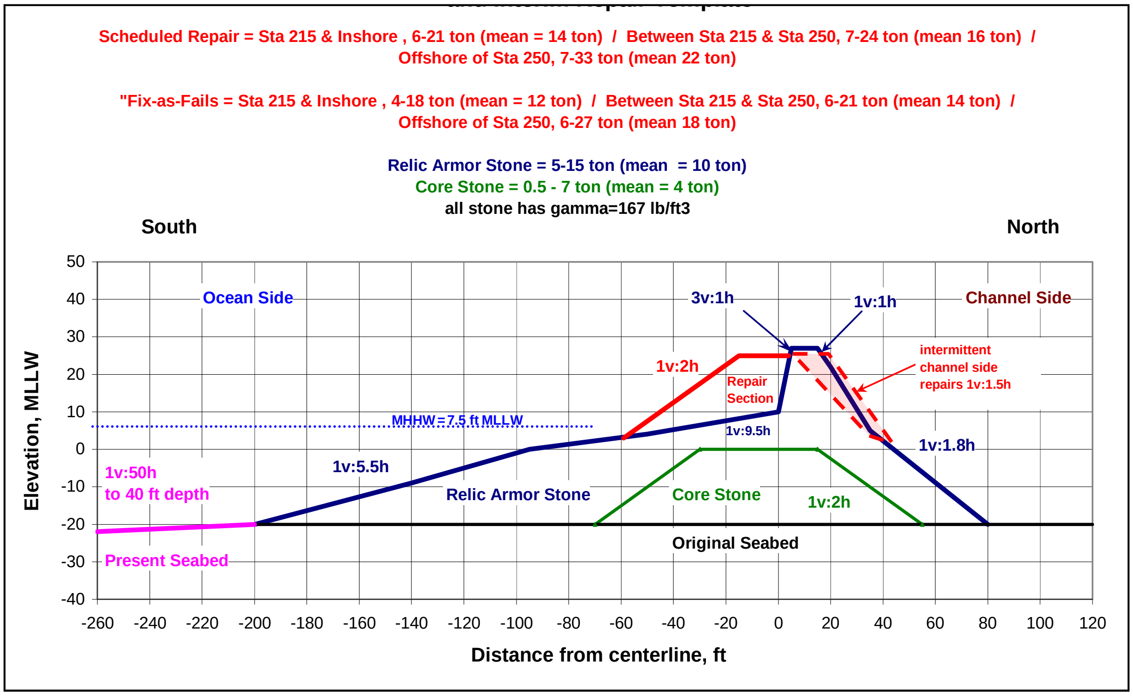
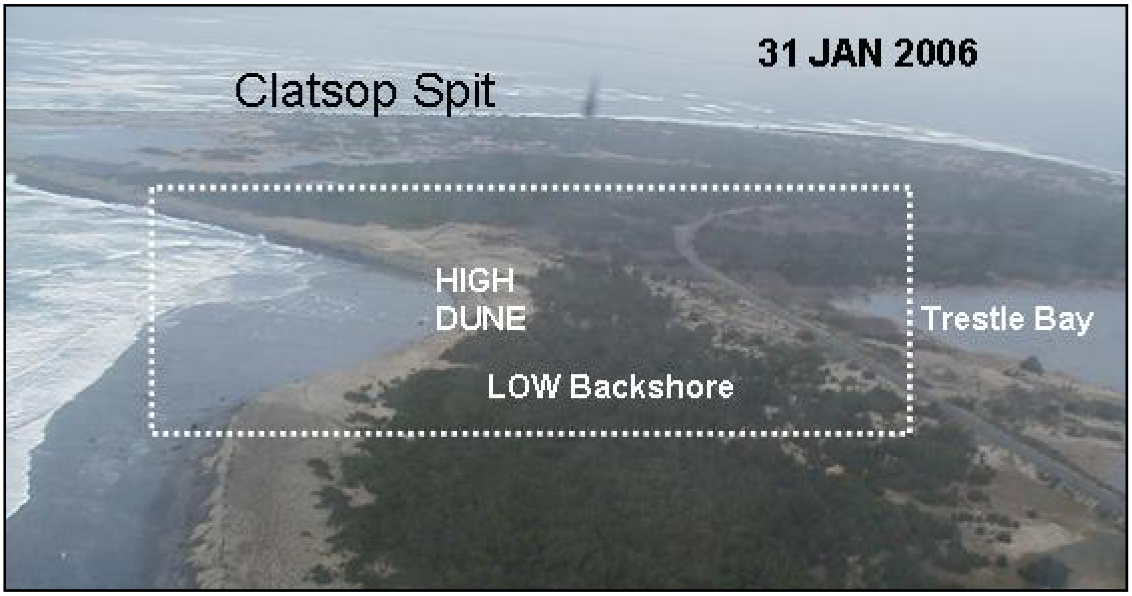


Figure 7. Detailed cross-section of the South Jetty trunk repair (representative).



South Jetty Root Erosion and Dune Augmentation. Currently, the coastal shore interface along the South Jetty is in a condition of advanced deterioration (Figures 8 and 9). The foredune separating the ocean from the backshore is almost breached. The backshore is a narrow strip of a low-elevation, accretion area that separates Trestle Bay from the ocean by hundreds of yards. The offshore area along the South Jetty (and to the south) continues to erode, promoting larger wave action that affects the shoreline along the South Jetty root. The back dune of Trestle Bay has continued to advance westward due to increased circulation in the bay, seasonal wave chop, and hydraulic surcharging. Under existing conditions, the shoreline at the root of the South Jetty will continue to erode and recede, resulting in a possible shoreline breach into Trestle Bay in approximately 8 to 16 years. If this sand spit breach occurs, the result would be catastrophic. The MCR inlet would establish a secondary flow way from the estuary to the ocean along this area (south of South Jetty). This condition would profoundly disrupt navigation at the MCR and bring lasting changes to the physical nature of the inlet.

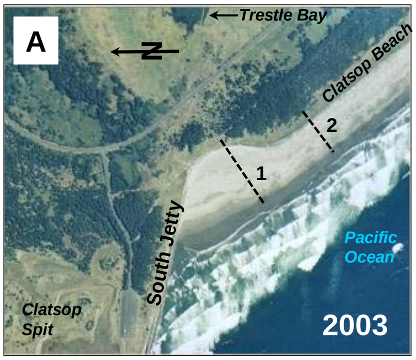
Figure 8. Aerial photograph showing Clatsop spit and South Jetty root erosion.



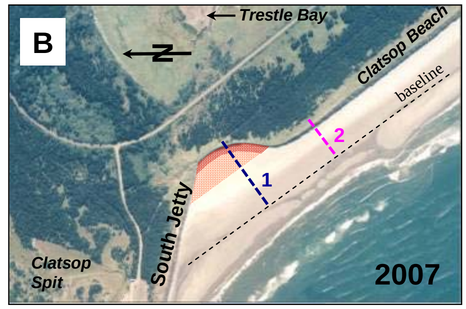
Approximately 40,000 to 70,000 cy of cobble in the shape of angular or rounded graded stone is proposed to be placed at the South Jetty root to fortify the toe of the foredune and to improve the foreshore fronting to resist wave-induced erosion/recession (Figure 9). Maximum crest width of the template is estimated to extend 70 feet seaward from the seaward base of the present foredune. Construction of the berm augmentation would take 2 to 6 weeks. To adequately protect the foredune during storm conditionsrequires that the top of the stone berm (crest) extend vertically to approximately 25 feet NAVD and have an alongshore application length of approximately 1,100 feet (3 acres), extending southward from the South Jetty root. The constructed template crest would be 10 to 15 feet above the current beach grade and have a 1 vertical:10 horizontal slope aspects from crest to existing grade. Cobble will not extend below MHHW. An additional layer of sand may be placed over this berm, or natural accretion may facilitate sand recruitment after construction of the adjacent spur groin.

Cobble material would be procured from upland sources and placed using trucks and bulldozers. The material would be transported on existing surface roads and through Fort Stevens State Park to a beach access point at the project site. There is an existing relic access road along the jetty root that will be refurbished and used to transport stone to the dune augmentation area.

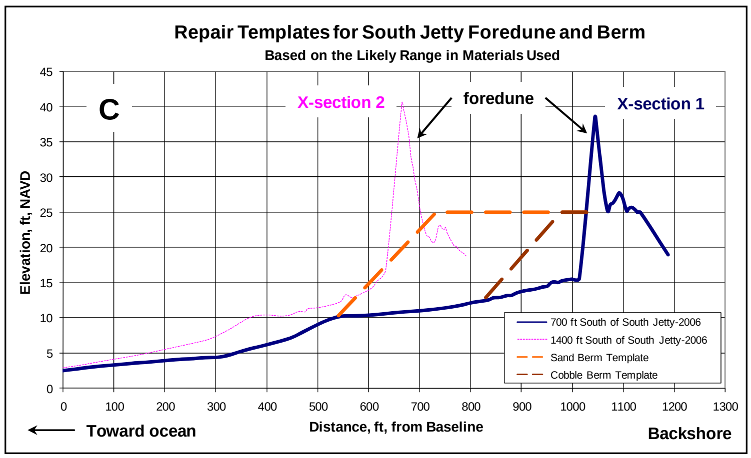
Figure 9. Aerial photographs of, and repair template for the South Jetty root shoreline area.



MCR South Jetty root, south side where Clatsop Spit joins with Clatsop Plains/Beach. Panels A and B show the erosion embayment along the south jetty root for 2003 (hIgh tide) and 2007 (low tide). The embayment & adjacent shore have receded 40 ft landward during 2003-2007, reducing the protective foredune along the embayment.



Panel C shows cross-sections 1 and 2 for 2007(shown in panels A & B). Severe erosion in this area had threatened the inlet stability during early 1930s, when jetty rehabilitation and sand augmentation measures were implemented. Erosion has again become chronic since the late 1970s. The foredune protects the backshore (elevation 15-18 ft NAVD) from wave surge action during storms. If the foredune is breached, the backshore will be rapidly eroded. Without erosion abatement, it is estimated that that the Pacific Ocean will establish hydraulic connectivity with Trestle Bay in 10-15 years from 2009, and again threaten inlet stability. Panel C shows two options for protecting the foredune within the erosion embayment: A SAND berm template requires ~225,000 cy of sand placement, and a COBBLE berm template requires ~60,000 cy of cobble placement.



The dune augmentation may require maintenance every 4 to 10 years (assuming 40% replacement volume). Consideration will be given to development of revegetation plans which incorporate native dune grasses to supplement foredune stabilization in the augmentation area. This bioengineering component could help restore habitat and take advantage of natural plant rooting functions that provide greater protection from erosive forces.

MCR Jetty A

The proposed action for Jetty A includes immediate rehabilitation with a small cross-section, two spur groins, and head capping (Figures 10, 11, 12, 13 and Table 4), as described below.

Jetty A Trunk and Root. The cross-section design from stations 40+00 to 91+00 will have a crest width of approximately 40 feet and will lie mostly within the existing jetty footprint based on the configuration of the original cross-section, previous repair cross-sections, and redistribution of jetty rock by wave action (Figures 10 and 11). Approximately 55,000 tons (~34,375 cy) of new rock will be placed on the existing jetty cross-section and relic armor stone on the estuary/channel side of the jetty and 75,000 tons (~46,875 cy) of new rock on the ocean side of the jetty. Although most of the work will occur above MLLW, there will also be some stone placement below this elevation. The small cross-section also has a higher likelihood of expanding beyond the relic base compared to repair actions.

Approximately 63,700 cy of rock will be placed above MHHW. This represents 63% of the overall stone placement on these portions of Jetty A. Approximately 28,940 cy of rock will be placed between MHHW and MLLW. This represents 29% of the overall stone placement on these portions of Jetty A. Approximately 8,030 cy of rock will be placed below MLLW. This represents 8% of the overall rock on these portions of Jetty A. In all zones, most of the proposed stone placement will occur on existing base relic stone that formed the original jetty cross-section. However, the footprint of the proposed prism could increase in width compared to the existing prism by up to 10 feet along the length of the jetty (though it would still be on the relic stone). This equals approximately 1.2 acres, but it is not expected to result in additional habitat conversion because it will on top of an area that is already comprised of jetty stone, and does not include any modification that changes the character, scope, or size of the original structure design.

Figure 10. Typical cross-section and locations of the trunk, root, and cap on Jetty A. The approximate locations of the spur groins are also shown.

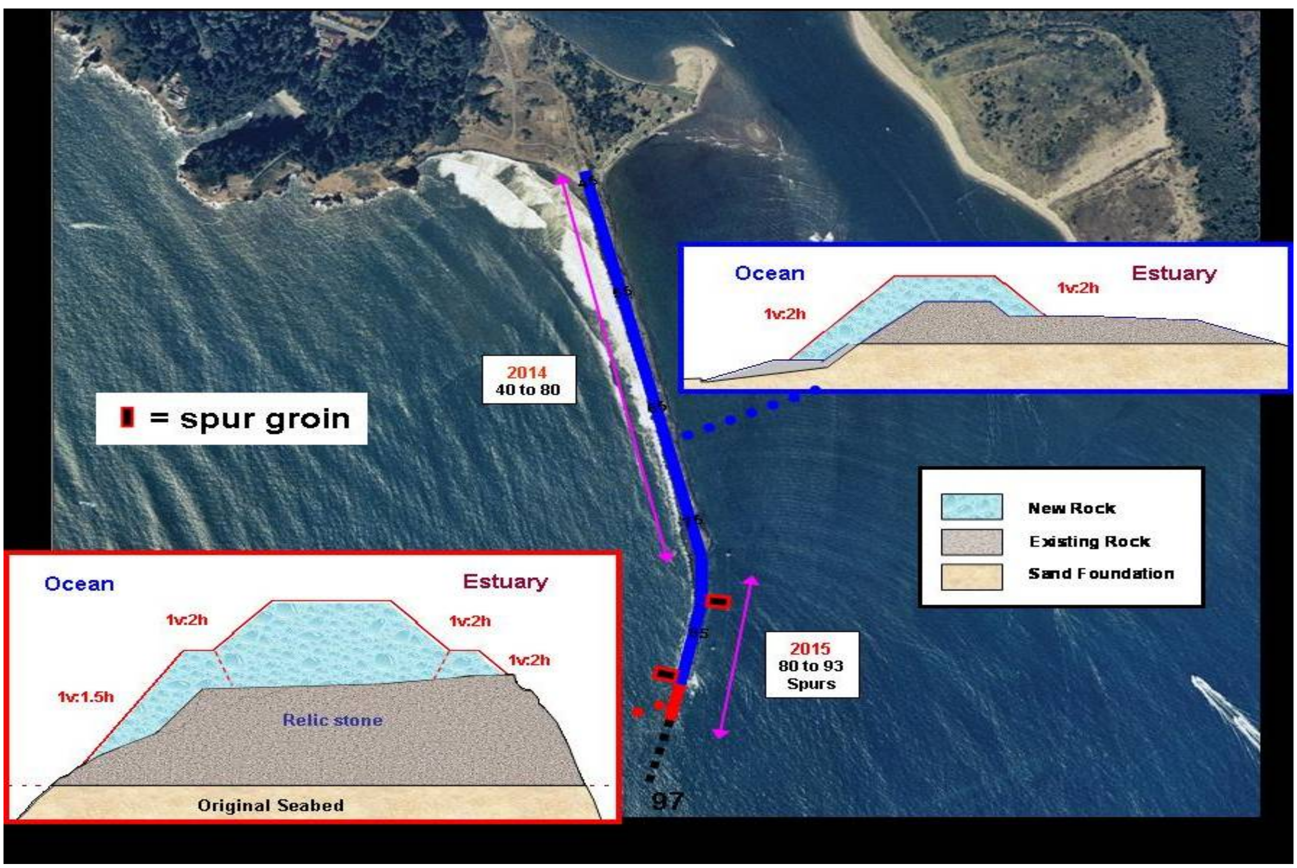
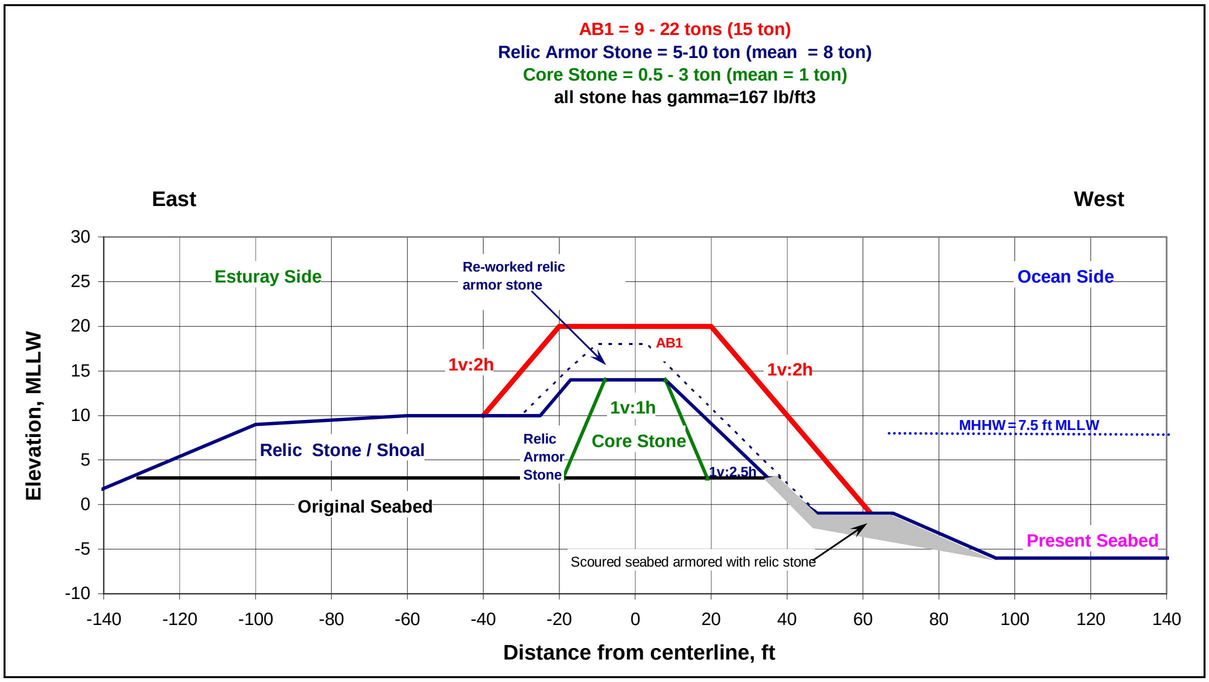


Figure 11. Detailed representative cross-section for Jetty A.



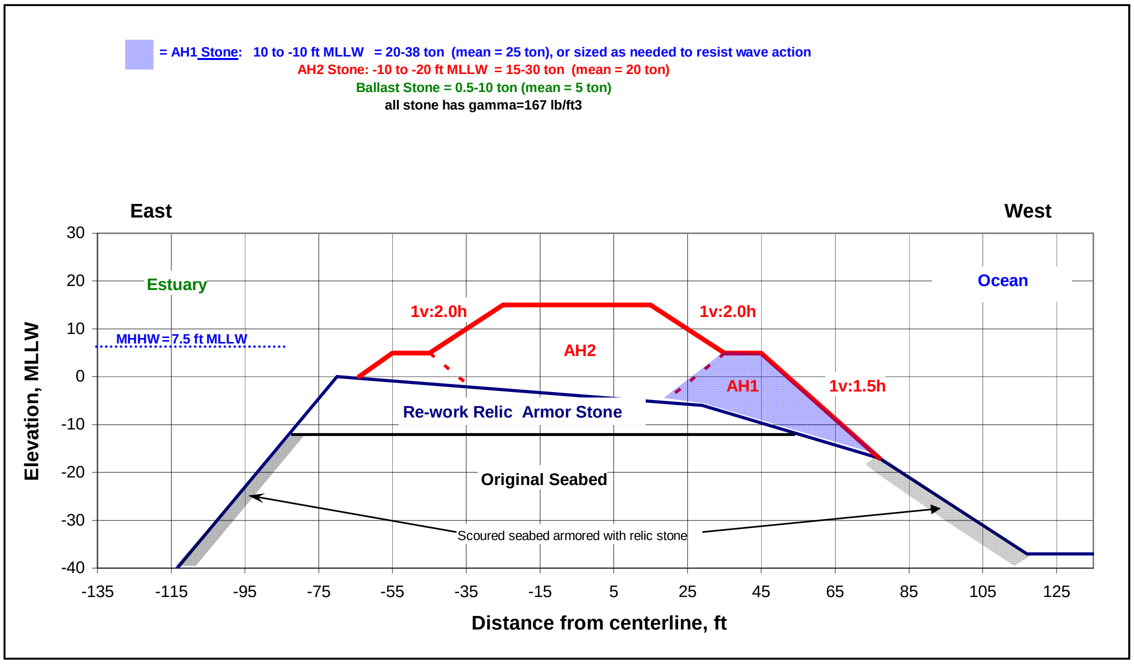
<u>Jetty A Head Capping</u>. An armor stone cap of approximately 24,000 tons (~ 15,000 cy) or equivalent concrete armor units will be placed on the head of the Jetty A to stop its deterioration (Table 4 and Figures 10, above, and Figure 12, below). As with the North and South Jetties, the stone to be placed on the head of Jetty A has been divided into elevation zones. Approximately 7,920 cy of rock will be placed above MHHW. This represents 44% of the overall stone placement on this portion of Jetty A. Approximately 4,740 cy of rock will be placed between MHHW and MLLW. This represents 26% of the overall stone placement on this portion of Jetty A. Approximately 5,420 cy of rock will be placed below MLLW. This represents 30% of the overall stone placement on this portion of Jetty A.

All proposed stone placement will occur on existing base relic stone that formed the original jetty cross-section and was displaced and flattened by wave action, and does not include any modification that changes the character or increases the scope or size of the original structure design. The footprint of the existing jetty mound on the flattened relic stone is approximately 0.64 acres, and the additional capping on the relic stone increases the width of the prism approximately 0.09 acres, for a total footprint of 0.73 acres on the existing relic stone.

Table 4. Jetty A head cap features.

Features	Jetty A
Location of cap	Stations 91 to 93
Timing of construction	2015
Dimensions of cap: length x width x height (feet)	200 x 160 x 40 (0.73 acres)
Stone size	30 to 40 tons
Area affected (outside relic stone)	None
% of cap constructed on relic stone	100%
Construction method	Land-based crane

Figure 12. Detailed representative cross-section for the Jetty A head capping.



Construction Measures and Implementation Activities

<u>Construction Schedule and Timing.</u> The preferred in-water work window for the Columbia River estuary at the mouth according to the Oregon Department of Fish and Wildlife is November 1 to February 28. However, seasonal inclement weather and sea conditions preclude safe, in-water working conditions during this timeframe. Therefore, it is likely that most of the in-water work for constructing spur groins, head capping, cross-section repairs, constructing off-loading facilities, *etc.* will occur outside this period, between April and October.

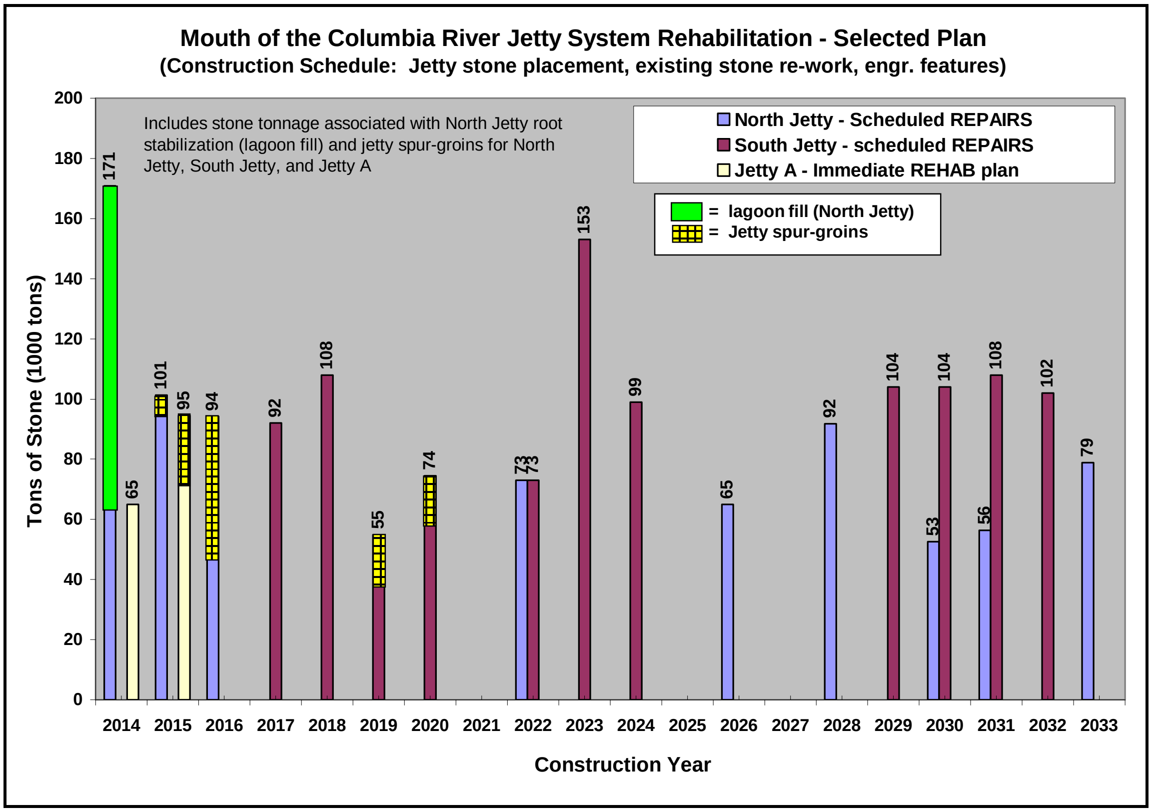
Most landward work on the Jetties will be occurring from April through October. Work on the more exposed sections of the Jetties is likely to occur from June through October. Placement work may extend beyond these windows if weather and wave conditions are conducive to safe construction and rock delivery. Rock delivery by land or water could occur year-round, depending on delivery location and weather breaks. Barge delivery would most likely occur during the months of April through October or at other times of the year depending on breaks in the weather and which jetty is being used. Quarrying of the rock may be limited to the months of April through October depending on the regulations pertinent to each quarry.

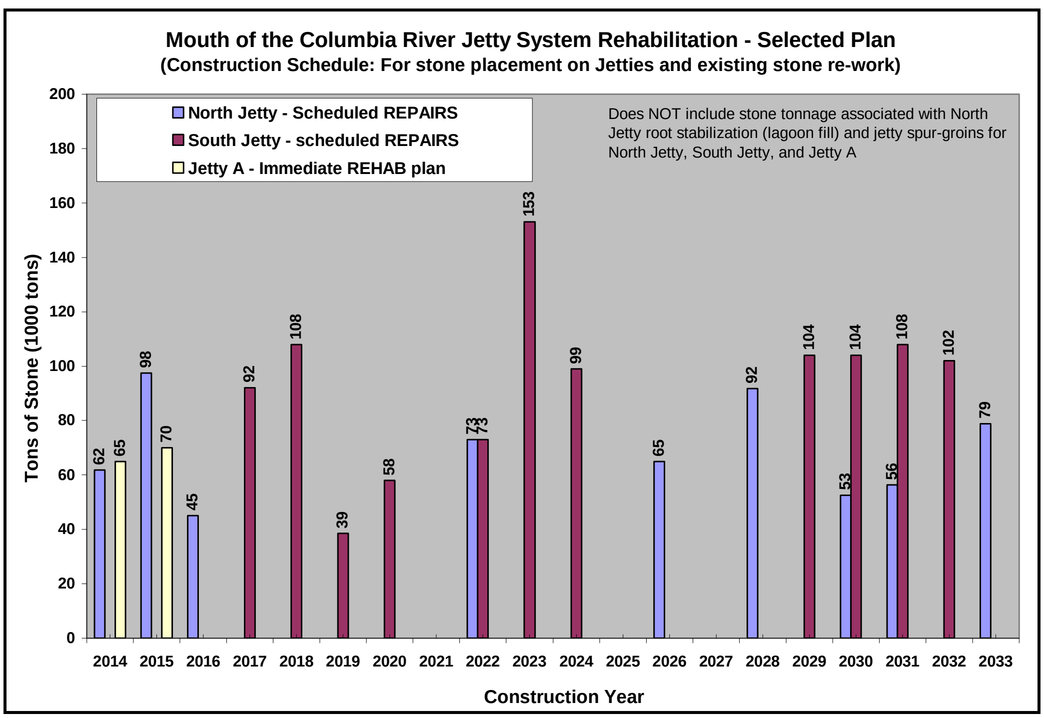
Work elements fall into four general categories for scheduling: (1) Rock procurement, quarrying, and delivery transport; (2) construction site preparation; (3) lagoon fill and dune augmentations; and (4) jetty repair and rehabilitation work with construction of the design features including head capping and spur groins. Site preparation would consist of the preparation of the rock stockpile storage and staging areas, as well as the construction of any barge-offloading facilities that may be required. The majority of the jetty rehabilitation work is expected to be conducted from the top of the jetty downward using an excavator or a crane.

For design and cost-benefit estimates, the project was modeled and designed for a 50-year operational lifespan. The schedule shown in Figures 13 and 14 illustrates construction actions at any one or some combination of all three of the Jetties for the duration of 20 years. Those figures also include a predicted schedule of repair actions that the Corps' model estimates will be necessary within that same time period. Additional repairs have also been predicted to occur after the initial 20-year construction schedule and within the 50-year lifespan of the project. Additional repairs beyond the 20-year schedule will be similar in scale and nature to those described above in the standard repair template. As previously explained, repair actions are generally triggered when a cross-section of the jetty falls below approximately 30 to 40% of the standard repair template profile. The schedule described further in the narrative is a combined reflection of constructing specific engineered features and forecasting needed repairs. Real-time implementation of repair actions will likely vary based on evolving conditions at the Jetties and could be shifted within and beyond this 20-year construction schedule.

In the construction schedule, rock production and stockpiling material is proposed to begin in 2013. The first jetty installation is scheduled for late spring 2014 and continues through 2033. The estimate assumes that the work will be accomplished with multi-year contracts.

Figures 13 and 14. Construction schedules for the rehabilitation of the MCR jetties.





Construction Sequence and General Schedule

Rock procurement will be initiated for the North Jetty repair in 2013. In 2014, the on-site work will begin with filling the lagoon area behind the North Jetty root (stations 20 to 60) and installing a culvert to divert overland flow to another area that will not impact the North Jetty root stability. The lagoon area will be filled with rock, gravel, and sand. Once the lagoon is filled, the filled portion will serve as a staging and stockpile area for the rock delivered to the North Jetty site. To control further head recession of the North Jetty, in 2014 construction will focus on reconstructing the jetty head (station 88 to 99). This work will require haul road construction on top of the jetty from station 70 out to the head requiring approximately 31,000 tons of rock. The North Jetty will require installing a barge offloading facility on the channel side of the jetty at approximately station 45+00. Dredging of 30,000 cy is anticipated to provide the minimum 25-ft working clearance. Concurrently, work will begin on Jetty A beginning with constructing the off-loading facility, 60,000 cy of dredging to accommodate the rock delivery by barge, and constructing the jetty crest haul road from station 40+00 to 80+00. Total new stone for 2013 would consist of approximately 50,000 tons of imported rock.

In 2015, construction will continue on the North Jetty head from station 99 to 101 and installation of one spur groin at station 50 on the channel side. The haul road will need to be reworked with approximately 26,000 tons of new topping material. Work will occur concurrently with Jetty A beginning with 60,000 cy of dredging, completion of the jetty crest haul road from station 80 to 93, and installation of two spur groins. Total new stone for 2015 would consist of approximately 160,000 tons of imported rock. Work on Jetty A is likely to be completed in the same year.

In 2016, work will continue on the North Jetty with the placement of 36,000 tons of large armor near the head at station 80 to 88. This will require refurbishing the haul road and building vehicle turnouts. In addition, three spur groins will be installed at station 70-C, 80-O, and 90-C with a total of 50,000 tons of new stone. Total new stone will consist of approximately 86,000 tons of imported rock, equivalent to 2,900 trucks or 13 barges. Site preparation work and stockpiling stone at the South Jetty will occur to prepare staging and stockpile areas for 2017 construction.

In 2017, construction on the South Jetty is projected to begin, starting with construction work near the head from stations 173 to 176 and 180 to 195. South Jetty construction will require either a haul road be constructed on top of the jetty or constructed from a marine plant in order to get out to the head. Total work effort in 2017 is projected to consist of approximately 74,000 tons of rock; equivalent to 2,500 trucks or 12 barges.

Work will continue on the South Jetty for the next 3 years, working towards the head in 2018 with a total of 86,000 tons of new armor at station 290 to 311. Head construction will begin in 2019 with 30,000 tons of new head armor and installation of 4 spur groins at stations 165–O, 210-C, 230-C, and 265-C for a total of 9,000 tons of spur groin rock. The South Jetty head is anticipated to be completed in 2020 with 44,000 tons of new stone.

In 2022, construction is projected to occur concurrently on the North and South jetties: (1) North Jetty stone placement at station 40 to 45 and station 65 to 73; and (2) stone placement on the

South Jetty at station 160 to 163, station 170 to 173, station 176 to 180, and station 195 to 200. Total rock tonnage for 2022 was estimated to be 115,000 tons.

In 2023, construction will continue on the South Jetty with the placement of approximately 118,000 tons of rock between stations 205 to 250. The haul road will need to be reworked with approximately 62,000 tons of quarry stone road base and topping material.

In 2024, construction will continue on the South Jetty with the placement of approximately 76,000 tons of rock between stations 270 to 290.

In 2026, construction would resume on the North Jetty with the placement of approximately 52,000 tons of rock between stations 20 to 30. The long time frame from the previous construction on the North Jetty will also require rebuilding the jetty haul road from station 20 to 30.

In 2030, construction is projected to occur on the North and South jetties: (1) North Jetty stone placement at station 30 to 40; and (2) stone placement on the South Jetty at station 223 to 237, and station 250 to 253. Total rock tonnage proposed to be placed is estimated at 129,000 tons.

In 2031, construction is projected to occur on the North and South jetties: (1) North Jetty stone placement at station 88 to 99; and (2) stone placement on the South Jetty at station 253 to 270. The North Jetty haul road will need to be re-built from station 65 to 99 and will require 30,000 tons of quarry waste material. Total armor stone rock tonnage proposed to be placed is estimated at 135,000 tons.

In 2032, construction will continue on the South Jetty with the placement of approximately 85,000 tons of rock between stations 295 to 311. Total rock tonnage proposed to be placed would require 2,850 trucks or 13 barge loads. The offloading facility will be removed and scheduled construction will be complete for the South Jetty.

The final anticipated year of North Jetty rehabilitation is projected to be the year 2033, when construction is completed at stations 80 to 88. Total rock tonnage estimated to be 63,000 tons, equivalent to 2,100 trucks or 10 barge loads. When the offloading facility is removed scheduled construction will be complete for the North Jetty.

Because construction at the North and South jetties is spaced out from 2014 through 2033 with intermittent work, dredging at the barge offloading sites will only be required prior to a year of actual rock delivery in preparation for upcoming construction work. The Jetty A barge offloading site will only require dredging to make that site accessible for 2 years. Dredging will only be needed if the clearance depth at the barge offloading site is not found to be adequate prior to rock delivery activities.

Sources and Transportation of Rock

Rock Quarries and Transport. It is not yet known where jetty rock will come from and how it will be transported to the jetty sites. However, one or more of the options discussed below would be employed (Figure 15 and Table 5). Stone sources located within 150 miles of a jetty are likely to be transported by truck directly to the jetty. Stone sources located at further distances, especially if they are located near waterways, are likely to be transported by truck to a barge on-loading facility, then transported by tug and barge to either a government-provided or commercial barge offloading site located nearby. Railway may also be an option for transporting stone, provided that an on-loading site is convenient to the quarry.

The Corps intends to use operating quarries rather than opening any new quarries. The contractor and quarry owner/operator will be responsible for ensuring that quarries selected for use are appropriately permitted and in environmental compliance with all State and Federal laws.

Canadian Quarries. Quarries in British Columbia are typically located adjacent to waterways and rock produced from these quarries will likely have a limited truck haul. Due to the long distance to the MCR, plus the immediate availability to deep water, rock would likely be loaded onto barges and shipped down the Washington Coast to barge offloading sites.

Washington Quarries. Quarries located in northern Washington are typically not on the water, but are generally located within 50 miles of a potential barge on-loading site. As a result, rock would need to be hauled, at least initially, by truck. Rock would be transported by trucks most likely to a barge on-loading facility or possibly all the way to the staging site at the jetty. Once the rock is loaded on barges, it would be transported down the coast to barge offloading sites.

It also is possible that railway systems may be used to transport rock much of the way to the Jetties. Burlington Northern Railroad operates a rail system that parallels Interstate 5 throughout Washington which would be the most likely route rock would be transported. Rock from the quarry would be taken by truck to a nearby railway station where they would be loaded onto railway cars and transported to an intermediate staging area. Trucks would then again take the rock the remainder of the way to the jetty staging areas.

Rock located within southern Washington would likely be trucked to the jetty staging areas. An exception to this would be a quarry that occurs within just a few miles of a port on the Washington Coast or a quarry that is near the Columbia River. In either of these two barge possibilities, rock would be delivered by truck to a barge on-loading facility, loaded on oceangoing or riverine barges, and delivered to one of the barge offloading facilities (see section on barge offloading facilities below). Truck hauling of rock from this area to the Jetties would be as described above.

Oregon Quarries. Rock located in northern Oregon within 50 miles of the North Jetty and Jetty A would likely utilize any of the main roads over to Highway 101 or Highway 30. From this point they would cross the Astoria-Megler Bridge and proceed west through Ilwaco to the jetty staging areas. Quarries exceeding 50 miles from the Jetties would likely utilize main roads at a farther distance from the jetty sites. This would involve longer haul distances on Highways 101, 30, 26, and others before crossing the Astoria-Megler Bridge and proceeding to the staging areas.

Truck hauling of rock from quarries within 50 miles of the South Jetty will most likely use any of the main roads over to Highway 101 or Highway 30. From this point they would proceed through Astoria and Warrenton, or Seaside and Gearhart to local roads leading to Fort Stevens State Park and the jetty staging areas. Quarries exceeding 50 miles from the jetty would likely utilize main roads at a farther distance from the jetty site. This would involve longer haul distances on Highways 101, 30, 26, and others before going through Astoria and Warrenton, or Seaside and Gearhart to local roads leading into Fort Stevens State Park and the staging areas.

The likely mode of transportation from southern Oregon quarries is trucking, or a combination of trucking and barging. Many of the quarries may be near the Oregon Coast; however, they may not be near a port facility that has barge on-loading capability. Providing that barge facilities are available, rock located south of Waldport would be loaded at the quarry onto trucks and traverse main public roads to the barge on-loading site, loaded on ocean-going barges, and shipped up the Oregon Coast to one of the barge offloading facilities (see section on barge offloading facilities below). Quarries north of Waldport would most likely be hauled by truck the entire distance.

Southern Oregon rock sources requiring trucking would be loaded onto lowboy trucks one to three at a time and would traverse main roads to more main arterials such as Highway 101 or, to a lesser degree, Interstate 5. An effort would be made to use the least distance possible to transport the rock without sacrificing transport time.

California Quarries. For northern California quarries, there would be a very long haul distance required to get rock to the jetty repair areas. Barging of rock would be the only economically feasible option. Rock would be transferred by truck from the quarries along main roads leading to Highway 101 to a barge offloading facility.

Figure 15. Potential quarry locations (red dots) for repairs to MCR Jetties. See corresponding quarry information in Table 5.

Table 5. Potential quarry and rock transport information. See Figure 27 for site map.

No.	Quarry	County and State	Nearest City	Road Miles from MCR	Unit Weight (pcf)	Reserves Available (tons)	Likely Transportation Method	Nearest Barge Facility
1	Columbia Granite Quarry	Thurston, WA	Vail, WA	129	168.5	28 M	Truck	N/A
2	Beaver Lake Quarry	Skagit, WA	Clear Lake, WA	251	181.1	1.86 M	Truck, then Barge	Anacortes, WA
3	Texada Quarry	BC, CANADA	Texada Island, BC	363	173.5+	275 M	Barge	Onsite
4	Stave Lake Quarry	BC, CANADA	Mission, BC	311	169.1	74 M	Truck, then Barge	Mission, BC, Canada
5	192nd Street Quarry	Clark, WA	Camas, WA	109	168.5	0.5 M	Truck/Barge	Camas, WA
6	Iron Mountain Quarry	Snohomish, WA	Granite Falls, WA	225	174	Unknown	Truck	N/A
7	Marble Mount Quarry	Skagit, WA	Concrete, WA	276	189.7	2 M	Truck, then Barge	Anacortes, WA
8	Youngs River Falls Quarry	Clatsop, OR	Astoria, OR	20	181.8	0.5 M+	Truck	N/A
9	Liscomb Hill Quarry	Humboldt, CA	Willow Creek, CA	515	179.1	0.5 M	Truck, then Barge	Eureka, CA
10	Baker Creek Quarry	Coos, OR	Powers, OR	275	200	Unknown	Truck, then Barge	Coos Bay, OR
11	Phipps Quarry	Cowlitz, WA	Castle Rock, WA	69	167.4	0.5 M	Truck	N/A
12	Cox Station Quarry	BC, CANADA	Abbotsford, BC	313	167.9	150 M	Barge	Onsite
13	Ekset Quarry	BC, CANADA	Mission, BC	309	172.2	10 M	Truck, then Barge	Mission, BC, Canada
14	Fisher Quarry	Clark, WA	Camas, WA	108	168.5	2 M	Barge	Camas, WA
15	Bankus Quarry	Curry, OR	Brookings, OR	347	183 & 195	0.7M	Truck, then Barge	Crescent City, CA

For water-based delivery of rock, a tow boat and barge would deliver the rock to the channel side of the Jetties where water depth, waves, and current conditions permit. During rock offloading, the barge may be secured to approximately 4 to 8 temporary dolphins/H-piles to be constructed within 200 feet of the jetty. Rock would be off-loaded from the barge by a land- or water-based crane and either placed directly within the jetty work area or stock piled on the jetty crest for subsequent placement at a later time.

For land-based delivery of rock, jetty access for rock hauling trucks would be via an existing paved road to the Benson Beach parking lot at Cape Disappointment State Park (North Jetty) and via an existing paved road to the parking lots C and D at the South Jetty. An existing overland route between Jetty A and North Jetty may also be used for land-based hauling. Work areas for delivery of rock, maneuvering of equipment, and stockpiling of rock near the Jetties have been identified and are shown in Figures 16, 17, and 18.

Barge Offloading Facilities

Stone delivery by water could require up to four barge offloading facilities that allow ships to unload cargo onto the jetty so that it can then be placed or stockpiled for later sorting and placement. The range of locations for these facilities is shown in Figures 16, 17, and 18. Depending on site-specific circumstances, offloading facilities may be converted to spur groins, may be partially removed and rebuilt, may be permanently removed, or may remain as permanent facilities upon project completion. Facility removal will depend on access needs and evolving hydraulic, wave, and jetty cross-section conditions at each offloading locations.

Facilities will range from approximately 200- to 5000-ft long (parallel to the jetty) and 20- to 50-ft wide (perpendicular to jetty), which ranges from about 0.48 to 2.41 acres in total area. For initial construction of all four facilities combined, approximately up to 96 Z- or H-piles could be installed as dolphins, and up to 373 sections of Z- or H-piles to retain rock fill. All piles will be between 12 and 16 inches in diameter. Facilities will have a 15 feet NGVD crest elevation and will be installed at channel depths between -20 and -30 NGVD. A vibratory hammer will be used for pile installation, and only untreated wood or steel piles will be used. Removal and replacement of the facilities could occur within the duration of the construction schedule. Volume and acreage of fill for these facilities are shown in Table 6.

Table 6. Approximate rock volume and area of barge offloading facilities and causeways.

Location	Approximate Length (ft)	Approximate Rock Volume (cy) Below 0 MLLW	Total Approximate Rock Volume (cy)	Approximate Square Feet	Acres
North Jetty	200	7,778	29,640 cy	21,000	0.48
Jetty A – near head	200	7,778	29,640 cy	21,000	0.48
Jetty A – mid-section causeway	5000	38,888	38,888	105,000	2.41
South Jetty – Parking Area D	450	17,417	33,688 cy	47,250	1.08
South Jetty – Along Jetty Turn-out	200		18,640 cy	21,000	0.48

Figure 16. North Jetty offloading, staging, storage and causeway facilities.

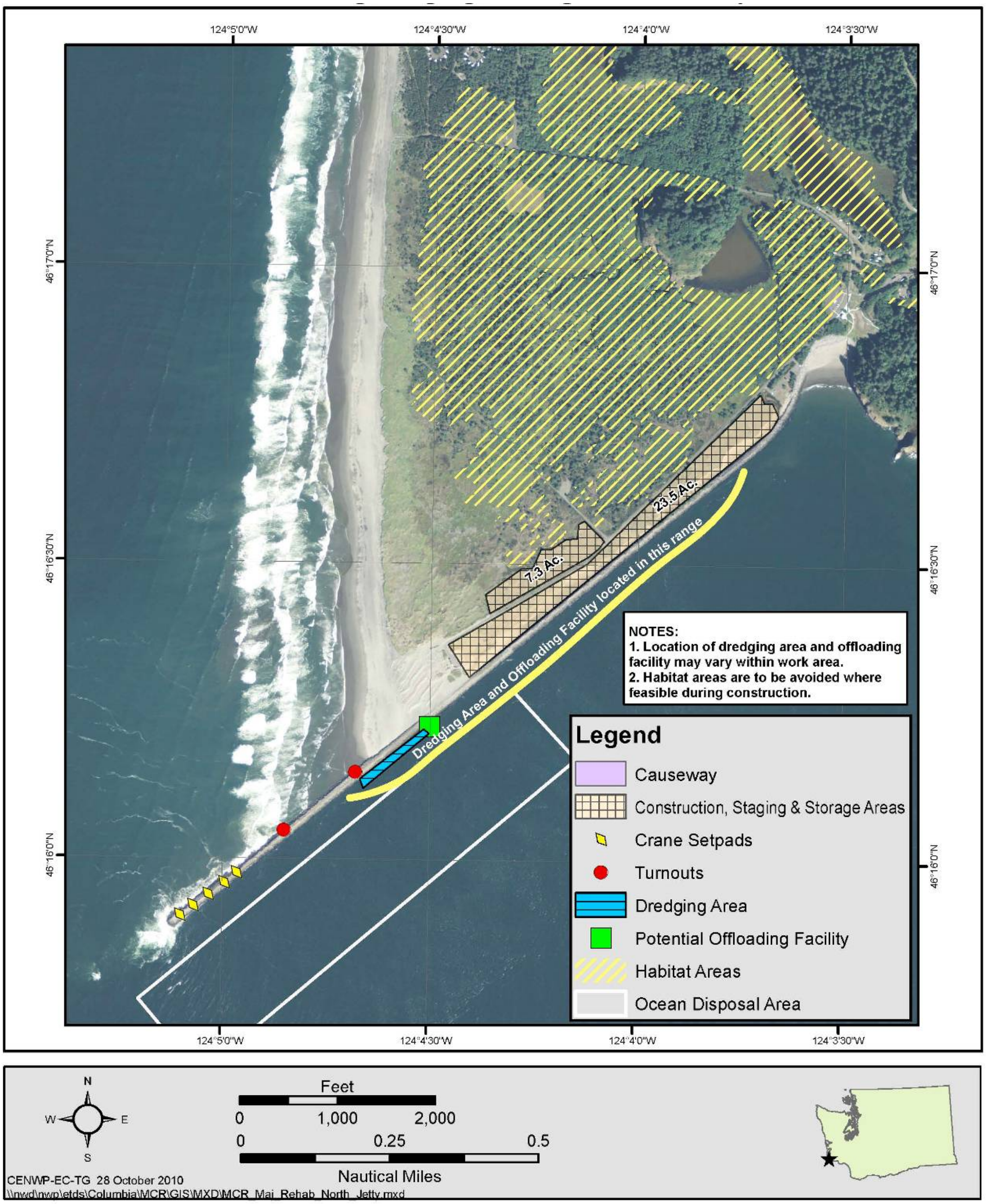


Figure 17. South Jetty offloading, staging, storage and causeway facilities.

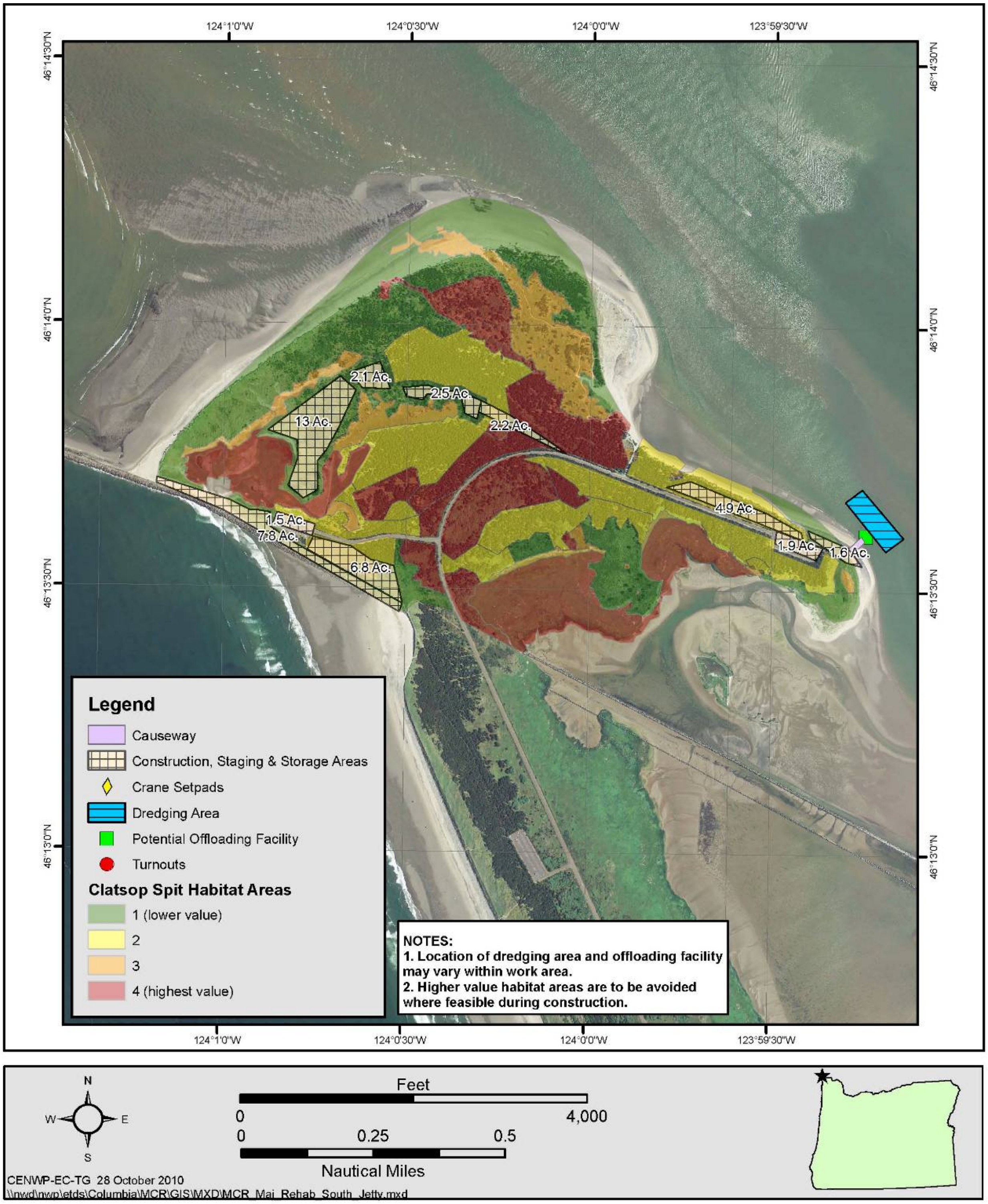


Figure 17 (continued). South Jetty offloading, staging, storage and causeway facilities.

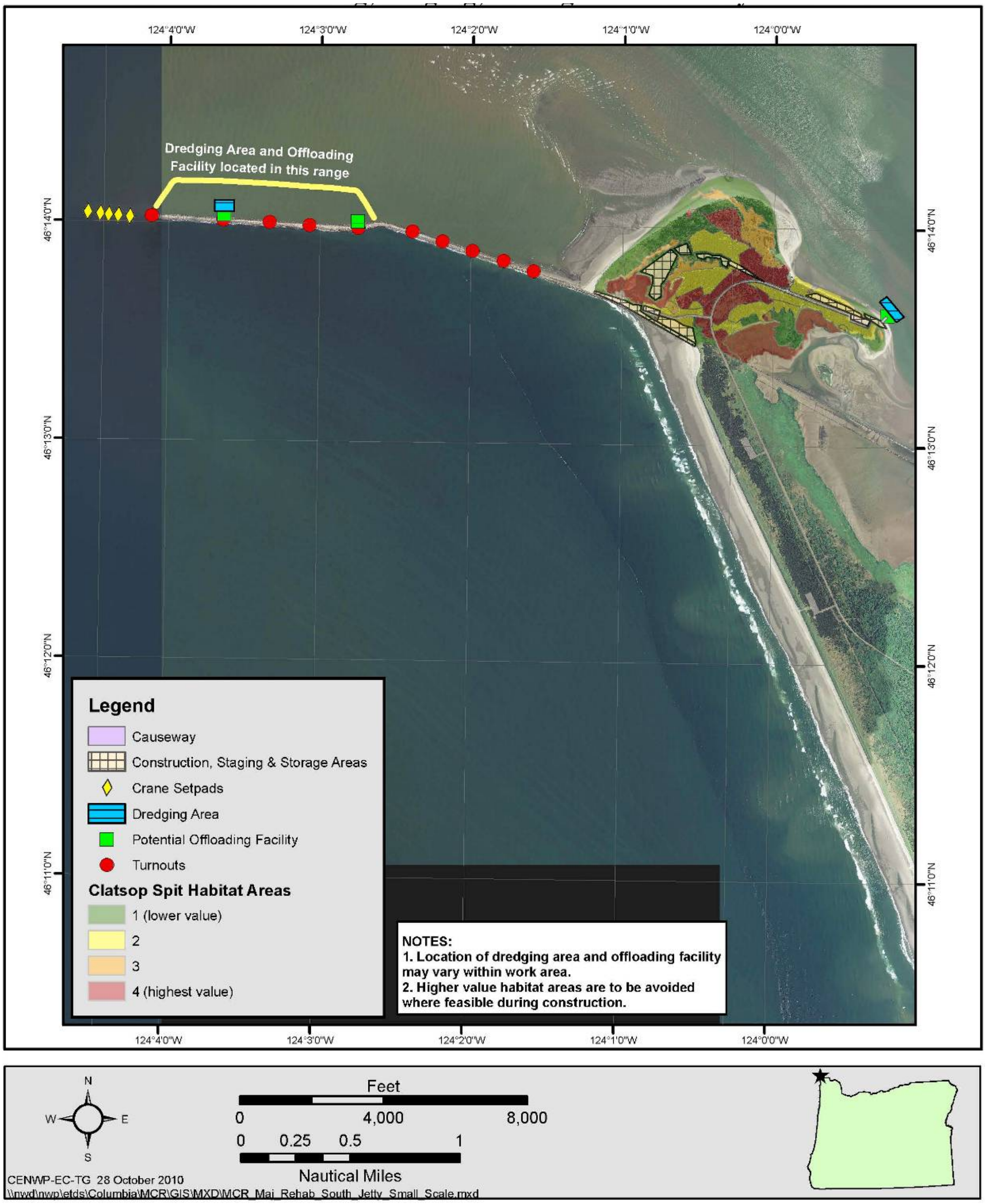
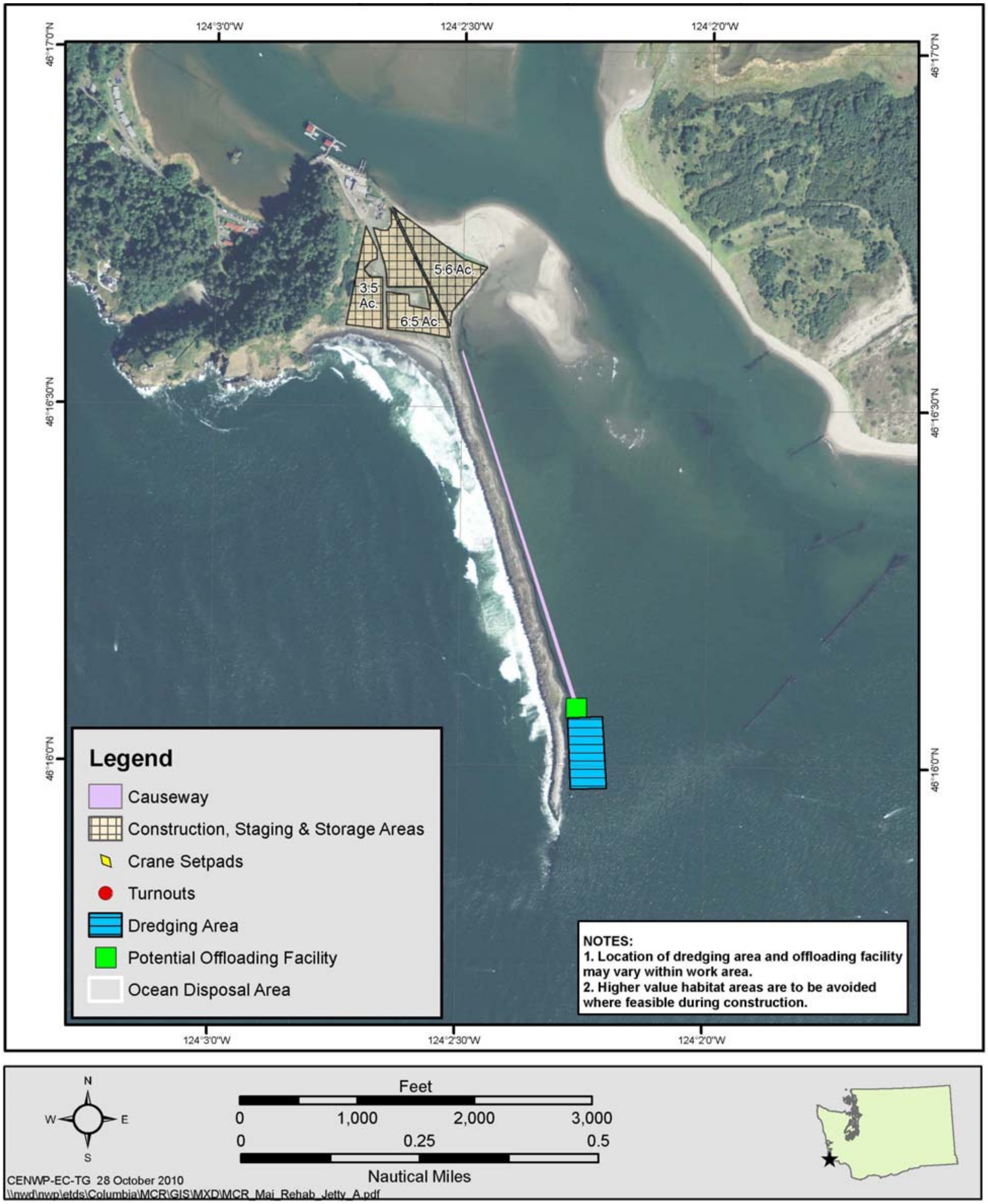


Figure 18. Jetty A offloading, staging, storage and causeway facilities.



The following existing private facilities may serve as potential offloading sites depending on availability for Corps' use:

- Commercial Site in Ilwaco. For the North Jetty, barges would pull up to a dock at Ilwaco where rock would be transferred by crane onto trucks that would proceed by public road to Cape Disappointment State Park. Trucks would then pass through the park grounds to the staging area adjacent to the jetty. For Jetty A, trucks would proceed through the Coast Guard facility to the staging area near the root of the jetty.

- Commercial Site in Warrenton. Nygaard Logging has a deep-water offloading site that could be used to offload rock. For the North Jetty/Jetty A. This site needs no improvement to accommodate deep-draft vessels.

If existing facilities are not available or do not have adequate capacity to provide access, barge offloading facilities could be constructed at each jetty, as described below:

- North Jetty: Between or on the spur groin at/between Station 50 or 70, a barge offloading facility will be constructed. If wave conditions make it feasible, the spur groin designed for this area will first function as an offloading facility prior to conversion and stone removal to reach the spur's design depth. Otherwise, a separate facility will be installed in the reach between these two stations such that wave conditions allow safe offloading. This offloading facility will require 4-8 dolphins of 3 piles each for vessel tie-up, and sheet-pile installation will be required to shore-up and retain rock at the offloading point.

- Jetty A: An offloading facility will be sited near the location of the proposed spur groin around Station 81, at the upstream portion of the jetty near the head. A 15-ft causeway will also be constructed along the entire length of the jetty on existing relic stone that runs adjacent to and abutting the upstream eastern portion of the jetty. This facility will likely remain a permanent facility, but may deteriorate due to wave and tidal action. This offloading facility will require 4-8 dolphins of 3 piles each for vessel tie-up, and sheet-pile installation will be required to shore-up and retain rock at offloading point.

- South Jetty: The South Jetty could have up to two associated offloading sites. One will be located at parking lot area D near the northeastern-most corner of the Spit. The second facility will be located along the jetty and will resemble an extra-large turn-out facility. It is likely to be located somewhere on the northern, channel-side of the jetty and west of Station 270 to take advantage of deeper bathymetry and subsequently less need for dredging. The facility at parking lot area D may be removed after 5 or more years depending on hydraulic impacts of the structure and spit. The facility along the jetty will likely be partially removed and rebuilt after each repair to avoid the potential for wave-focusing on the jetty. Otherwise, it will remain in place until around 2033. Each offloading facility will require 4-8 dolphins of 3 piles each for vessel tie-up, and sheet-pile installation will be required to shore-up and retain rock at offloading point.

Dredging for Barge Offloading Facilities. Transport of rock would most likely be done by ocean-going barges that require deeper draft (20-22 feet) and bottom clearance than river-going barges when fully loaded. Therefore, dredging will be required to develop each of the barge offloading facilities. Under-keel clearance should be no less than 2 feet. The elevation at barge offloading sites should have access to navigable waters and a dredge prism with a finish depth no higher than -25 feet MLLW, with advance maintenance and disturbance zone depths not to extend below -32 feet MLLW. These facilities should also provide for a maneuvering footprint of approximately 400 feet x 400 feet. The depth along the barge unloading sites would be maintained during the active period for which the rock barges will be unloaded.

Subsequently, periodic maintenance may be required as facilities weather wave and current conditions at the MCR. Facilities may also occasionally be partially removed and reconstructed, which could slightly increase the frequency of disturbance. Depending on the specific facility and contemporary conditions at the time, removal would then occur at the end of the scheduled construction duration. Temporally, this limits the repetition of disturbance activities associated with the construction of these facilities. Use of the facilities may be annual with periodic breaks in between, depending on the construction schedule and conditions at the Jetties. Annual use is likely at one or more of the facilities and will be seasonally concentrated in the spring, summer, and fall. Though unlikely, occasional breaks in weather could allow offloading at other times of the year.

A clamshell dredge would likely be used for all dredging, though there is a small chance that a pipeline dredge could be feasible but is unlikely to be used. The material to be dredged is medium to fine-grained sand, typical of MCR marine sands. Disposal of material would occur in-water at an existing, approved disposal site. The volume of material to be dredged is shown in Table 7; these estimates are based on current bed morphology and may change. Also, maintenance dredging to a finish depth of -25 feet MLLW will be needed before offloading during each year of construction. Dredging is likely to occur on a nearly annual basis for the duration of the project construction period, but this will be intermittent per jetty, depending on which one is scheduled for construction in a particular year.

Table 7. Estimated dredging volumes for barge offloading facilities.

Location*	Estimated Dredging Volume (cy)		Approximate Acres
	Initial	Est. Maintenance**	
North Jetty	30,000	30,000	3.73
Jetty A	60,000	80,000	3.73
South Jetty	20,000	20,000	4.19
South Jetty - Parking Area D	20,000	20,000	4.19

* Some of the locations will not be used on an annual basis; it depends on the construction schedule for each jetty.
**All dredging will be based on surveys that indicate depths shallower than -25 feet MLLW.

Clamshell dredging will be done using a bucket operated from a crane or derrick that is mounted on a barge or operated from shore. Sediment removed from the bucket is generally placed on a barge before disposal. This type of dredge is typically used in shallow-water areas.

The following overall impact minimization practices and best management practices (BMPs) will be used for all maintenance dredging for offloading facilities:

1. To reduce the potential for entrainment of juvenile salmon or green sturgeon, the cutterheads will remain on the bottom to the greatest extent possible and only be raised 3 feet off the bottom when necessary for dredge operations.
2. To reduce turbidity, if a clamshell bucket is used, all digging passes shall be completed without any material, once in the bucket, being returned to the wetted area. No dumping of partial or half-full buckets of material back into the project area will be allowed. No dredging of holes or sumps below minimum depth and subsequent redistribution of sediment by dredging dragging or other means will be allowed. All turbidity monitoring will comply with the state of Oregon's 401 water quality certification conditions.
3. If the captain or crew operating the dredges observes any kind of sheen or other indication of contaminants, he/she will immediately stop dredging and notify the Corps' environmental staff to determine appropriate action.
4. If routine or other sediment sampling determines that dredged material is not acceptable for unconfined, in-water placement, then a suitable alternative disposal plan will be developed in cooperation with the NMFS, EPA, Oregon Department of Environmental Quality (ODEQ), Washington Department of Ecology (WDOE), and other agencies.

Dredged Material Disposal Sites. Two dredged material disposal sites, the shallow-water site (SWS) and the North Jetty site, are located near the North Jetty. These are the most likely sites to be used for the proposed action. Modeling (BA) has showed that the potential changes to the two disposal sites from the proposed action would not inhibit their use as disposal sites. Spur groin construction at the North Jetty would avoid the North Jetty disposal site. The northern-most cells of this site immediately adjacent to the jetty will be avoided to reduce the possibility of vessel impact with the spur groins.

Pile Installation and Removal

For initial construction of all four facilities combined, approximately up to 96 Z- or H-piles could be installed as dolphins, and up to 373 sections of sheet pile to retain rock fill. All piles will be between 12 and 16 inches in diameter. As mentioned earlier, inclement weather and sea conditions during the preferred in-water work window (IWWW) preclude safe working conditions during this time period. Therefore, installation of piles is most likely to occur outside the IWWW. Pile installation and subsequent removal is likely to occur once, likely in the late spring or early summer prior to or during the first season of construction on the associated jetty. The Portland District Corps of Engineers has proposed to prohibit installation of pilings associated with the major rehabilitation of the jetty system at the Mouth of the Columbia River until on or after May 1 of each year during construction of the proposed action. The change was made to prevent pile driving effects on Southern Resident Killer Whales that have been known to visit the MCR region in March or April. Subsequently, periodic maintenance may be required as piles weather barge use and wave and current conditions at the MCR. Piles may also occasionally be partially removed and installed, which could slightly increase the frequency of disturbance.

The piles will be located within 200 feet of the jetty structure. Because the sediments in the region are soft (sand), use of a vibratory driver to install piles is feasible and the only pile driving method that Corps is proposing. The presence of relic stone may require locating the piling further from the jetty so that use of this method is not precluded by the existing stone. The dolphins/Z- and H-piles would be composed of either untreated timber or steel piles installed to a depth of approximately 15 to 25 feet below grade in order to withstand the needs of off-loading barges and heavy construction equipment. Because vibratory hammers will be implemented in areas with current velocities greater than 1.6 feet/second, the need for hydroacoustic attenuation is not an anticipated issue. Piling will be fitted with pointed caps to prevent perching by piscivorous birds to minimize opportunities for avian predation on listed species. Some of the pilings and offloading facilities may be removed at the end of the construction period.

Rock Placement

Placement of armor stone and jetty rock on the MCR jetties would be accomplished by land or limited water-based equipment. Only clean stone will be used for rock placement, where appropriate and feasible. Where appropriate, there may also be some re-working and reuse of the existing relic and jetty prism stone. Fill for the jetty haul roads will not be cleaned prior to installation. Dropping armor stone from a height greater than 2 feet will be prohibited. During placement there is a very small chance of stone slippage down the slope of the jetty. However, this is unlikely to occur due to the size and cost of materials and placement.

A jack-up barge may also be used to do water-based rock placement. This would only be applicable at the South Jetty. For armor stone and rock placement at the head, a jack-up barge with crane could be used to serve as a stable work platform. Once into place, the jack-up barge would be jacked up on six legs so that the deck is at the same elevation as the jetty. The legs are designed to use high-pressure water spray from the end of the legs to agitate the sand and sink the legs under their own weight. The jacking process does not use any lubricants that contain oils, grease, and/or other hydrocarbons. The stone and rock will be barged to the jackup barge and offloaded onto the jetty head. The jackup barge will keep moving around the head of the jetty to complete the work. A jack-up barge would not be used on the North Jetty or Jetty A to avoid interference with navigation of fishing boats and crab and fish migrations.

For land-based rock placement, a crane or a large track-hoe excavator could be situated on top of the jetty. The placement operation would require construction of a haul road along the jetty crest within the proposed work area limits. The crane or excavator would use the haul road to move along the top of jetty. Rock would be supplied to the land-based placement operation by land and/or marine-based rock delivery. For marine-based rock, the land-based crane or excavator would pick up rock directly from the barge or from a site on the jetty where rock was previously offloaded and stockpiled, and then place the rock within the work area. For land-based rock, the crane or excavator would supply rock via a truck that transports rock from the stockpile area. The crane or excavator would advance along the top of the jetty via the haul road as the work is completed.

In order to place stones, a haul road will be constructed on the 30-foot crest width of each jetty to allow crane and construction vehicle access. Roads will consist of an additional 3 feet of top fill material, which could also entail an additional 2 feet of width spill-over. These roads will remain in place for the duration of construction. Due to ocean conditions and the wave environment, these roads will likely need yearly repair and replacement. They will not be removed upon completion. Ramps from the beach up to the jetty road will also be constructed to provide access at each jetty.

At approximately 1,000-foot intervals, turnouts to allow equipment access and passage will be constructed on the North and South jetties. These will consist of 50-foot long sections that are an additional 20 feet wide. Some of this stone for these facilities may encroach below MLLW. On the North Jetty, there will be approximately two turnouts. South Jetty will have approximately eight turnouts with two additional larger-sized turnouts. These larger turnouts will be in the range of 300 feet long with an additional 20-foot width. One of these larger turnouts will function as an offloading facility on South Jetty. At Jetty A, the causeway will function as the turnout facility.

Towards the head of each jetty, additional crane set up pads will be constructed at approximately 40-foot increments to allow crane operation during the placement of the larger capping stones. Set-up pads will roughly entail the addition of 8 extra feet on each side of the crest for a length of about 50 feet. Some of this stone for these facilities may encroach below MLLW. Approximately five set-up pads will be required to construct each jetty head.

Construction Staging, Storage, and Rock Stock Piles

Jetty repairs and associated construction elements would entail additional footprints for activities involving equipment and supply staging and storage, parking areas, access roads, scales, general yard requirements, and rock stock pile areas. For the most efficient work flow and placement, a 2-year rock supply would be maintained on site and would be continuously replenished as placement occurred on each jetty. In order to estimate the area needed, a surrogate area was determined for a reference volume of 8,000 cy, which was then used to extrapolate the area needed at each jetty. These results are shown in Table 8.

Table 8. Acreages needed for construction staging, storage, and rock stock piles.

Location	Approximate Acres
North Jetty	31
Jetty A	23
South Jetty	44

Several actions will be taken to avoid and minimize impacts from these activities. Staging and stockpiles will remain above MHHW, and where feasible have also been sited to avoid impacts to wetlands and habitats identified as having higher ecological value. In order to maintain erosive resilience along the shoreline, a vegetative buffer will be preserved. When available and possible, partial use will be made of existing parking lots. Additional measures specific to each jetty have also been considered. Besides access roads in the areas identified in Figures 16, 17 and 18, no additional roadways or significant roadway improvements are anticipated. Some roadway repair and maintenance will likely be required on existing roads experiencing heavy use by the Corps.

At the North Jetty, the lagoon and wetland fill necessary for root stabilization will also serve a dual purpose as for the bulk of staging and storage activities. At the South Jetty, a small spur road will be required to connect the existing road with the proposed staging area and is indicated in Figures 16, 17, and 18. The existing road along the neck of the South Jetty that will be used for dune augmentation work may require minor repair/improvements for equipment access. Construction access to the area receiving dune augmentation will be limited to an existing access road along the relic jetty structures at the neck of the spit. Equipment will be precluded from delivery using the access point from parking lot B in order to avoid impacts to water quality and razor clam beds in the vicinity of the proposed dune fill area. Grading equipment may have to access the area by driving along the shore, but this route will be used as a last resort and equipment will be limited to dry sand where feasible. Additionally, the proposed actions will avoid the more sensitive habitat areas south of parking lot D.

If possible, the project will avoid and minimize impacts to the adjacent marshland by allowing crossing between the construction area and jetty via a Bailey bridge, which may require small removable abutments on either end of the marsh crossing. Otherwise a series of culverts and associated fill will be installed, or equipment will be required to enter and exit from the same access road on the northeast end of the main staging area indicated in Figures 16, 17 and 18.

Additionally, at the outlet of the marsh complex a culvert will be installed under the construction access road, which will allow continuous hydrologic connectivity between affected portions of the marsh and ocean exchange through the jetty. This will also avoid equipment passage through marsh waters. To connect the staging area to the jetty haul road, a temporary gravel access road would be constructed from the staging area nearest the jetty to the jetty crest. The access road would measure approximately 400 feet in length by 25 feet in width, would be above MHHW, would require approximately 4,000 cy of sand, gravel and rip rap, and would require the installation and removal of a temporary culvert near station 178+00 to maintain tidal exchange into and out of the intertidal wetland and through the jetty. The staging areas and haul roads, except for the jetty haul road, would be removed and restored to pre-construction conditions once repairs to the jetty are completed.

Prior to in-water work for installing the construction access road and culverts across the southern portion of the marsh wetland outlet at the South Jetty, the Corps will conduct fish salvage and implement fish exclusion to and from the wetland complex upstream of the proposed culvert. Also, post-installation of the culvert, the Corps will develop and implement fish monitoring as necessary to ensure that no listed fish species are stranded. If listed fish species are found, NMFS will be contacted immediately to determine the appropriate course of action.

For the previous North and South Jetties rehabilitation, the Corps conducted fish monitoring in the marsh wetland at the South Jetty. During monitoring, non-listed species, *e.g.*, threespine stickleback (*Gasterosteus aculeatus*), were observed in the marsh wetland. No salmon, green sturgeon, or eulachon were observed. The NMFS does not expect listed species to occur in the marsh wetland based on previous monitoring information. In addition, the marsh wetland location at the backside of the South Jetty, and the sub-marginal habitat—intermittent wetland with poor water quality and dense algae—make listed species presence unlikely.

At Jetty A, adequate area may not be available for the estimated storage and staging needs. Therefore, construction sequencing will accommodate the supply that can be fit into the acreage available. Land-based delivery options may be precluded due to road access constraints, though some existing access may prove available and feasible depending on load and truck sizes.

The following measures will also be required at each location to further avoid and minimize impacts to species. Before significant alteration of the project area, the project boundaries will be flagged. Sensitive resource areas, including areas below ordinary high water, wetlands and trees to be protected will be flagged. Chain link fencing or something functionally equivalent will likely encircle much of the construction areas.

Temporary Erosion Controls

Temporary erosion controls will be in place before any significant alteration of the site. If necessary, all disturbed areas will be seeded or covered with coir fabric at completion of ground disturbance to provide immediate erosion control. Erosion control materials (and spill response kits) will remain on-site at all times during active construction and disturbance activities (*e.g.*, silt fence, straw bales). If needed these measures will be maintained on the site until permanent ground cover or site landscaping is established and reasonable likelihood of erosion has passed. When permanent ground cover and landscaping is established, temporary erosion prevention and sediment control measures, pollution control measures and turbidity monitoring will be removed from the site, unless otherwise directed.

An erosion sediment and pollution control plan (ESPCP) or stormwater pollution prevention plan (SWPPP), as applicable to each State, will outline facilities and BMPs that will be implemented and installed prior to any ground disturbing activities on the project site, including mobilization. The Corps retains a general 1200-CA permit from Oregon Department of Environmental Quality (DEQ), and will also work with US Environmental Protection Agency (EPA) to obtain use of the NPDES general permit for stormwater discharge from construction activities. At a minimum, these ESCP and SWPPP plans will include the following elements and considerations. Construction discharge water generated on-site (debris, nutrients, sediment and other pollutants) will be treated using the best available technology. Water quality treatments will be designed, installed, and maintained in accordance with manufacturer's recommendation and localized conditions. In addition, the straw wattles, sediment fences, graveled access points, and concrete washouts may be used to control sedimentation and construction discharge water. Construction waste material used or stored on-site will be confined, removed, and disposed of properly. No green concrete, cement grout silt, or sandblasting abrasive will be generated at the site.

Emergency Response

To avoid the need for emergency response, a Corps Government Quality Assurance Representative will be on-site or available by phone at all times throughout construction. Emergency erosion/pollution control equipment and BMPs will be on site at all times; Corps staff will conduct inspections and ensure that a supply of sediment control materials (*e.g.*, silt fence, straw bales), hazardous material containment booms and spill containment booms are available and accessible to facilitate the cleanup of hazardous material spills, if necessary.

Hazardous Materials

Spill Containment and Control (BA). A description of spill containment and control procedures will be on-site, including: notification to proper authorities, specific cleanup and disposal instructions for different products, quick response containment and cleanup measures that will be available on the site including a supply of sediment control materials, proposed methods for disposal of spilled materials, and employee training for spill containment. Generators, cranes, and any other stationary power equipment operated within 150 feet MHHW will be maintained as necessary to prevent leaks and spills from entering the water. Vehicles / equipment will be inspected daily for fluid leaks and cleaned as needed before leaving staging and storage area for operation within 150 feet of MHHW. Any leaks discovered will be repaired before the vehicle / equipment resumes service. Equipment used below MHHW will be cleaned before leaving the staging area, as often as necessary to remain grease-free. Additionally, the Corps proposes to use a Wiggins fast fuel system or equivalent to reduce leaks during fueling of cranes and other equipment in-place on the Jetties. Also, spill pans will be mounted under the crane and monitored daily for leaks.

Water Quality Monitoring. In-water work will require turbidity monitoring that will be conducted in accordance with 401 water quality certifications conditions to ensure the project maintains compliance with State water quality standards. Dynamic conditions at the Jetties in the immediate action area preclude the effective use of floating turbidity curtains (or approved equal). BMPs will be used to minimize turbidity during in-water work. Turbidity monitoring will be conducted and recorded each day during daylight hours when in-water work is conducted. Representative background samples will be taken according to the schedule set by the resource agencies at an undisturbed area up-current from in-water work. Compliance samples will be taken on the same schedule, coincident with timing of background sampling, down-current from in-water work. Compliance sample will be compared to background levels during each monitoring interval. Additional 401 water quality certification conditions and protocols may be required.

Habitat Improvement Projects. The Corps has incorporated a suite of habitat improvement projects to assist with the recovery of ESA-listed species. These actions are not proposed to directly mitigate or compensate for any project-related impacts to listed species, but are proposed as conservation measures under section 7(a)(1) of the ESA. These actions represent the Corps' affirmative commitment to fulfill responsibility to assist with conservation and recovery of ESA-listed species.

Habitat improvement features will be designed to create or improve fish habitat, specifically tidal marsh, swamp, and shallow-water and flats habitat, and to improve fish access to these habitat features. Habitat improvement projects currently address three general categories: actions that create, improve, and restore wetlands; actions that improve in-water habitats, and actions that restore upland habitats. From the list of possible habitat improvement features shown in Table 9, one or a combination of projects will be selected for further development and implementation. Selection will occur with input from the AMT, and work is likely to be completed concurrently with jetty repair actions.

Actions intended to provide benefits and improvements to in-water habitat include levee breaches, inlet improvements, or tide gate retrofits, as appropriate. Additional associated actions include: (1) Excavation in sand dunes and uplands to specified design elevations in order to create additional intertidal shallow-water habitat with dendritic channels and mud flats; and (2) excavation for potential expansion of the floodplain terraces.

Specific opportunities for additional projects such as the following were not identified but could warrant further investigation if none of the projects in the list is determined to be feasible: (1) Removal of overwater structures and fill in the estuary; (2) removal of relic pile-dike fields; (3) removal of fill from Trestle Bay or elsewhere; (4) removal of shoreline erosion control structures and replacement with bioengineering features; (5) beneficial use of dredged material to create ecosystem restoration features (Lois Island Embayment from Columbia River Channel Improvement is an example that may be applicable here); and (6) restoration of eelgrass beds. Certain pile fields and engineering features may be providing current habitat benefits that could be lost with removal, and such actions would require appropriate hydraulic analysis coordination with engineers and resource agencies.

For potential habitat improvement projects located in Trestle Bay, there are additional monitoring and assessment opportunities. A separate hydraulic/engineering study should investigate whether or not an expansion of low-energy, intertidal habitat near Swash Lake could effectively provide additional storage capacity and affect circulation in the Bay such that erosive pressure at neck of Clatsop Spit could be reduced. It would be worth evaluating whether or not projects that expand floodplain and intertidal areas in the Bay provide significant energy dissipation and additional low-energy storage capacity to offset or redirect erosive pressures. Alternatively, if other habitat improvement concepts are pursued that include removal of additional piles or creation of additional inlets; it would be worth investigating whether these actions could have indirect positive impacts that further reduce concern with erosion at the neck. Evaluating actions in this light would provide valuable information and insight regarding possible solutions and concerns for erosion and breaching at the neck area of Clatsop Spit on Trestle Bay.

Monitoring and maintenance of habitat improvement actions will likely be required to ensure successful establishment of goals and satisfactory return on investment. Regular coordination with the AMT will further facilitate selection and implementation of habitat improvement actions.

Wetland Mitigation. As required under section 404 of the Clean Water Act, the Corps will mitigate for impacts to wetlands that could not be otherwise avoided or minimized. The Corps estimated that 38.28 acres of wetlands will be filled in association with the proposed action, and the Corps will mitigate at a 2:1 ratio for a total of 76.56 acres of restored wetland habitats. Wetland mitigation plans currently address three general categories: actions that create, improve, and restore wetlands; actions that improve in-water habitats, and actions that restore upland habitats. From the list of possible wetland mitigation and habitat improvement features shown in Table 9, one or a combination of projects will be selected for further development and implementation. Selection will occur with input from the AMT, and work is likely to be completed concurrently with jetty repair actions.

Wetlands and shallow-water habitat will be filled as a result of the project. Official wetland delineations have not yet been completed for all three of the Jetties. However, available preliminary information has allowed the project delivery team (PDT) to site construction activities and features to reduce anticipated impact to wetlands. This information has also been used to calculate initial estimates regarding the possible acreage of impacts. The approximated acreages identified as potentially impacted are North Jetty ~4.78 acres, South Jetty up to ~22 acres and Jetty A up to ~11 acres. This comes to an estimated total of ~38.28 acres of potential wetlands impacts. To reiterate, official delineations must be completed, and these numbers will be revised accordingly after report results and project design details are further developed and available. These estimates are on the conservatively high end of what final wetland impacts will likely be.

In-water habitats, both shallow intertidal and deeper subtidal areas will also be affected by the project. Changes to in-water habitats will occur from maintenance dredging and from placement of the spur groins, jetty cross-sections, turnouts, barge offloading facilities, and causeways. There will also be permanent lagoon fill at the North Jetty root. Without drawing a distinction between depths, initial acreage estimates for all in-water impacts include North Jetty ~11.75 acres, South Jetty ~21.2 acres, and Jetty A ~7.23 acres. This comes to an approximated total of ~40.18 acres of potential in-water conversions. Shallow-water habitat is especially important to several species in the estuary; therefore, specific initial estimates were also calculated regarding shallow-water habitat (defined as -20 feet to -23 feet below MLLW). About 30 acres (out of the ~40 acres mentioned above) of area at these depths will be affected by groins, maintenance dredging, and construction of the causeways and barge offloading facilities. However, this estimate does not include any expansion of the jetty's existing footprint or overwater structures from barge offloading facilities. The approximate acreage breakdowns entail: spur groin fill = 1.56 acres (defined as -20 feet or less below MLLW; ~3.26 acres total area including all depths); dredging areas for barges ~20 acres, likely all shallow (less than -23 feet below MLLW); and causeway fill~ 7 acres, likely all shallow (less than -23 feet deep below MLLW). For this analysis, there was no distinction drawn between periodically exposed intertidal habitat and shallow-water sandflat habitat. As with wetland estimates, these approximations will be updated as project designs are refined and as additional analyses and surveys are completed to quantify changes in jetty and dune cross-sections.

Table 9. Possible wetland mitigation and habitat improvement features.

Feature/Site	Area Affected	Type and Function
Trestle Bay	5-8 acres with potential of additional acres	Estuarine Saltwater Marsh Wetland and Intertidal Mudflat Creation and Restoration • Create and expand estuarine intertidal brackish saltwater marsh wetland habitat. • Expand and restore Lyngby sedge plant community. • Expand/increase intertidal shallow-water habitat, including dendritic mud flats and off-channel habitat. • Remove and control invasive species and improve/restore diversity and density of native plant assemblages. • Increase habitat complexity for fisheries benefit. • Potentially expand floodplain terrace and improve riparian function. • (Re)introduce natural tidal disturbance regime to area currently upland dunes.
Walooskee to Youngs Bay	~151 acres	Levee Breach for Estuarine Emergent Wetland and Brackish Intertidal Shallow-water Habitat Restoration • Restore connection between Walooskee and Youngs River via levee breach. • Restore and expand estuarine intertidal brackish marsh wetland habitat. • Expand and restore Lyngby sedge and native estuarine vegetation community to improve trophic foodweb functions. • Restore and expand brackish intertidal shallow-water habitat including dendritic mud flats and off-channel edge habitat. • Remove and control invasive species and improve/restore diversity and density of native plant assemblages. • Increase habitat access and complexity for fisheries benefit including expanded foraging, rearing, and refugia habitat types. • Improve riparian function. • Potentially restore floodplain terrace and increase flood storage capacity. • (Re)introduce natural tidal disturbance regime to area currently diked pasture land. • Restore hydrologic regime and restore/improve water quality function. • Improve capacity for additional carbon sequestration via native root masses. • Increase and restore hyporheic functions for improved water quality and potential creation of cold water refugia.
Walooskee to Youngs Bay	~39 acres	Levee Breach and/or Tide Gate Retrofits for Emergent Wetland and Intertidal Shallow-water Habitat Restoration • Restore connection with Walooskee River via levee breach and/or tide gate retrofits. • Restore and expand intertidal marsh wetland habitat. • Expand and restore native vegetation community to improve trophic foodweb functions. • Restore and expand intertidal shallow-water habitat including dendritic and off-channel edge habitat. • Remove and control invasive species and improve/restore diversity and density of native plant assemblages. • Increase habitat access and complexity for fisheries benefit including expanded foraging, rearing, and refugia habitat types. • Improve riparian function. • Potentially restore floodplain terrace and increase flood storage capacity. • Restore hydrologic and natural tidal disturbance regime and restore/improve water quality function to area currently functioning as diked pasture land. • Improve capacity for additional carbon sequestration via native root masses. • Increase and restore hyporheic functions for improved water quality and potential creation of cold water refugia.
Slough to Youngs River	~250-500 acres	Levee Breach for Estuarine Wetland and Intertidal Restoration • Restore connection between Slough and Youngs River via levee breach. • Restore and expand estuarine intertidal brackish marsh wetland habitat. • Expand and restore Lyngby sedge and native estuarine vegetation community to improve trophic foodweb functions. • Restore and expand brackish intertidal shallow-water habitat including dendritic mud flats and off-channel edge habitat.

Feature/Site	Area Affected	Type and Function
		• Remove and control invasive species and improve/restore diversity and density of native plant assemblages. • Increase habitat access and complexity for fisheries benefit including expanded foraging, rearing, and refugia habitat types. • Improve riparian function. • Potentially restore floodplain terrace and increase flood storage capacity. • Restore hydrologic and natural tidal disturbance regimes to an area currently functioning as diked pasture land. • Improve capacity for additional carbon sequestration via native root masses. • Increase and restore hyporheic functions for improved water quality and potential creation of cold water refugia.
Youngs River - Diked Farmland, Freshwater Intertidal Restoration	45-50 acres With potential up to 80 acres	Levee Breach for Wetland and Intertidal Restoration • Restore connection with Youngs River via levee breach. • Restore and expand freshwater intertidal wetland habitat. • Expand and restore native vegetation community to improve trophic foodweb functions. • Restore and expand intertidal shallow-water habitat including dendritic mud flats and off-channel edge habitat. • Remove and control invasive species and improve/restore diversity and density of native plant assemblages. • Increase habitat access and complexity for fisheries benefit including expanded foraging, rearing, and refugia habitat types. • Improve riparian function. • Potentially restore floodplain terrace and increase flood storage capacity. • (Re)introduce natural tidal disturbance regime to area currently diked pasture land. • Restore hydrologic regime and restore/improve water quality function. • Increase and restore hyporheic functions for improved water quality and potential creation of cold water refugia.
Tributary Cr. to Youngs River	~5 or more acres	Estuarine Wetland and Intertidal Restoration; Tributary Reconnection to Youngs Bay • Convert diked pasture land to brackish estuarine wetland and shallow-water intertidal habitat. • Improve and restore hydrologic regime and increase regular hydrologic connectivity between Crosel Cr. And Youngs Bay estuary. • Improve and restore fish passage and provide access throughout greater range of flows to off-channel juvenile rearing, refuge and foraging habitats. • Remove and control invasive species and improve/restore diversity and density of native plant assemblages. • Increase habitat complexity for fisheries benefit. • Improve adult salmonid access to headwaters and potential spawning habitat. • Potentially expand floodplain terrace and improve riparian function. • (Re)introduce natural flow regime and tidal disturbance regime to area currently functioning as pasture land.
Tributary Cr. and Slough to the Columbia River - near Clatskanie	Up to ~43 acres	Levee Breach and/or Tide Gate Retrofits for Emergent Wetland and Intertidal Shallow-water Habitat Restoration and Tributary Reconnection • Restore connection between Tandy and Graham creeks and Westport Slough and Columbia River via levee breach and/or tide gate retrofits. • Restore and expand intertidal wetland habitat. • Expand and restore native vegetation community to improve trophic foodweb functions. • Restore and expand intertidal shallow-water habitat including dendritic and off-channel edge habitat. • Remove and control invasive species and improve/restore diversity and density of native plant assemblages. • Increase habitat access and complexity for fisheries benefit including expanded foraging, rearing, and refugia habitat types. • Improve riparian function. • Potentially restore floodplain terrace and increase flood storage capacity. • Restore hydrologic and natural tidal disturbance regime and restore/improve water quality function to area currently functioning as diked pasture hayfields.

Feature/Site	Area Affected	Type and Function
		• Improve capacity for additional carbon sequestration via native root masses. • Increase and restore hyporheic functions for improved water quality and potential creation of cold water refugia. • Improve adult salmonid access to headwaters and potential spawning habitat.
Knappa - Warren Slough	~100 or more acres	Preservation and Expansion of Estuarine Intertidal Restoration; Improve Tributary Reconnection for Fish Passage • Maintain and enhance evolving restoration that has occurred since inundation of previously diked pasture land to estuarine wetland and shallow intertidal habitat. Maintain restored ecosystem function and intertidal shallow-water habitat established post-breach. • Maintain and enhance restored hydrologic regime and increase regular hydrologic connectivity between Hall Cr. and Warren Slough. • Maintain and improve existing fish passage and provide access throughout greater range of flows to off-channel juvenile rearing, refuge and foraging habitat types. • Maintain and increase habitat complexity for fisheries benefit. • Improve adult salmonid access to headwaters and potential spawning habitat. • Remove and control invasive species and improve/restore diversity and density of native plant assemblages; Improve riparian function as appropriate. • Potentially expand floodplain terrace. • Maintain restored natural tidal disturbance regime, dendritic channels, and connection between Hall Cr. and Warren Slough.
Snowy Plover Work on Clatsop Spit	Up to ~22 acres	Forego Revegetation and Convert Upland Areas to Snowy Plover Habitat • Convert upland scrub-shrub habitat with invasive species to snowy plover habitat via periodic tilling and application of shell hash.
Wetland Creation at Cape Disappointment	Up to ~10 acres	Creation and Expansion of Interdunal Wetland Complex • Excavation of new interdunal wetlands adjacent to existing wetlands. • Establishment of native wetland plant communities and removal of invasive species around a buffer zone. • Restoration or provision of hydrology to newly excavated wetlands via appropriate elevation design. • Restoration of wetland connectivity between existing fragmented wetlands via culvert retrofits, if feasible.
Tide Gate Retrofits for Salmonid Passage	Variable	Select Tributaries from ODFW Priority Culvert Repair List - Tributary Reconnection • Restore and improve existing fish passage and provide access throughout greater range of flows to off-channel juvenile rearing, refuge and foraging habitat types. • Restore and increase habitat complexity for fisheries benefit. • Restore and improve adult salmonid access to headwaters and potential spawning habitat.

The Corps seeks to achieve no net loss in wetland habitat; to protect, improve and restore overall ecosystem functions; and to provide actions that would benefit listed species in the vicinity of the project. Towards that end, specific project footprints and activities described above have been identified, categorized, and quantified with conservative estimates where appropriate. The calculated extents were strictly based on the area of habitat that was converted. They did not include value or functional assignments regarding the significance of the conversion; whether it would be beneficial, neutral, or detrimental effect; or whether conversions would create unforeseen, indirect far-field effects. For example, acreage of conversion for shallow sandy sub-tidal habitat to rocky sub-tidal habitat was calculated in the same manner as conversion from shallow intertidal habitat to shallow sub-tidal habitat. Per initial consultation with resource agencies, a preliminary suggested ratio of 2:1 for wetland mitigation will likely be required.

Specific opportunities have been identified in the Columbia River estuary and Youngs Bay (Table 9) and are under consideration to improve and restore functions affected in each of the generalized habitat categories (wetland, in-water, and upland). Depending on further development of wetland mitigation and habitat improvement alternatives, a specific project or combination of projects will be designed and constructed concurrently as the proposed repair and rehabilitation options are completed over time. Mitigation actions and extents will be commensurate with wetland impacts and ratios identified. Proposed projects are subject to further analysis, and unforeseen circumstances may preclude further development of any specific project. In all cases, final selection, design, and completion of specific improvement features is contingent on evolving factors and further analyses including hydraulic and hydrologic conditions, real estate actions, cultural resource issues, *etc.* For this reason a suite of potential proposals has been identified, and subsequent selection of one or some combination of projects and designs will occur during continued discussion with resource agencies participating on the AMT. Depending on the projects selected for wetland mitigation, some of these wetland restoration actions may require separate consultations under the ESA.

Actions adjacent to or in the vicinity of the North and South Jetties that could potentially mitigate wetland impacts include: (1) Excavation of low and high saltwater marsh wetlands and new interdunal wetlands adjacent to existing wetlands; (2) establishment of native wetland plant communities and removal of invasive species around a buffer zone for wetlands; (3) restoration or provision of hydrology to newly excavated wetlands via appropriate elevation design; and (4) restoration of wetland connectivity between existing fragmented wetlands.

Post-construction upland restoration would include the following actions: (1) Re-establishing native grasses, shrubs, and trees where appropriate; (2) controlling and removing invasive species like scotch broom and European beach grass in the project vicinity; and (3) re-grading/tilling the area to restore natural contours.

Monitoring and maintenance of wetland mitigation actions will likely be required to ensure successful establishment of goals and satisfactory return on investment. Regular coordination with the AMT will further facilitate selection and implementation of wetland mitigation actions.

Action Area

"Action area" means all areas to be affected directly or indirectly by the action and not merely the immediate area involved in the action (50 CFR 402.02). For this consultation, the action area (Figure 1) includes: (1) An area extending 6.2 miles offshore of Columbia River mile -1; (2) an area extending 6.2 miles north and 6.2 miles south of the Columbia River mile -1; and (3) The Columbia River from river mile zero to river mile 13.5.

This action area is based on the effects from pile installation and removal which will extend over a 6.2 mile radius, including behavioral effects to marine mammals.

NMFS initially considered a larger action area that included off-shore shipping lanes associated with barge traffic for rock transport. However, at the time of this consultation it is unknown where the rock will come from. Because rock may be transported from any or all of the quarries identified as potential rock sources listed in Table 5, NMFS did not have sufficient information to consult on the potential effects. What we do know is that rock will be delivered to the MCR Jetties, and that effects associated with barge traffic will occur within the action area as defined above.

Federally-listed anadromous fish, marine mammals, and turtle species are present in the action area (Table 10), as well as EFH species including five coastal pelagic species, 40 Pacific Coast groundfish species, and coho, Chinook, and pink salmon (Table 18).

Table 10. Federal Register notices for final rules that list threatened and endangered species, designate critical habitats, or apply protective regulations to listed species considered in this consultation. Listing status: 'T' means listed as threatened under the ESA; 'E' means listed as endangered; "P" means proposed.

Species	Listing Status	Critical Habitat	Protective Regulations
Marine and Anadromous Fish			
Chinook salmon (*Oncorhynchus tshawytscha*)			
Lower Columbia River	T 6/28/05; 70 FR 37160	9/02/05; 70 FR 52630	6/28/05; 70 FR 37160
Upper Willamette River	T 6/28/05; 70 FR 37160	9/02/05; 70 FR 52630	6/28/05; 70 FR 37160
Upper Columbia River spring-run	E 6/28/05; 70 FR 37160	9/02/05; 70 FR 52630	ESA section 9 applies
Snake River spring/summer run	T 6/28/05; 70 FR 37160	10/25/99; 64 FR 57399	6/28/05; 70 FR 37160
Snake River fall-run	T 6/28/05; 70 FR 37160	12/28/93; 58 FR 68543	6/28/05; 70 FR 37160
Chum salmon *(O. keta*)			
Columbia River	T 6/28/05; 70 FR 37160	9/02/05; 70 FR 52630	6/28/05; 70 FR 37160
Coho salmon (*O. kisutch*)			
Lower Columbia River	T 6/28/05; 70 FR 37160	1/10/2011; 76 FR 1392	6/28/05; 70 FR 37160
Oregon Coast	T 2/11/08; 73 FR 7816	2/11/08; 73 FR 7816	2/11/08; 73 FR 7816
Southern Oregon / Northern California Coasts	T 6/28/05; 70 FR 37160	5/5/99; 64 FR 24049	6/28/05; 70 FR 37160
Sockeye salmon (*O. nerka*)			
Snake River	E 6/28/05; 70 FR 37160	12/28/93; 58 FR 68543	ESA section 9 applies
Steelhead (*O. mykiss*)			
Lower Columbia River	T 1/05/06; 71 FR 834	9/02/05; 70 FR 52630	6/28/05; 70 FR 37160
Upper Willamette River	T 1/05/06; 71 FR 834	9/02/05; 70 FR 52630	6/28/05; 70 FR 37160
Middle Columbia River	T 1/05/06; 71 FR 834	9/02/05; 70 FR 52630	6/28/05; 70 FR 37160
Upper Columbia River	T 1/05/06; 71 FR 834	9/02/05; 70 FR 52630	2/018/06; 71 FR 5178
Snake River Basin	T 1/05/06; 71 FR 834	9/02/05; 70 FR 52630	6/28/05; 70 FR 37160
Green sturgeon (*Acipenser medirostris)*			
Southern	T 4/07/06; 71 FR 17757	10/09/09; 74 FR 52300	P 5/21/09; 74 FR 23822
Eulachon (*Thaleichthys pacificus*)			
Eulachon	PT 3/13/09; 74 FR 10857	1/05/11; 76 FR 515	Not applicable
Marine Mammals			
Eastern Steller sea lion (*Eumetopias jubatus*)	T 5/5/1997; 63 FR 24345	8/ 27/93; 58 FR 45269	11/26/90; 55 FR 49204
Blue whale (*Balaenoptera musculus*)	E 12/02/70; 35 FR 18319	Not applicable	ESA section 9 applies
Fin whale (*Balaenoptera physalus*)	E 12/02/70; 35 FR 18319	Not applicable	ESA section 9 applies
Humpback whale (*Megaptera novaeangliae*)	E 12/02/70; 35 FR 18319	Not applicable	ESA section 9 applies
Southern Resident Killer whale (*Orcinus orca*)	E 11/18/05; 70 FR 69903	11/26/06; 71 FR 69054	ESA section 9 applies
Sei whale (*Balaenoptera borealis*)	E 12/02/70; 35 FR 18319	Not applicable	ESA section 9 applies
Sperm whale (*Physeter macrocephalus*)	E 12/02/70; 35 FR 18319	Not applicable	ESA section 9 applies
Marine Turtles			
Leatherback turtle (*Dermochelys coriacea*)	E 6/02/70 ; 39 FR 19320	3/23/79; 44 FR 17710	ESA section 9 applies

ENDANGERED SPECIES ACT BIOLOGICAL OPINION

Section 7(a) (2) of the ESA requires Federal agencies to consult with NMFS to ensure that their actions are not likely to jeopardize the continued existence of endangered or threatened species, or adversely modify or destroy their designated critical habitat. The Opinion that follows records the results of the interagency consultation for this proposed action. NMFS did not include an incidental take statement for marine mammals at this time because any taking of these listed species must first be authorized with the issuance of an incidental harassment authorization or letter of authorization for Steller sea lions and humpback whales.

To complete the jeopardy analysis presented in this Opinion, NMFS reviewed the status of each listed species[2] considered in this consultation, the environmental baseline in the action area, the effects of the action, and cumulative effects (50 CFR 402.14(g)). From this analysis, NMFS determined whether effects of the action were likely, in view of existing risks, to appreciably reduce the likelihood of both the survival and recovery of the affected listed species.

For the critical habitat destruction or adverse modification analysis, NMFS considered the status of the entire designated area of the critical habitat considered in this consultation, the environmental baseline in the action area, the likely effects of the action on the function and conservation role of critical habitat, and cumulative effects. NMFS used this assessment to determine whether, with implementation of the proposed action, critical habitat would remain functional, or retain the current ability for the primary constituent elements (PCEs) to become functionally established, to serve the intended conservation role for the species.[3]

If the action under consultation is likely to jeopardize the continued existence of an ESA-listed species, or destroy or adversely modify critical habitat, NMFS must identify any reasonable and prudent alternatives for the action that avoid jeopardy or destruction or adverse modification of critical habitat and meet other regulatory requirements (50 CFR 402.02).

Status of the Species

The summaries that follow describe the status of the ESA-listed species, and their designated critical habitats, that occur within the geographic area of this proposed action and are considered in this Opinion. More detailed information on the status and trends of these listed resources, and their biology and ecology, can be found in the listing regulations and critical habitat designations published in the Federal Register (Table 11).

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[2] An "evolutionarily significant unit" (ESU) of Pacific salmon (Waples 1991) and a "distinct population segment" (DPS) (Policy Regarding the Recognition of District Vertebrate Population; 61 FR 4721, Feb 7, 1996) are both "species" as defined in section 3 of the ESA.

[3] Memorandum from William T. Hogarth to Regional Administrators, Office of Protected Resources, NMFS (November 7, 2005) (Application of the "Destruction or Adverse Modification" Standard Under Section 7(a)(2) of the Endangered Species Act).

It is also likely that climate change will play an increasingly important role in determining the abundance of ESA-listed species, and the conservation value of designated critical habitats, in the Pacific Northwest. During the last century, average regional air temperatures increased by 1.5°F, and increased up to 4°F in some areas (USGCRP 2009). Warming is likely to continue during the next century as average temperatures increase another 3 to 10°F (USGCRP 2009). Overall, approximately one-third of the current cold-water fish habitat in the Pacific Northwest is likely to exceed key water temperature thresholds by the end of this century (USGCRP 2009).

Precipitation trends during the next century are less certain than for temperature but more precipitation is likely to occur during October through March and less during summer and more of the winter precipitation is likely to fall as rain rather than snow (ISAB 2007, USGCRP 2009). Where snow occurs, a warmer climate will cause earlier runoff so stream flows in late spring, summer, and fall will be lower and water temperatures will be warmer (ISAB 2007, USGCRP 2009).

Higher winter stream flows increase the risk that winter floods in sensitive watersheds will damage spawning redds and wash away incubating eggs (USGCRP 2009). Earlier peak stream flows will also flush some young salmon and steelhead from rivers to estuaries before they are physically mature, increasing stress and the risk of predation (USGCRP 2009). Lower stream flows and warmer water temperatures during summer will degrade summer rearing conditions, in part by increasing the prevalence and virulence of fish diseases and parasites (USGCRP 2009). Other adverse effects are likely to include altered migration patterns, accelerated embryo development, premature emergence of fry, and increased competition and predation risk from warm-water, non-native species (ISAB 2007).

The earth’s oceans are also warming, with considerable interannual and inter-decadal variability superimposed on the longer-term trend (Bindoff *et al.* 2007). Historically, warm periods in the coastal Pacific Ocean have coincided with relatively low abundances of salmon and steelhead, while cooler ocean periods have coincided with relatively high abundances (Scheuerell and Williams 2005, Zabel *et al.* 2006, USGCRP 2009). Ocean conditions adverse to salmon and steelhead may be more likely under a warming climate (Zabel *et al.* 2006).

Over the past few decades, the sizes and distributions of the populations considered in this Opinion generally have declined due to natural phenomena and human activity, including the operation of hydropower systems, over-harvest, hatcheries, and habitat degradation. Enlarged populations of terns, seals, sea lions, and other aquatic predators in the Pacific Northwest have been identified as factors that may be limiting the productivity of some Pacific salmon and steelhead populations (Bottom *et al.* 2005, Fresh *et al.* 2005).

Climate change, as described in the introduction above, is likely to adversely affect the conservation value of designated critical habitats in the Pacific Northwest. These effects are likely to include, but are not limited to, depletion of cold water habitat and other variations in quality and quantity of tributary spawning, rearing and migration habitats and estuarine areas.

Species Descriptions and Limiting Factors.

Eulachon. Eulachon (smelt) are endemic to the eastern Pacific Ocean ranging from northern California to southwest Alaska and into the southeastern Bering Sea. Eulachon occur only on the coast of northwestern North America, from northern California to southwestern Alaska. In the portion of the species' range that lies south of the U.S./Canada border, most eulachon production originates in the Columbia River Basin. In this basin, the major and most consistent spawning runs occur in the mainstem of the Columbia River (from just upstream of the estuary, RM 25 to immediately downstream of Bonneville Dam at RM 146). Periodic spawning occurs in the Grays, Skamokawa, Elochoman, Kalama, Lewis, Cowlitz, and Sandy rivers (Emmett *et al.* 1991, Musick *et al.* 2000). In the Columbia River and its tributaries, spawning usually begins in January or February (Beacham *et al.* 2005).

Eulachon are anadromous fish that spawn in the lower reaches of rivers in early spring. They typically spend 3 to 5 years in saltwater before returning to freshwater to spawn from late winter through mid-spring. Spawning occurs over sand or coarse gravel substrates. Eggs are fertilized in the water column, sink, and adhere to the river bottom. Most adults die after spawning and eggs hatch in 20-40 days. Larvae are carried downstream and are dispersed by estuarine and ocean currents shortly after hatching. Runs tend to be erratic, appearing in some years but not others, and appearing only rarely in some river systems (Hinrichsen 1998). Eulachon are important in the food web as a prey species. Eulachon spawning runs have declined in the past 20 years, especially since the mid-1990s (Hay and McCarter 2000). The cause of these declines remains uncertain. Eulachon are caught as bycatch during shrimp fishing, but in most areas the total bycatch is small (Beacham *et al.* 2005). Predation by pinnipeds may be substantial, and other risk factors include global climate change and deterioration of marine and freshwater conditions (73 FR 13185).

The major factors limiting recovery of eulachon include climate change on ocean conditions, climate change on freshwater habitat, eulachon by-catch, dams and water diversions, and predation (NMFS 2008a).

Steller Sea Lion. The eastern DPS Steller sea lions range from southeast Alaska to southern California with a minimum abundance of 45,000 animals (NMFS 2008c), and have increased at 3% per year for the past 30 years (NMFS 2008c). The greatest increases have occurred in southeast Alaska and British Columbia (together accounting for 82% of pup production), but performance has remained poor in California at the southern extent of their range. In Southeast Alaska, British Columbia and Oregon, the number of Steller sea lions has more than doubled since the 1970s. There are no substantial threats to the species, and the population continues to increase at approximately 3% per year. The final Steller sea lion recovery plan identifies the need to initiate a status review for the eastern Steller sea lion and consider removing it from the Federal List of Endangered Wildlife and Plants (NMFS 2008c). The eastern Steller sea lion breeds on rookeries in southeast Alaska, British Columbia, Oregon, and California; there are no rookeries in Washington. Haulouts are located throughout the eastern population's range (NMFS 2008c).

Steller sea lions are generalist predators, able to respond to changes in prey abundance. Their primary prey includes a variety of fishes and cephalopods. Some prey species are eaten seasonally when locally available or abundant, and other species are available and eaten year-round (review in NMFS 2008c). Pacific hake appears to be the primary prey item across the range of eastern Steller sea lion (NMFS 2008c). Other prey items include Pacific cod, walleye Pollock, salmon, and herring, among other species.

Steller sea lions occur in Oregon waters throughout the year, and use breeding rookeries at Rogue Reef and Orford Reef and haulout locations along the Oregon coast. There are four haulout sites used by Steller sea lions in the lower Columbia River and these include the tip of the South Jetty, where greater than 500 Steller sea lions commonly occur, and three locations proximate to and at the Bonneville Dam tailrace area where Steller sea lions occasionally occur. Critical habitat of Steller sea lions is not affected by the proposed action, and is therefore not discussed.

Steller sea lion use of the South Jetty. The South Jetty of the Columbia River is used by Steller sea lions for hauling out and is not designated critical habitat. Use occurs chiefly at the concrete block structure and the rubble mound. The proposed action will re-build the cap of the South Jetty at its present location, which is approximately 600 feet from the rubble mound and 1,400 feet from then concrete block structure. Erosion has turned the block structure and the rubble mound into islands. California sea lions (*Zalophus californianus*) also use this area and can intermingle with Steller sea lions. Steller sea lions appear to out-compete California sea lions for the preferred haul out area on the concrete block structure. Both species use the rubble mound extensively during high tides, when the concrete block structure is underwater.

Steller sea lions are present, in varying abundances, all year (Table 11). Abundance is typically lower from May-July when adults are at the breeding rookeries, although this is not always true as evidenced by a flyover count of the South Jetty on May 23, 2007 where 1,146 Steller sea lions were observed on the concrete block structure and none on the rubble mound (WDFW 2007). Those counts represent a high-use day on the South Jetty. Only non-breeding individuals are typically found on the jetty during May-July, and a greater percentage of juveniles are present. Abundance increases following the breeding season. All population age classes, and both males and females, use the South Jetty to haul out.

Table 11. Average number of pinnipeds by month at the South Jetty, 1995-2004.

Month	Number of Years Surveyed	Average Number of Steller Sea Lions
January	1	246
February	4	246
March	1	635
April	3	613
May	4	252
June	8	245
July	4	385
August	2	486
September	0	---
October	1	168
November	1	923
December	1	1,106

Data from Oregon Department of Fish and Wildlife.

Humpback Whales. Humpback whales occur in all major oceans of the world. The abundance and population trends of humpback whales are difficult to estimate, but based on the available data humpback whales appear to be increasing in abundance across much of their range (Carretta *et al*. 2010). Calambokidis *et al*. (2008) estimated that the current population of humpback whales in the North Pacific is approximately 18,000 to 20,000 whales, not counting calves. More recently, the abundance was estimated to be over 21,000 individuals (Barlow *et al*. 2011). The estimated growth rate for this stock is between 7% and 8%, annually (Carretta *et al*. 2010).

There are at least three separate populations of humpback whales in the North Pacific, of which one population migrates and feeds along the U.S. west coast. This population, previously called the California / Oregon / Washington stock, winters in coastal waters of Mexico and Central America and migrates to areas ranging from the coast of California to southern British Columbia in summer/fall (Carretta *et al*. 2010). Within this population, regional abundance estimates vary among the feeding areas. Average abundance estimates ranged from 200 to 400 individuals for southern British Columbia/northern Washington, and 1,400 to 1,700 individuals for California/Oregon (Calambokidis *et al*. 2008). There is a high degree of site fidelity in these feeding ranges with almost no interchange between these two feeding regions.

Humpback whales forage on a variety of crustaceans, other invertebrates and forage fish (review in NMFS 1991). In their summer foraging areas, humpback whales tend to occupy shallow, coastal waters. In contrast, during their winter migrations humpback whales tend to occupy deeper waters further offshore, and are less likely to occupy shallow, coastal waters. Humpback whales are sighted off the Washington and Oregon coasts close to shore (Figure 1 from Carretta *et al*. 2010, Lagerquist and Mate 2002, Oleson *et al*. 2009).

Humpback whales are known to predictably forage an average of 22 miles offshore of Grays Harbor, Washington during spring and summer months (Oleson *et al*. 2009). Grays Harbor is approximately 45 miles north of the project site. Oleson *et al*. (2009) documented 147 individual humpback whales foraging off Grays Harbor from 2004 to 2008, and foraging whales (1-19 whales sighted per day) were sighted on 50% of the days surveyed (22 of 44 survey days).

We have limited fine-scale information about humpback whale foraging habits and space use along the Washington coast, and do not have specific fine-scale information for the project area. Based on the available information, humpback whales are likely to occur within 6.2 miles of the Jetties or 8.6 miles of shore (where in-water sound from pile driving activities may be audible) given their general tendency to occupy shallow, coastal waters when foraging, and the available information on their fine-scale use of a proximate location. Based on this information humpback whales are likely to pass through and may forage in the project vicinity.

Current threats to the species include mortality and serious injury from entanglement with fishing gear and collisions with ships, whale watch harassment, proposed harvest (*i.e*., Japan's proposal for scientific whaling), and anthropogenic sound in the ocean that is a habitat concern for low-frequency sound specialists, such as humpback whales (NMFS 1991).

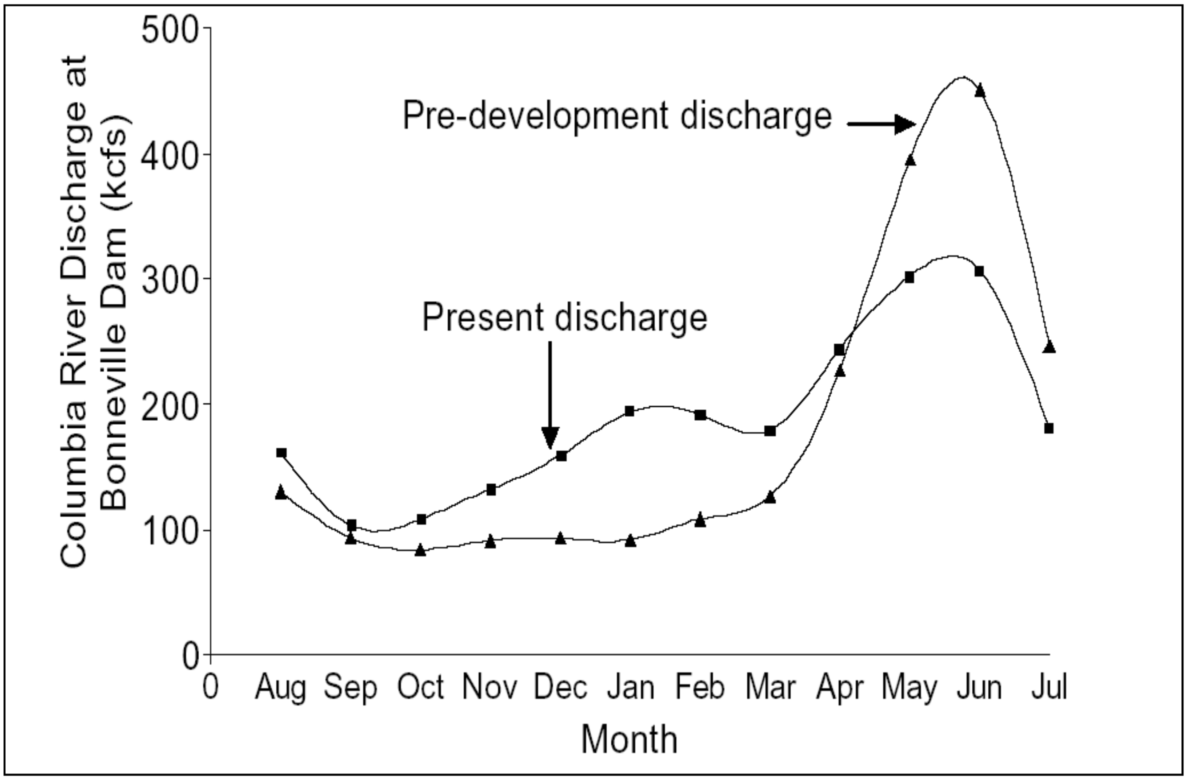
Environmental Baseline

The environmental baseline includes the past and present impacts of all Federal, State, or private actions and other human activities in the action area, the anticipated impacts of all proposed Federal projects in the action area that have already undergone formal or early section 7 consultation, and the impact of State or private actions which are contemporaneous with the consultation in process (50 CFR 402.02).

Overview

The Lower Columbia River extends from Bonneville Dam (RM 146) to the mouth of the Columbia River. Historically, unregulated discharges at the mouth ranged from 79,000 cubic feet per second (cfs) to over 1 million cfs, with average discharges of 273,000 cfs (Figure 19). Currently, discharge at the mouth of the river ranges from 100,000 to 500,000 cfs, with an average of 260,000 cfs.

Figure 19. Annual monthly river discharge at Bonneville Dam under current operations as compared to historical river discharge with no mainstem dams.



Source: Corps Portland District

The highest discharges in the river occur between December and March. Stream discharge in the lower Columbia River is influenced by snowmelt, winter rainstorms, and dam regulation. Stream discharge peaks generally occur during April through June. Local flooding in the lower Columbia River now begins when stream discharge reaches about 450,000 cfs, while the unregulated peak discharge would have been 602,000 cfs. Low stream flow generally occurs between August and October.

Discharge and sediment load have been altered by construction of 31 irrigation and hydropower dams, and 162 smaller dams, in the basin since 1890. Before 1890, the Columbia River estuary had extensive sand beds and variable river discharges. However, the construction of upriver hydroelectric dams has dramatically changed the nature of the estuary, as these dams have translated into different discharge rates and sediment discharges. Moreover, channel deepening, use of jetties and dredging to stabilize channels, development of perennial wetland areas, and isolation of remaining wetlands from the mainstem river have altered the physical character of the estuary; these changes have affected the biological systems supported by the estuary.

Physical Characteristics

The Columbia River estuarine environment extends from the river's mouth to approximately RM 38. The river varies from 2 to 5 miles wide throughout the estuary. Tidal effect extends almost 150 miles upstream (Corps 1983), but the saltwater wedge is limited to approximately RM 20 (Corps 1999). The North and South Jetties and Jetty A were constructed at the mouth to help stabilize the channel, reduce the need for dredging, and provide protection for ships. A series of pile dikes also were historically constructed for similar reasons. The navigation channel is currently maintained at authorized depths of 48 to 55 feet deep below MLLW and 0.5-mile wide from RM -3 to RM 3. River flows are controlled by upstream storage dams. A dredged material disposal site near the North Jetty was established in 1999 to protect the North Jetty from erosion. Approximately 100,000 to 500,000 cy of sand are placed there annually. The MCR shallow-water site (SWS), deep water site (DWS), and Chinook Channel Area D Sites are also active disposal locations within the action area but offshore and upstream of MCR, respectively. Historic disposal sites no longer active within vicinity of the Jetties include Site E located within the expanded SWS and sites A, B, and F, which are in deeper water but still shoreward of the active DWS.

The Corps regularly conducts operations and maintenance activities to maintain the jetty system and the authorized navigation channels and facilities. In the action area, there are several turning and mooring basins and Federally-authorized periodically dredged channels extending to various ports from the navigation channel. The Columbia River channel improvements project was recently completed and deepened the navigation channel to -48 feet CRD from approximately RM 3 to 104.

Waves, Currents, and Morphology

The MCR is a high-energy environment. The ocean entrance at the MCR is characterized by large waves and strong currents interacting with spatially variable bathymetry. Approximately 70% of all waves approaching the MCR are from the west-northwest. During winter storm conditions, the ocean offshore of the Jetties river entrance is characterized by high swells approaching from the northwest to southwest combined with locally generated wind waves from the south to southwest. From October to April, average offshore wave height and period is 9 feet and 12 seconds, respectively. From May to September, average offshore wave height and period is 5 feet and 9 seconds, respectively, and waves approach mostly from the west-northwest (Figure 20).

Occasional summer storms produce waves approaching MCR from the south-southwest with wave heights of 6.5 to 13 feet and wave periods of 7 to 12 seconds. Astronomical tides at MCR are mixed semi-diurnal with a diurnal range of 7.5 feet. The instantaneous flow rate of estuarine water through the MCR inlet during ebb tide can reach 1.8 million cfs. Tidally dominated currents within the MCR can exceed 8.2 feet per second. A large, clockwise-rotating eddy current has been observed to form between the North Jetty, the navigation channel, and Jetty A during ebb tide. A less pronounced counter-clockwise eddy forms in response to flood tide. Horizontal circulation in the estuary is generally clockwise (when viewed from above), with incoming ocean waters moving upstream in the northern portion of the estuary and river waters moving downstream in the southern portion. Vertical circulation is variable, reflecting the complex interaction of tides with river flows and bottom topography and roughness (Corps 1983). The North Jetty eddy has varying strength and direction (based on location and timing of tide) ranging from 0.3 to 3.3 feet per second.

Figure 20. Photograph of the South Jetty in September.

As waves propagate shoreward toward the mouth of the Columbia River, the waves are modified (waves begin to shoal and refract) by the asymmetry of the mouth of the Columbia River underwater morphology. Nearshore currents and tidal currents are also modified by the Jetties and the mouth of the Columbia River morphology. These modified currents interact with the shoaling waves to produce a complex and agitated wave environment within the mouth of the Columbia River.

The asymmetric configuration of the mouth of the Columbia River and its morphology is characterized by the significant offshore extent of Peacock Spit on the north side of the North Jetty, southwesterly alignment of the North/South jetties and channel, and the absence of a large shoal on the south side of the mouth of the Columbia River. The asymmetry of the mouth of the Columbia River causes incoming waves to be focused onto areas which would not otherwise be exposed to direct wave action. An example of this wave-focusing effect is the area along the south side of the North Jetty. Upon initial inspection, it would appear that this area is most susceptible to wave action approaching the mouth of the Columbia River from the southwest. However, this is not the case; the opposite is what occurs. The area located between the North Jetty, the navigation channel, and Jetty A is affected by wave action during conditions when the offshore wave direction is from the west-northwest, because of the refractive nature of Peacock Spit. Waves passing over Peacock Spit (approaching from the northwest) are focused to enter the mouth of the Columbia River along the south side of the North Jetty. Conversely, large waves approaching the mouth of the Columbia River from the southwest are refracted/diffracted around the South Jetty and over Clatsop Spit, protecting the south side of the North Jetty from large southerly waves.

Channel stability at the mouth of the Columbia River is related to the Jetties and the morphology of Peacock and Clatsop spits (Moritz *et al.* 2003). Because of phased jetty construction from 1885 to 1939, and the associated response of morphology, mouth of the Columbia River project features and the resultant morphology are now mutually dependent both in terms of structural integrity and project feature functional performance.

Foundation Conditions

The project has two main shoaling areas. The outer shoal extends from approximately RM -1.6 to RM -1.0. The inner shoal, Clatsop Shoal, extends from approximately RM 0.0 to RM 2.6, beginning on the south side and crossing the channel near RM 1.0. To maintain the channel's depth, dredging is conducted and materials dredged from the project are placed in one of two EPA ocean dredged material disposal sites designated under Section 102 of the Marine Protection, Research, and Sanctuaries Act (MPRSA)—DWS or the SWS, or alternately in a Clean Water Act Section 404 North Jetty site (Corps 2008).

The MCR jetties were constructed on these underwater sand shoals which are crucial project elements. These shoals are currently receding, which could affect the sediment budget supplying the adjacent littoral zones north and south of the MCR. As morphology near the Jetties undergoes significant erosion, the Jetties will be undermined by waves and currents.

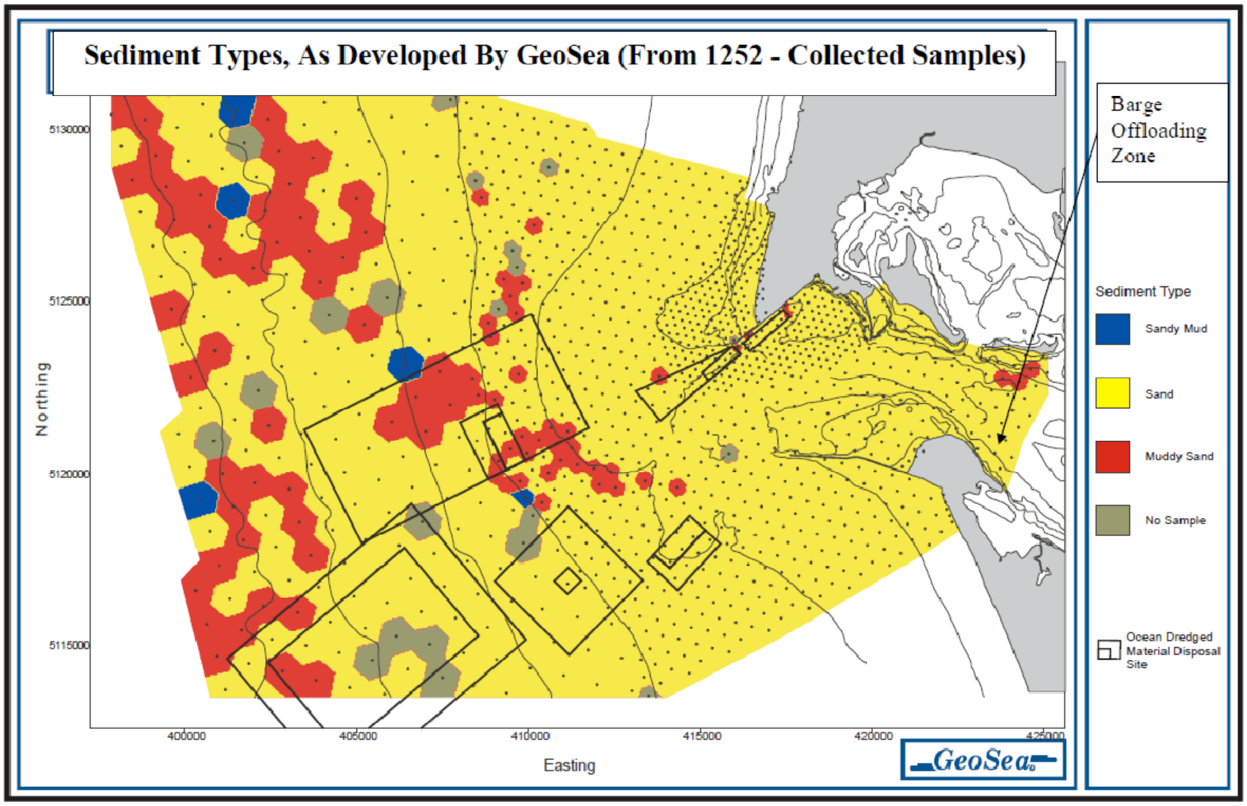
Landforms

Near the Oregon shore of the estuary, Clatsop Spit is a coastal plain. On the Washington shore, Cape Disappointment is a narrow, rocky headland. Extensive accretion of land has occurred north of the North Jetty since its construction. This accreted land, however, is now in the process of recession as is evident by erosion at Benson Beach. The Corps is in the process of placing Columbia River sand back into the littoral drift cell north of the North Jetty at Benson Beach. Behind the headland are a beach dune and swale. Wetlands occur on accreted land north of the North Jetty and on Clatsop Spit.

Sediment Quality

In 2000 a sediment trend analysis (STA) was conducted by GeoSea Consulting, under contract to the Corps. Over twelve hundred (1,252) samples were collected in the MCR and surrounding off-shore locations (Figure 21). Physical analyses, of the samples surrounding the study area (6 samples selected), indicate the project area consists of >99% sand. Select samples (10) from the GeoSea study for the MCR maintenance dredging program were analyzed for physical and chemical contamination. These samples indicated that no contaminates were detected at or near the dredged material evaluation framework (DMEF) screening levels. See: http://www.nwp.usace.army.mil/ec/h/hr/Reports/Mcr/mouth00.pdf for the complete report on chemical results (Corps 2008).

Figure 21. Sediment trend analysis in MCR area.



In 2005, a Tier I evaluation was conducted near the proposed the South Jetty barge offloading site following procedures set forth in the Inland Testing Manual (ITM) and the Upland Testing Manual (UTM). The methodologies used were those adopted for use in the DMEF for the Lower Columbia River Management Area, November 1998, and its updated draft 2005 version, the Sediment Evaluation Framework (SEF). This Tier I evaluation of the proposed dredge material indicated that the material was acceptable for both unconfined in-water and upland placement. No significant, adverse ecological impacts in terms of sediment toxicity were expected from disposal (Corps 2005a).

In 2008 using USEPA’s ocean survey vehicle Bold, ten Van Veen surface grab samples were collected from sites previously sampled during the September 2000 sediment evaluation study. Percent sand averaged 98.45% with a range of 99.3 to 97.0%. Percent silt and clay averaged 1.59%, ranging from 3.0 to 0.7%. Per the Project Review Group approved sediment evaluation plan, no chemical analyses were conducted. Physical results for the 2000 and 2008 sampling events were compared. The mean percent sand for all samples in September 2000 was 98.11%, for June 2008 it was 98.45%. Within both data sets, sediment towards the outer portion of the mouth was finer than sediments towards the center of the mouth (Corps 2008).

Other Activities and Conditions

Commercial and recreational fishing activities also have some influence on listed species and their prey items in the action area. The major fisheries are for bottom fish, salmon, crab, and other species of shellfish. Crab fishing occurs from December to September with the majority of the catch occurring early in the season. Most crab fishing occurs north of the Columbia River mouth at depths ranging from 25 to 250 feet mean sea level (MSL). Dungeness crab population numbers are subject to large cyclic fluctuations in abundance. Modeling studies by Higgins and others (1997) show that small scale environmental changes, such as a short delay in the onshore currents in spring, can dramatically impact survival of young-of-the-year crab but have no effect on adults and older juveniles inshore. Bottom fishing by trawl for flatfish, rockfish, and pink shrimp occurs year-round throughout the entire offshore area, primarily at depths offshore from the Jetties. Many of these species interact with listed species in a predator-prey relationship that, in some cases, can change over the course of each species' life history. Fisheries could have some effect on prey availability and species numbers in the action area.

Physical Environment at the MCR

The MCR is a high-energy, stochastic environment. For example, from October to April, average offshore wave height and period is 9 feet and 12 seconds, respectively. From May to September, average offshore wave height and period is 5 feet and 9 seconds, respectively, and waves approach mostly from the west-northwest (Figure 20). Occasional summer storms produce waves approaching MCR from the south-southwest with wave heights of 6.5 to 13 feet and wave periods of 7 to 12 seconds. Astronomical tides at MCR are mixed semi-diurnal with a diurnal range of 7.5 feet. The instantaneous flow rate of estuarine water through the MCR inlet during ebb tide can reach 1.8 million cfs. Tidally dominated currents within the MCR can exceed 8.2 fps.

Navigation Channels

Offshore and inland navigation channels in the Pacific Ocean from Vancouver British Columbia in Puget Sound, to Eureka, and Humbolt Bay, California are connected to a navigation route that extends along the entire western seaboard called the Pacific Deep Water Spine. The Spine can be accessed from approximately 33 routes. These access routes are not maintained and are generally in the 40-foot or deeper range. The Spine is also not maintained, and is up to and over 100 feet deep. Generally, ships transit anywhere between 5 and 20 miles offshore depending on weather (in high winds or seas they may need to tack or 'zigzag' to avoid rolling too violently or losing too much speed, *etc.*). A few areas along the coast are rocky farther off the shoreline, and those spots are given wider berth. Between Eureka, California, and the Port Angeles Puget Sound, there are roughly 192 ports, moorages, terminals, and wharf facilities that serve various types and levels of vessel traffic. At any one time, there can be hundreds or thousands of commercial and pleasure crafts in transit between Eureka and Puget Sound.

A large suit of actions have impacted and are continuing to impact the environment within these channels, including but not limited to dredging, disposal, jetties, boating, floating navigational and fishing devices, fishing, float planes, sonar, contaminant leaks and disposal, and submarines. However, NMFS is unaware of any past, present, or contemporaneous projects or impacts from Federal, State, or private actions and other human activities that are relevant to the interaction of the proposed action and listed species within the navigation channels described above. That interaction of the proposed action and listed species is described in the effects to marine mammals section, below.

Effects of the Action

Effects of the action refers to the direct and indirect effects of an action on the species or critical habitat, together with the effects of other activities that are interrelated or interdependent with that action, that will be added to the environmental baseline (50 CFR 402.02). Indirect effects are those that are caused by the proposed action and are later in time, but still are reasonably certain to occur. Interrelated actions are those that are part of a larger action and depend on the larger action for their justification. Interdependent actions are those that have no independent utility apart from the action under consideration. Insignificant effects are so mild that the effect cannot be meaningfully measured, detected, or evaluated. Discountable effects cannot be reasonably expected to occur. Beneficial effects are contemporaneous positive effects without any adverse effects to the species or critical habitat.

Effects on Habitat

The only proposed activities NMFS expects will affect Steller sea lions are rock placement and pile installation and removal. The only proposed activity NMFS expects to affect humpback whales is pile installation and removal.

For Pacific salmon and steelhead, green sturgeon, and eulachon, NMFS expects construction-related effects on water quality, hydraulic and hydrological processes and estuarine, marine, and upland habitats to be insignificant or discountable.

The following is a discussion of each project element and the rationales supporting our effects analysis.

Rock Transport. As discussed in the proposed action, barge transport of stone from quarry sites is likely and would occur mostly during daylight hours along major navigation routes in existing harbors and navigation channels. Traffic from the proposed action will be limited mostly to summer months when fair weather allows safe passage. Although transport will occur on an annual basis, stone may or may not be delivered to one or more jetties seasonally. Loaded water-borne container traffic identified as foreign in- and outbound to/from Portland that would likely have crossed the MCR in 2008 totaled approximately 195,489 ships (Corps 2010). The number of additional barge trips per year attributable to the proposed action is likely to be somewhere between 8 and 25 ships. This is small annual percentage increase (0.004 to 0.01%) relative to the current number of other commercial and recreational vessels already using any of these potential routes. Due to the slow travel speed of the barges of less than 12 knots, infrequency of these vessel trips, geographic limitation to existing navigation channels, and the minimal duration of barges in any particular area, NMFS concludes that the effects to estuarine, marine, and upland habitats associated with rock transport are discountable.

Rock Placement. As described in the proposed action, rock placement will occur on an annual basis starting in the late spring through the late to early fall, will occur at more than one jetty per season, and will occur regularly throughout the duration of construction. The vast majority of the stone placement for construction of the jetty head, trunk, and root features will occur on existing relic jetty stone and within the existing structural prism. Jetty barbs, crane set-up pads and vehicle turnouts will also require the placement of rock. Rock placement on each jetty is discussed below.

North Jetty

- **Jetty Trunk:** Approximately 58% of the overall rock placement on trunk of the jetty will be placed above MHHW; approximately 25% of the volume will be placed between MHHW and MLLW; and approximately 18% of the volume placed will be below MLLW. The footprint will not be extended beyond the relic jetty stone or structure.
- **Spur Groins:** A small percentage (approximately 0.1%) of the overall stone placement for spur groins will be above MHHW; approximately 4% will be placed between MHHW and MLLW; and approximately 95.9% will be placed below MLLW. Spur groin placement may result in a change in habitat type, sandy to rocky, of up to 1.55 acres. Channel-side groins will be submerged a minimum of 5 to 35 feet below MLLW.
- **Capping:** Approximately 49% of the overall stone placement on the capping portions of the jetty will be placed above MHHW; approximately 24% of the volume will be placed between MHHW and MLLW; and approximately 27% of the volume placed will be below MLLW. Capping stone will not be placed beyond the footprint of the relic jetty stone.
- **Barge offloading facilities:** Rock placement for barge offloading facilities, turn-outs, and set-up pad facilities may result in a change in habitat type, sandy to rocky, of up to 0.63 acres.

South Jetty

- **Jetty Trunk:** Approximately 68% of the overall stone placement on the trunk of the jetty will be placed above MHHW; approximately 19% of the volume will be placed between MHHW and MLLW; and approximately 13% of the volume placed will be below MLLW. The footprint will not be extended beyond the relic jetty stone or structure.

- **Spur Groins:** A small percentage (approximately 0.1%) of the overall stone placement for spur groins will be above MHHW; approximately 12.3% will be placed between MHHW and MLLW; and approximately 87.6% will be placed below MLLW. Spur groin placement may result in a change in habitat type, sandy to rocky, of up to 1.10 acres.
- **Capping:** Approximately 52% of the overall stone placement on the capping portions of the jetty will be placed above MHHW; approximately 25% of the volume will be placed between MHHW and MLLW; and approximately 23% of the volume placed will be below MLLW. This feature will not be expanded beyond the footprint of the relic jetty stone or structure.
- **Barge Offloading Facilities:** Stone placement for barge offloading facilities, causeways, turn-out, and set-up pad facilities may result in a change in habitat type, sandy to rocky, of up to 1.96 acres.

Jetty A

- **Jetty Trunk**: Approximately 63% of the overall stone placement on the trunk of the jetty will be placed above mean higher high water (MHHW); approximately 29% of the volume will be placed between MHHW and MLLW; and approximately 8% of the volume placed will be below MLLW. The footprint of Jetty A is likely to be expanded beyond the relic jetty stone or structure, but will not extend more than 10 feet beyond the existing prism. This may result in a change in habitat type, sandy to rocky, of up to 1.2 acres.
- **Spur Groins:** 100% of the spur groin construction will be below MLLW, and may result in a change in habitat type, sandy to rocky, of up to 0.61 acres. Both groins will be submerged a minimum of 5 below MLLW.
- **Capping:** Approximately 44% of the overall stone placement on the capping portions of the jetty will be placed above MHHW; approximately 26% of the volume will be placed between MHHW and MLLW; and approximately 30% of the volume placed will be below MLLW. This feature will not be expanded beyond the footprint of the relic jetty stone or structure.
- **Barge Offloading Facilities:** Stone placement for barge offloading facilities, causeways, turn-out, and set-up pad facilities may result in a change in habitat type, sandy to rocky, of up to 2.89 acres.

Rock placement will have two types of effects: direct effects on the substrate on which the rock is placed, and indirect effects on hydraulic and hydrological processes. The indirect effects will be discussed in the *Hydraulic and Hydrological Processes* section below.

Direct effects of rock placement will include covering the existing substrate and changing the elevation of rock in that location. The estimated total footprint for all rock placement actions is approximately 82.36 acres (approximately 992,371 cy). This includes actions from stone placement at the trunk, root, head cap, spur groins, and barge offloading facilities. Of the approximately 82.36 acres of rock placement, approximately 49.91 acres (North Jetty approximately 15.41 acres; South Jetty approximately 27.2 acres; and Jetty

A approximately 7.3 acres) will be on top on relic stone above MHHW, and therefore have no direct effects on aquatic habitat. Of the remaining 32.45 acres of rock placement, 22.49 acres will be on top of existing rock in rocky subtidal habitats and intertidal habitat, and approximately 9.96 acres will be on top of sub-tidal and intertidal habitats that will change from sandy to rocky substrate (North Jetty approximately 2.18 acres; South Jetty approximately 3.06 acres; and Jetty A approximately 4.7 acres). The majority of habitat change will happen at the spur groin locations.

As summarized above, approximately 22.49 acres of rocky subtidal and intertidal habitat will have new rock placed on top of the existing rock. The subtidal and intertidal species, *e.g.*, barnacles, sea stars, anemones, mussels, in this approximate 22.49 acres of rocky habitat, will be affected. When repair and rehabilitation activities are completed, there will be an increase in rocky habitat for these subtidal and intertidal species. Effects on subtidal and intertidal species are not expected to meaningfully affect productivity and abundance as field sampling for benthic infauna densities in the subtidal habitats in MCR ranges between 7,999 taxa richness to 267,283 taxa richness per 10.8 square feet of subtidal substrate sampled (Siipola 1994).

While individual subtidal and intertidal species will be affected, the placement of rock in these habitat types is not likely to have significant effects on the subtidal and intertidal habitat affected or the subtidal and intertidal species in the MCR for the following reasons: as summarized above, rock placement will result in approximately 9.96 acres of sub-tidal and intertidal habitat to change from a sandy substrate to one with a rocky substrate. In these areas, subtidal and intertidal species associated with the sandy substrate will be affected. The new rocky substrate will be quickly recolonized by these subtidal and intertidal species that are associated with rocky habitat on the rest of the jetty system.

The approximate 9.96 acres of sandy substrate habitat is a small percentage of the total jetty area and a small percentage of the available adjacent remaining shallow-water sand habitat in the vicinity of the Jetties. Within an estimated 3-mile proximity of the MCR jetties, approximately 19,575 acres of shallow-water habitat exists, *i.e.*, anything -20 feet or shallower, of which 9.96 acres represents a maximum potential change in habitat type, sandy to rocky, of 0.05%.

Increases in suspended sediment will occur during rock placement. Residence time of suspended sediment in the water column is likely to be short lived and attenuate to background levels within minutes. Rock placement will take place in areas with continuous wave activity and are highly dispersive areas. Habitat-associated effects on water quality (*i.e.*, increases in suspended sediment) will be insignificant as natural background levels of suspended sediments in the vicinities of the Jetties tend to be high due to turbulent and dynamic hydraulic forces.

Therefore, NMFS concludes the effects associated with rock placement on estuarine, marine, sub-tidal and intertidal habitats will be insignificant.

Construction Access, Staging, Storage, and Rock Stockpiling. Activities related to staging, storage, and rock stockpiling will occur on an annual basis, throughout the year, and may occur at one or more jetties simultaneously. BMPs such as protective fencing, set-backs, and an erosion and sediment control plan or stormwater protection plan will be implemented to avoid stormwater erosion and run-off from disturbed areas. Whenever feasible, stabilizing dune vegetation and riparian vegetation will be preserved. Avoidance and minimization measures have reduced the construction footprint where possible. When construction activities are suspended for the season, appropriate demobilization and site stabilization plans will limit the distribution and duration of any effects. For higher value habits like marsh wetlands and slough sedge communities, activities will be limited to areas where previous disturbance and development have already occurred. Therefore, NMFS expects effects on fish-bearing waters to be negligible.

Effects to upland habitats will occur above mean high tide elevation and may include: repetitive ground disturbance, de-vegetation, residual rock side-cast, and soil compaction. Vegetation to be removed is located in upland areas above mean high tide elevation. Vegetation in these upland areas provides no functional habitat for listed species as the area is comprised of sand and European beachgrass. BMPs will prevent sediments disturbed by construction staging, storage, and rock stockpiling from reaching marine and estuarine waters.

Therefore, NMFS concludes the effects associated with construction access, staging, storage, and rock stockpiling on estuarine, marine, and upland habitats will be insignificant.

Dredging. Dredging will be performed before and during the construction and maintenance of barge offloading facilities, and is likely to occur during early summer, but is unlikely to occur at all facilities annually. It is likely only one or perhaps two facilities would be dredged on a periodic basis as needed. For Jetty A, the initial amount of material to be dredged is 60,000 cy with maintenance dredging at 80,000 cy per year of activity (2 years) for a total of 220,000 cy. For the North Jetty, the initial amount of material to be dredged is 30,000 cy with 30,000 cy per year of activity (9 years) for a total of 300,000 cy. For the South Jetty and South Jetty Area D, the initial amount of material to be dredged is 40,000 cy with 40,000 cy per year of activity (11 years) for a total of 480,000 cy.

The effects of dredging on physical habitat features include intermittent bottom elevation changes and intermittent increases in suspended sediment. Dredging will temporarily increase water depths of intertidal habitats to subtidal, or shallow subtidal habitats to deeper subtidal habitats. While dredging will change water depths in the dredged areas, the effects on habitat quality adjacent to the Jetties are unlikely to be significant as these areas are subject to stochastic changes associated with wave action, particularly winter storms, which can deposit ocean-derived sediment measuring several feet in a single storm. Dredging at Area D will temporarily increase water depths in the area delineated for dredging. While water depths in this area are less than -20 feet MLLW, NMFS does not expect dredging to result in significant effects to riverine habitats as this area represents 0.02% of the estimated 19,575 acres of shallow-water habitat in the MCR.

Increases in suspended sediment will occur during dredging. Increases in suspended sediment in the water column are likely to be short-lived and attenuate to background levels within minutes. This is because the dredging, especially in areas adjacent to the Jetties, will take place in areas with continuous wave activity and highly dispersive currents. Also, sediment tests have confirmed that material to be dredged is 97% or greater sand, which creates little suspended sediment when dredged. Because the dredged material is 97% or greater sand it does not pose a risk of resuspending contaminants.

Therefore, NMFS concludes the effects associated with dredging on estuarine and marine habitats and benthic infauna are insignificant.

Disposal of Dredged Materials. Disposal is likely to occur on an annual basis, originating from one or more of the offloading facilities. The duration of disposal will be limited, and disposal will likely occur early in the construction season prior to use of offloading facilities. As mentioned previously, all disposal of dredged material will be placed at previously evaluated and approved in-water disposal sites. NMFS has previously evaluated the effects of disposal of dredged materials at these disposal sites (NMFS 2005a) and concluded that disposal of dredged materials for the Columbia River operations and maintenance dredging program did not result in adverse effects to estuarine, marine habitats.

Therefore, NMFS concludes the effects of disposal of dredged materials on estuarine and marine habitats will be insignificant.

Barge Offloading Facilities. As described in the proposed action, the installation of 4 barge offloading facilities and one causeway is likely to occur once, likely in the late spring or early summer prior to or during the first season of construction on the associated jetty. Effects of barge offloading facility installation and removal are discussed under their respective sections, *i.e.*, *Rock Placement, Pile Installation and Removal, and Dredging*.

Pile Installation and Removal. For initial construction of all four facilities, up to 96 Z- or H-piles could be installed as dolphins, and up to 373 sections of sheet pile installed to retain rock fill. Installation of piles is likely to happen between May and June. Piles may be removed and installed several times using a vibratory hammer. NMFS conservatively estimates in this analysis that all the piles will be all be driven and removed, and that 31 piles will be driven and removed twice for a total of less than 1,000 pile driving or removed events. Installation and removal of piles with a vibratory hammer will introduce sound waves into the MCR area intermittently over 20 years.

Habitat-associated effects with pile installation and removal are in and of themselves insignificant. For example, the average sound pressure level recorded during a recent test pile program in Newport, Oregon in 2010 (NMFS 2010d), using vibratory hammers was

146 dB SEL-average, well below the potential onset of injury threshold of sound pressure levels of 206 dB, and accumulated sound exposure levels of 183 dB (for fish that weigh 2 grams or less) and 187 dB (for fish that weigh greater than 2 grams). The relevant issue is the sound exposure level (SEL), psi or dB, produced, expressed, and transmitted through the water and the potential effects, *e.g.*, barotrauma, the transient energy field poses to fishes. Effects to habitat, such as suspended sediment, are likely to be so minor and transient that they could not be measured against background levels.

Therefore, NMFS concludes effects associated with pile installation and removal on estuarine and marine habitats will be insignificant.

Wetland and Lagoon Fill and Culvert Replacement. Wetland (1.78 acres) and lagoon (4.71 acres) fills and culvert replacements will occur above the high tide line and will be functionally disconnected from the Columbia River as the wetland and lagoon areas are located on the landward side of North Jetty (Figure 2). The filling of the wetland and lagoon that drain into the MCR is likely to have small but insignificant effects on water quality and nutrient inputs to the Columbia River.

Therefore, NMFS concludes effects associated with wetland and lagoon fill and culvert replacement on estuarine and marine habitats will be insignificant.

Dune Augmentation. Under existing conditions, the shoreline at the root of the South Jetty will continue to erode and recede, resulting in a possible shoreline breach into Trestle Bay in approximately 8 to 16 years, and the MCR inlet would establish a secondary flow way from the estuary to the ocean along this area (south of South Jetty). Although the effects of preventing a breach at Trestle Bay on riverine and marine habitats and listed species are unknown and uncertain, the proposed action will maintain the primary flow from the estuary and result in limited changes to the existing physical nature of the inlet.

The dune augmentation at a beach below the South Jetty will occur above mean high tide. The Corps determined that the dune augmentation actions will have immeasurable effects on riverine and marine habitats. Since all work will occur above MHHW NMFS concludes effects associated with dune augmentation on estuarine and marine habitats will be insignificant.

Jetty Road System. The roads on top of the Jetties will be built with a mix of rock and sediment. These roads are likely to deteriorate during storm events. The rate of erosion and the release of substrate through the Jetties are likely to be immeasurable in terms of effects on estuarine and marine habitats.

Therefore, NMFS concludes effects associated with the jetty road system on riverine and oceanic habitats will be insignificant.

Construction-Associated Leaks and Spills. The Corps will require the contractor to provide a spill prevention and management plan that will include measures to avoid and minimize the potential for leaks and spills, and to respond quickly to minimize damages should spills occur. Good construction practices, proper equipment maintenance, appropriate staging set-backs, and use of a Wiggins fueling system, a pressure lock-out fueling device that prevents fuel leaks, would further reduce the likelihood of leak and spill potential and exposure extent and its associated effects. NMFS has determined that spills large enough to adversely affect habitat functions cannot be reasonably expected to occur.

Therefore, NMFS concludes effects associated with the construction and contaminants on estuarine, marine, and upland habitats will be discountable.

Hydraulic and Hydrological Processes. The United States Geological Survey (USGS) and Engineer Research and Development Center (ERDC) conducted numerical modeling studies to evaluate changes in circulation and velocity, salinity, and sediment transport at the MCR for various rehabilitation design scenarios of the MCR jetty system (USGS 2007). The purpose of the USGS evaluation was to assess the functional performance of the extended jetty system and to aid in the assessment of potential impacts to habitat from repair and rehabilitation. The proposed action is significantly different from what was modeled in this study, because under the current proposal the Jetties are not being built out to their original lengths. However, results under the larger build-out scenario are still relevant for comparing and evaluating previously estimated potential changes to the MCR system as a whole. Previous modeling work also remains reasonably valid for consideration because the current proposed action would cap the Jetties at their present location, which is essentially the same length as the original base conditions used for the previous models.

As summarized above, the hydraulic and hydrological models completed by the USGS and ERDC in 2007 make predictions based on previous MCR jetty designs that were larger but similar in shape to the current proposed action. It is likely that any previously predicted effects to hydraulic and hydrological conditions would be significantly greater than those effects under the current proposed action. Likewise, 2007 and 2010 models made predictions for the most high-energy time of the year, October and November, because these months represent the time at which the jetty rebuild is most likely to have significant hydraulic and hydrological effects. Therefore, the proposed action will have similar effects as modeled in 2007, but with significantly smaller magnitudes. These effects are described in detail below.

Water Circulation and Velocity. The primary factors controlling circulation in the Columbia River estuary are river flow, tides, and currents. The Columbia River estuary has a large range between high and low tides and receives a huge river discharge. These conditions result in rapid and turbulent currents. The variability in the above mentioned parameters also results in a large variability in velocity. Quinn (2005) noted that there is great spatial variation in estuaries and that physiochemical attributes of the water such as depth, salinity, temperature, turbidity, and velocity vary over complex temporal scales including season, lunar, and tidal periods. The USGS modeling results, for example, show that in near-surface waters near the landward portions of the North Jetty, velocities with tides can exceed 3.3 feet/second during August and September. Under the larger rebuild scenario, changes to bed and surface velocities and current directions predicted by the models were minor, particularly with respect to fluctuations that already occur. Therefore, any previously predicted effects to water circulation and velocity will be significantly less and of smaller magnitude under the current proposed action.

Salinity. As described above, the primary factors controlling circulation in the Columbia River estuary are river flow, tides, and currents. Salinity distribution is, in turn, determined by the circulation patterns and the mixing process which is driven by tidal currents. The variability in the above mentioned parameters results in a large variability in salinity. The USGS modeling results, for example, showed that in near-surface waters near the landward portions of the North Jetty, salinity naturally varies with tides from 12 parts per thousand (ppt) to 30 ppt during October-November (USGS 2007, Moritz 2010).

During the August-September timeframe, changes to bed layer salinity were predicted in the water between Jetty A and the North Jetty. An increase in range of mean salinities of 0-4 ppt from 26-28 ppt to 28-30 ppt was predicted to occur over some of this area (Moritz 2010, and USGS 2007). This could be calculated as up to approximately 15% change, but was still well under the 20 ppt (or up to 67%) range of natural variability.

A salinity pattern change was predicted for the near-surface layer in waters between Jetty A and the North Jetty, where mean salinity was also predicted to increase 0-4 ppt from 18-20 ppt to 20-22 ppt. For the near-surface layer, this increase in mean salinities included the area in close proximity to much of the landward portion of the North Jetty. For the near-surface layer, a decrease in mean salinities of 0-4 ppt from 12-14 ppt to 14-16 ppt was predicted to occur over a relatively small area south of West Sand Island, which is located just east of Jetty A (USGS 2007, Moritz 2010).

In summary, the larger rebuild scenario was predicted to have minor, localized effects on mean salinities. These resulting effects to salinity are minor with respect to fluctuations that already occur in the MCR. Therefore, the proposed action will have similar effects as modeled in 2007, but with significantly smaller magnitudes under the current proposed action.

Plume Dynamics. The Columbia River plume is the zone of freshwater/saltwater interface where the freshwater exiting the Columbia River meets and rises above the denser saltwater of the Pacific Ocean, just seaward of the MCR. The plume is formed as thin, buoyant lenses of fresher water flowing over denser, oceanic water and is more pronounced when flow from the river is large in comparison to tidal volume. The Columbia River plume is ephemeral (may persist for several hours) and is controlled by fluctuating tide. A frontal boundary (front) is formed between the river plume and adjacent marine waters. The front is richer in zooplankton than adjacent marine waters and plume waters, due to increased abundance of surface-oriented organisms (Morgan *et al.* 2005). The plume front is easily identified by well-defined horizontal gradients in salinity and water clarity and by the accumulations of foam and flotsam (De Robertis *et al.* 2005).

The USGS model for the larger rebuild scenario predicted small changes to residual velocity and current directions for both the bed layer and the near-surface layer for the August-September and October-November timeframes in the plume. A decrease in bed layer salinity of 0-4 ppt (from 28-30 ppt to 26-28 ppt) was predicted in the plume over an oval area west of the terminus of the North Jetty. Only small changes were predicted to residual bed load transport and residual total load transport within the plume for the August-September and October-November timeframes (USGS 2007, Moritz 2010).

As stated above for other effects to hydraulic/hydrological conditions, the changes that were previously predicted for the larger rebuild scenario are significantly less likely to be produced by the current proposed action and are likely to be of smaller in magnitude, duration, and extent because of the smaller scale of the proposed action.

Bed Morphology. Temporary effects from hydraulics and hydrologic process would occur as a single event with construction as described under Rock Placement. Any minor subsequent effects would be long-term, but are insignificant when considered within the range of natural dynamic conditions and are of limited geographical extent.

The larger rebuild scenario with spur groins would have caused some bed level changes along the seaward channel side of the North Jetty. The USGS model predicted changes for both modeled timeframes, but were more pronounced in the winter with an average differences of 8.3% in bed elevation of 4.1 to 4.9 feet change from the existing 39.4- to 78.7-foot depth. The predicted change is small considering the dynamic environment at the MCR. The ERDC modeling also predicted that a temporary increase in bed level due to sedimentation would occur upstream of the spurs and that a temporary decrease in bed level due to erosion would occur immediately downstream of the spurs. The larger rebuild scenario was predicted to change bed levels. The largest change to bed level predicted was hydraulic changes that led to a deeper water habitat than currently exists along the channel side of the seaward half of the North Jetty. For both the August-September and the October-November time frames the models predicted this change in bed level, but the change was more pronounced for the latter, with differences in bed elevation of 4.1 to 4.9 feet. However, this change is relatively small, because the water here is already 39.4 to 78.7 feet deep (Connell and Rosati 2007, Moritz 2010).

As stated above for other effects to hydraulic/hydrological conditions, the changes that were previously predicted for the larger rebuild scenario are likely to be of smaller magnitude because of the smaller scale of the current proposed action.

In summary, previous modeling results indicated the changes to velocities, currents, salinity, plume dynamics, and bed morphology are minimal under the much larger jetty length rebuild scenarios. Also, the existing or “original” conditions of the previous model represented jetty lengths that are retained under the proposed action. Based on these previous results, no significant overall changes to the hydraulics or hydrology, and associated processes of the MCR system are likely under the new, significantly smaller proposed action. Therefore, NMFS concludes that the hydraulic and hydrological effects from repair and rehabilitation of the Jetties on estuarine and marine habitats will be insignificant.

Occurrence of Listed Species in the Action Area

Salmonids. A variety of anadromous fish occur in the Columbia River near-and offshore areas. Occurrence of adult salmon in the offshore area is correlated primarily with their period of upstream migration. Juvenile salmon are present following their migration out of the Columbia River estuary, primarily in the spring.

Anadromous species occur throughout the year, with many using the estuary as a rearing and nursery area. Adult salmonids use the estuary during upstream migrations on their way to spawning grounds. Juvenile salmonids occur in the action area during their out-migration to the ocean (Figure 22 and Table 12). Juveniles that have already become smolts are present in the lower river for a short time period. Juveniles that have not become smolts, such as lower river stock Chinook subyearlings, spend extended periods of time rearing in the lower river. They normally remain in the lower river or estuary until summer or fall, or even until the following spring when they smoltify and then migrate to the ocean.

Figure 22. General trends in presence and abundance of juvenile salmonids in the lower Columbia River estuary at and downstream of Jones Beach (RKM 75; Dawley *et al.* 1986, McCabe *et al.* 1986, Roegner *et al.* 2004, Bottom *et al.* 2008, Carter *et al.* 2009).

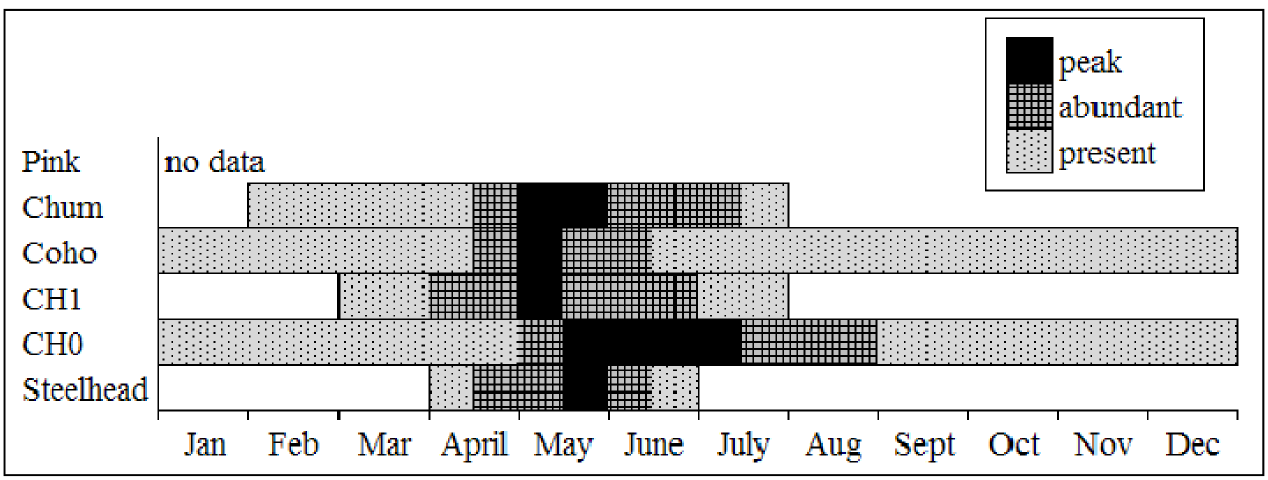


Table 12. Migration timing of juvenile salmon and steelhead (stock composite) in the Lower Columbia River based on Dawley *et al.* (1984) and ODFW (2003) (for chum salmon).

Species		J	F	M	A	M	J	J	A	S	O	N	D
Chinook	Yearling												
	Sub-yearling												
	The data gaps for sub-yearling Chinook in mid-September to mid-October and mid-December to mid-January are due to no sampling efforts.												
Chum													
Coho													
Sockeye													
Steelhead													

Dark shading represents peak (high abundance) migration. Light shading represents non-peak (low abundance) migration or rearing.

In 2005, Pacific Northwest National Lab (PNNL) initiated a multi-year study on acoustically tagged sub-yearling and yearling Chinook salmon and steelhead in the vicinity of the MCR North and South jetties (McMichael *et al.* 2006). Detection nodes were placed across the channel at RM 5.6 (primary node) and at RM 1.8 (secondary node). The secondary node did not extend all the way to the south side of the channel, however. As a result, fish could pass close to the South Jetty without being detected. A third set of detection nodes were placed near the North Jetty disposal area. Chinook salmon, both sub-yearling and yearling, were run-of-the-river fish tagged and released at the Bonneville Second Powerhouse bypass at the juvenile fish facility. Steelhead were Snake River-origin hatchery fish that were collected from fish transport barges between John Day and Bonneville dams and released mainly at Skamania Landing downstream of Bonneville Dam (some were transported and released at Astoria-Megler Bridge).

Based on a review of the 2005 through 2009 acoustic tag studies, the earlier studies deployed a narrower set of detection nodes. In subsequent years detection nodes were placed within ±300 feet of the North Jetty and ±800 feet of the South Jetty, with a detection range of 656 feet. Although fish may pass close to the South Jetty without being detected, the data from the multi-year study indicates that salmon and steelhead are oriented towards the navigation channel, and were consistently detected at distances greater than 656 feet from the North and South Jetties. Although this does not mean salmon or steelhead do not occur in the area between the Jetties and the navigation channel, an area measuring 3,200 feet wide and 6,500 feet wide, for the North Jetty and South Jetty, respectively, the data consistently indicate that salmon and steelhead in these areas outside of the navigation channel and between the Jetties are highly unlikely to occur within a few hundred feet of the Jetties. Furthermore, in addition to the information provided from the acoustic studies that report only 5.5% of fish detected occurred in the large area between the Jetties and the navigation channel, based on the description of the physical conditions described above under *Physical Environment at the MCR*, NMFS does not expect salmon or steelhead to occur in the construction zone as there is no biological reason, (*e.g.*, food, high-energy refugia, predator avoidance) for listed species to expend energy in this high-energy, hostile environment.

In the 2005 study, sub-yearling Chinook salmon moved back and forth past the nodes, remaining longer in the vicinity of the nodes than yearling Chinook salmon and steelhead, and tended to use nearshore areas (closer to the North Jetty) more than yearling Chinook salmon and steelhead. Yearling Chinook salmon and steelhead were concentrated more in deeper waters near the navigation channel than sub-yearling Chinook salmon. Larger fish tended to spend less time (9 to 24 minutes) within the MCR detection area that smaller subyearling Chinook (mean = 160 minutes). Yearling Chinook salmon and steelhead demonstrated a more directed emigration pattern relative to sub-yearling Chinook salmon. Sub-yearling Chinook salmon residence times within the detection areas were up to 15 to 20 times longer than yearling Chinook salmon and steelhead, usually passing on two to three ebb tides instead of one. Also, they took longer to reach the MCR from Bonneville Dam (average 4.5 days) than yearling Chinook salmon and steelhead (mean = 3.5 days; McMichael *et al.* 2006).

Though these metrics do not indicate actual time fish spent in the area around the Jetties themselves, they can be used to roughly extrapolate the overall range of residence time in the area. Considering the sampled area was approximately 70 acres out of approximately 2,600 acres across the river between the tips of the Jetties and Cape Disappointment, extrapolating from the data indicate that subyearling Chinook salmon could spend anywhere from a few hours to a maximum of approximately 4.6 days within the larger MCR area. Steelhead and yearling Chinook salmon spend even less time (usually a few hours to less than 1 day), as they are more directed in their emigration (McMichael *et al.* 2006). Furthermore, detections at each array were within a spherical range of approximately 656 feet, which means fish detected on arrays closest to the Jetties could still be up to 656 feet away from the structure itself (McMichael *et al.* 2010). Therefore, juvenile residence time within the MCR area and their potential exposure to jetty repair activities is of short and relatively limited duration.

The PNNL conducted subsequent similar studies that monitored and mapped migration pathways and habitat associations and behaviors relative to these pathways for acoustic-tagged juvenile yearling Chinook salmon, steelhead, and subyearling Chinook salmon downstream of Bonneville Dam as they migrated seaward through the Columbia River and its estuary. In the action area in 2009, receiver arrays were deployed across the entire river channel at two locations near the mouth of the river at East Sand Island and the Columbia River bar. Partial arrays were also deployed across the primary channel at the Astoria Bridge (McMichael *et al.* 2010).

The 2009 PNNL study indicated that acoustic-tagged yearling Chinook detected in the Bonneville Dam forebay and at the mouth of the Columbia River had a mean travel time of 3.4 days. Travel times decreased throughout the migration period. Travel rates of both yearling Chinook salmon and steelhead decreased as they moved between Oak Point and the Astoria Bridge, and increased and was more variable downstream of RM 13.7. Steelhead had a mean travel time of 3.1 days, and travel times decreased throughout the migration period. Subyearling Chinook salmon had a mean travel time of 4.1 days between RM 5.2 and RM 146. Travel times increased slightly throughout the migration period. Travel rate of subyearling Chinook salmon decreased as they moved between the array at Cottonwood Island, RM 8.7 and RM 70, and then increased and was more variable downstream of RM 13.7. Furthermore, timing of arrival of tagged fish at most arrays in the lower 31 miles of the estuary was influenced more by tide than by time of day for all three groups. Most tagged fish passed the lower three arrays on ebb tides, and this relationship was most evident when the difference between high and low tide was greatest (McMichael *et al.* 2010).

These studies give some indication of distribution near the Jetties and offloading facilities, although arrays were not specifically at these locations. Similar to the 2007 and 2008 studies, results obtained from 2009 also indicated that a greater proportion of subyearling Chinook salmon migrated through off-channel areas (outside the primary channel) than yearling Chinook salmon or steelhead, which concentrated more towards the navigation channel (McMichael *et al.* 2010). For 2007 and 2008 (when more arrays were located nearer the South Jetty than in 2005) migration patterns for subyearling Chinook indicated cross-channel distribution that in the vicinity of the MCR was more skewed towards the Washington shore. However, fish distribution did not peak at the nodes in closest proximity to the Jetties (Carter *et al.* 2009). Furthermore, in 2007, approximately 93% of juvenile yearling Chinook detected passed farther than 656 feet away from the North Jetty (656 feet is the approximate spherical detection radii of the arrays), and over 99% detected passed at an even greater distance away from the South Jetty (Carter *et al.* 2009). In 2008, approximately 96% of detected juvenile subyearling Chinook passed at a distance greater than 656 feet from the North Jetty, and over 99% passed at an even farther distance away from the South Jetty (Carter *et al.* 2009). Results for 2009 showed similar trends for all juveniles, and in particular subyearling Chinook.

In 2010, nodes were briefly moved for a short time so that one node was placed on the upriver side of Jetty A, one at the tip of Jetty A, and one on the western, oceanside of Jetty A (McMichael *et al.* 2010). Preliminary results indicated that 378 subyearling Chinook were detected at the upstream node, 385 at the tip, an only eight at the ocean side node. This seems to indicate that fish move downstream towards Jetty A without moving very close to Jetty A on the ocean side (McMichael *et al.* 2010). Furthermore, at the array near the mouth, in 2010, seven out of the 1,144 fish (or 0.6%) detected on the array passed on the node nearest the North Jetty (McMichael *et al.* 2010).

Green Sturgeon. Green sturgeon spend more time in the marine environment than other sturgeon species (Adams *et al.* 2002 and in press). Juvenile and adult green sturgeon are likely to use the action area as habitat for adult and subadult migration and feeding, as well as growth and development to adulthood by subadults. When not spawning, this anadromous species is broadly distributed in nearshore marine areas from Mexico to the Bering Sea (NMFS 2010e). Green sturgeon use bays, estuaries, and sometimes the deep riverine mainstem in lower elevation reaches of non-natal rivers along the west coast of North America, but the distribution and timing of estuarine use is poorly understood (NMFS 2010e). Green sturgeon in the ocean will usually remain inside the 328-foot depth contour (Erickson and Hightower 2004).

Observations of green sturgeon in the Columbia River are concentrated in the estuary but have been made as far upriver as Bonneville Dam. No evidence exists for spawning in this system (Rien *et al.* 2002). Radio-tagged southern DPS green sturgeon in the Sacramento River occur seasonally in northern estuaries including the Columbia River estuary during the summer and early fall (Moser and Lindley 2006). In the Columbia River, Israel and May (2006) found the percentage of southern DPS fish to exceed 80% of total northern and southern DPS fish during late summer and early fall of some years.

The Corps and USGS have recently been working on a study of green sturgeon in the Coos and Columbia River estuaries. Although results are preliminary and sample sizes are relatively small, acoustic receivers detected green sturgeon several times off the tip of Jetty A, near the North Jetty, and in the area of Social Security beach off the Clatsop Spit (Parsley 2010). Information about specific use in the action area is still under development.

The preliminary acoustic telemetry work by the USGS on green sturgeon in the Columbia River estuary included the placing of acoustic receiver arrays approximately 300 feet from Jetty A and the North Jetty. The USGS used both acoustic and pressure-sensitive tags for this study. The receivers were capable of detecting tagged fish within 2,000 feet of the receiver, with 70 percent detection efficiency. The pressure-sensitive tags were able to detect fish at minimum depths, *e.g.*, 100 feet. Both receivers cannot determine how close the fish are to the Jetties, only that the fish were within the range of detection.

Although the USGS acoustic telemetry study does not provide information on proximity of fish relative to the Jetties, the behavioral and distribution information available on green sturgeon and their use of the Columbia River suggests that green sturgeon are likely to be in deeper areas of the MCR. Although information on habitat preferences is limited for subadult and adult green sturgeon in the Columbia River, information on white sturgeon (*Acipenser transmontanus*) in the Columbia River suggests that larger fish tend to congregate in deep pools. In a study by Parsley and Beckman (1994) they reported average water depths for juvenile white sturgeon in the Columbia River of 55 feet. This suggests, assuming habitat preferences are similar between the two species, that green sturgeon are unlikely to be found in proximity of the footprint or construction zone of the Jetties, but located more towards the navigation channel at the MCR.

Eulachon. A large percentage of the total eulachon production originates in the Columbia River basin. Spawning occurs in the mainstem of the Columbia River upstream of the estuary (Emmett *et al.* 1991, Musick *et al.* 2000) in January or February (Beacham *et al.* 2005). Additionally, eulachon usually spawn every year in the Cowlitz River, with inconsistent runs and spawning events occurring in the Gray's, Elochoman, Lewis, Kalama, and Sandy rivers (ODFW and WDFW 2009). Prior to the construction of Bonneville Dam, occasional reports were received of smelt occurring upstream as far as Hood River, Oregon, and possibly farther (Smith and Saalfeld 1955). In times of great abundance, (*e.g.*, 1945, 1953) eulachon have been known to migrate as far upstream as Bonneville Dam (Smith and Saalfeld 1955, Howell et al 2001), and are suspected of passing through the ship locks, having reached the Klickitat River (Smith and Saalfeld 1955). Though eulachon have been observed migrating up the Columbia River, spawning has not been documented in the mainstem above RM 80 (Romano *et al.* 2002).

Larval forms outmigrate through the estuary and juvenile forms rear in marine waters extending out along the continental shelf (NMFS 2008a). Eulachon larvae are approximately 0.2 inches in length and, are rapidly flushed to the ocean, often within days of hatching, and subsist on their yolk sac during this downstream dispersal (WDFW and ODFW 2001).

Information on the distribution and ecology of juvenile eulachon is scarce because they are too small to be detected in fisheries surveys, and too large to capture in ichthyoplankton surveys (Hay and McCarter 2000). It is likely that juvenile eulachon rear in near-shore marine areas at moderate or shallow depth (Barraclough 1964) and feed on pelagic plankton, including euphausiids (krill). As they grow at sea, they tend to utilize waters of greater depths and have been found as deep as 2,051 feet (Allen and Smith 1988).

Adult eulachon range in size from 5.5 to 12 inches and are planktivorous in the ocean, but stop feeding when returning to fresh water to spawn (McHugh 1939, Hart and McHugh 1944). The homing instinct of eulachon is not clearly understood, but it is postulated that larvae may spend weeks to months in nearby estuarine environments, where they grow significantly in size and may develop the capacity to imprint on large estuaries and eventually home to these areas as adults (McCarter and Hay 1999, Hay and McCarter 2000).

Eulachon return to fresh water to spawn at 2 to 5 years of age. Spawning in the lower Columbia River can occur soon after freshwater entry (ODFW and WDFW 2009). Eulachon typically enter the Columbia River in early to mid-January (although a small 'pilot' run may occur in December), followed by tributary entry in mid- to late January. Peak tributary abundance is usually in February, with variable abundance through March and an occasional showing in April (ODFW and WDFW 2009). Therefore, adult eulachon are unlikely to be present as in-water work, which is scheduled for April through October with June through October being the most likely time for in-water work due to high ocean wave and high river flow conditions in spring, and river entry have little if any overlap.

Larvae eulachon may be present in the near-and offshore oceanic environments of the action area. Although most larval eulachon should have been flushed out of the estuary to the ocean prior to the April through October in-water construction period, it is likely that not all larvae will be pelagic by April or May.

Effects on Listed Species

NMFS expects rock placement and pile installation and removal to adversely affect Steller sea lions, pile installation and removal to adversely affect humpback whales, and maintenance dredging to adversely affect eulachon.

The NMFS expects effects of construction (*i.e.*, rock transport, rock placement, construction access, staging, rock stockpiling, dredging, disposal of dredge materials, barge offloading facilities, pile installation and removal, lagoon and wetland fill, culvert replacement, dune augmentation, water quality, hydraulic and hydrological processes) on salmon, steelhead, and green sturgeon to be insignificant or discountable.

The following is a discussion of the effect of each project element on listed species and the rationales supporting our effects analysis.

Pacific Salmon and Steelhead, Green Sturgeon, and Eulachon

Rock Transport. Loaded water-borne container traffic identified as foreign in- and outbound to/from Portland that would likely have crossed the MCR in 2008 totaled approximately 195,489 ships (Corps 2010). The number of additional barge trips per year attributable to the proposed action is likely to be somewhere between 8 and 25 ships. This represents a small annual percentage increase of 0.004 to 0.01% relative to the current number of other commercial and recreational vessels already using any of these potential routes. NMFS is not aware that ship traffic in the shipping lanes of the Pacific Coast or in the MCR is currently adversely affecting salmonid, eulachon, or green sturgeon behavior. Therefore, an increase in ship traffic of 0.004 and 0.01% is unlikely to affect salmon, steelhead, eulachon, or green sturgeon behavior, fitness, migration patterns, physiology, or spatial distribution, especially since barges will be traveling at less than 12 knots. Therefore, NMFS concludes that the effects associated with rock transport on listed species are discountable.

Construction Access, Staging, Storage, and Rock Stockpiling. As described in the *Effects on Habitat* section above, effects to upland habitats will occur above mean high tide elevation. Vegetation to be removed is located in upland areas above mean high tide elevation; vegetation in these upland areas provides no habitat functions for listed species as the area is comprised of sand and European beachgrass, and BMPs will prevent disturbed sediments created by construction staging, storage, and rock stockpiling from reaching marine and estuarine waters. Therefore, NMFS concludes effects associated with construction access, staging, storage, and rock stockpiling on listed species are discountable.

Rock Placement. NMFS does not expect any listed species to be injured or killed during or as a result of placing rock for repairs and rehabilitation. This is because most of the rock will be placed on existing, relic stone that is not used by listed species (Steller sea lions being the exception). On average, 55% of all rock will be placed above MHHW, and will have no effect on listed species, except Steller sea lions. On average 24% of all rock will be placed between MLLW and MHHW. Therefore 79% of the rock will be placed in areas where few if any listed species are likely to occur, significantly reducing the probability for listed species to be injured or killed. While on average 21% of the rock will be placed below MLLW, NMFS does not expect listed species to occur in this zone as there is no biological reason (*e.g.*, food, high-energy refugia, predator avoidance) for listed species to expend energy in this high-energy, hostile environment.

Adult salmonids use deep-water water habitats when migrating through the MCR and adult and sub-adult green sturgeon migrate in deep water at the MCR, farther offshore than the spur groins and barge offloading facilities. Because rock placement will occur during June through October, eulachon larvae are unlikely to be present, and construction-related effects are expected to be discountable.

NMFS expects affects to behavior, fitness, migrating rates, or spatial distribution for adult eulachon will be insignificant as the spur groins are small (60 to 250 feet) lateral extensions of the Jetties that extend from the jetty roots to enhance stabilization of the jetty base. The MCR is more than 2 miles wide and affects on adult eulachon behavior, fitness, migration patterns, physiology, or spatial distribution are not reasonably certain to occur.

Therefore, NMFS concludes effects associated with the rock placement on listed species, are discountable.

<u>Habitat-Species Effects.</u> As described in the *Effects on Habitat* section, 9.96 acres of sandy, shallow-water inter-tidal habitat will change to rocky inter-tidal or above-tidal habitat, and 22.49 acres of rocky sub- or inter-tidal habitat will change to rocky sub-, inter-, or above- tidal habitat. The proposed habitat-type changes are not likely to result in adverse effects on behavior, fitness, migration patterns, physiology, or spatial distribution of juvenile salmon and steelhead, adult salmon and steelhead, green sturgeon, and eulachon, for the following reasons.

For salmon and steelhead, green sturgeon, and eulachon, the MCR is not used for extended periods of time, and the research on juvenile salmon and steelhead behavior at the MCR suggest that the Jetties provide no ecological function for behavioral or physiological requirements as they migrate to the ocean.

Within an estimated 3-mile proximity of the MCR jetties, approximately 19,575 acres of shallow water (-20 feet MLLW or shallower) habitat exists, of which 9.96 acres represents a conversion of 0.05 % of the shallow-water habitat. In comparison to higher peaks in distribution nearer the navigation channel, only a small percentage of juvenile salmon and steelhead, *e.g.*, approximately 5.5% use the areas between the navigation channel and the Jetties.

Based on a review of the 2005 through 2009 acoustic tag studies, the earlier studies deployed a narrower set of detection nodes. In subsequent years detection nodes were placed within ±300 feet of the North Jetty and ±800 feet of the South Jetty, with a detection range of 656 feet. Although fish may pass close to the South Jetty without being detected, the data from the multi-year study indicates that salmon and steelhead are oriented towards the navigation channel, and were consistently detected at distances greater than 656 feet from the North and South Jetties. Although a small percent occurred in the area between the Jetties and the navigation channel, an area measuring 3,200 feet wide and 6,500 feet wide, for the North Jetty and South Jetty, respectively, the data consistently indicate that salmon and steelhead in these areas outside of the navigation channel and between the Jetties are highly unlikely to occur within a few hundred feet of the Jetties. Furthermore, based on the description of the physical conditions described above under *Physical Environment at the MCR*, NMFS does not expect salmon or steelhead to occur in the construction zone as there is no biological reason, (*e.g.*, food, high-energy refugia, predator avoidance) for listed species to expend energy in this high-energy, hostile environment..

Residence time of juveniles within the larger MCR area ranges from a few hours up to, at most, a few days for the less-directed subyearling Chinook emigrants. The residence of these fish within proximity of the Jetties is therefore likely to be even shorter than the above estimates. While green sturgeon are likely to occur in the MCR as they enter and exit the Columbia River, it is likely they will be deep pools or the navigation channel rather, than near the Jetties. Eulachon are not dependent upon these rocky sub- or inter-tidal habitats in the MCR for spawning or emigration of larvae.

The anticipated area of shallow-water habitat to be altered by the proposed action intermittently is so small compared to the overall area available in the MCR, 0.05% of the area, that no significant reduction in prey available to listed species or behavioral effects are likely to result. More importantly, salmonids in the MCR feed primarily on marine insects, euphausiids (krill), zooplankton, crab megalopa, fishes, *e.g.*, Pacific herring, Groot and Margolis (1991), as opposed to benthic organisms.

Therefore, NMFS concludes effects associated with the rock placement and habitat changes on listed species will be insignificant.

Fish Predation. While piscivorous fish (*e.g.*, Pacific staghorn sculpin (*Leptocottus armatus*), and lingcod (*Ophiodon elongates*) may occupy suitable areas of new rock, these species currently occur at the Jetties and it is most likely these fish will recolonize areas where rock is being placed on existing rock habitat. Therefore, it is unknown whether piscivorous fish would increase or merely redistribute. Even if the number of piscivorous fish along the Jetties increased, it is unknown if predation rates on listed species would increase, especially since few if any listed fish are likely to be within a few hundred feet of the Jetties, based on the acoustic telemetry data, and the harsh physical environmental conditions.

As a result of jetty repairs and rehabilitation, NMFS does not expect adult or larval life stages of eulachon to be subject to potential increases in predation associated with the proposed action as: (1) There is no data available to suggest a relationship, and (2) larval eulachon are likely too small at 0.2 inches to provide any energy benefit to predators like Staghorn sculpin and lingcod.

NMFS does not expect adult and juvenile green sturgeon, adult salmon and steelhead to be affected by the proposed increase in rocky habitat for predators because they are too large to be eaten by these predators.

The proposed increase in rocky habitat and potential increase in piscivorous fish density is not reasonably likely to lead to increases in predation rates on listed fish by piscivorous fish for the following reasons:

1. The acoustic telemetry studies suggest only a small percentage of juvenile salmon and steelhead, approximately 5.5% use the areas between the Jetties and the navigation channel. This indicates that very few if any of listed salmon and steelhead will pass close enough to the Jetties to be consumed via ambush predation.
2. The MCR is a high energy, stochastic environment even during summer and fall when most of the repair and rehabilitation activities will take place, and residence time of juveniles within the larger MCR area ranges from a few hours up to at most a few days.
3. The increase in the jetty prism and expansion of the footprint below MHHW will be very small relative to the existing structure; therefore, the increase in piscivorous fish habitat and the potential increased recruitment of piscivorous fish will also be very small relative to the current number of those already along the Jetties.

Based on the above, NMFS concludes predation-associated effects on listed species are discountable.

<u>Bird Predation.</u> Key avian predators in the vicinity of the structures includes Bonaparte's gull (*Larus philadephia*), surf scoter (*Melanitta perspicillata*), common loon (*Gavia immer*), Pacific loon (*Gavia pacifica*), cormorants (*Phalacrocorax* spp.), Northwestern crow (*Corvus caurinus*), tern (*Sterna* spp.), Western grebe (*Aechmophorus occidentalis*), and bald eagle (*Haliaeetus leucocephalus*). The proposed increase in rock, particularly above MHHW, is reasonably likely to be used for perching by piscivorous birds. However, perching opportunities are already abundant along the Jetties and in the MCR. Neither avian density nor avian predation success in the MCR is likely to be limited by the quantity of rocky perches. Therefore, new perching sites are not likely to increase avian predation in a way that could be meaningfully attributed to the proposed action. Therefore, NMFS concludes predation-associated effects of the proposed action on listed species are discountable.

Mammal Predation. Marine mammals (*i.e.*, Steller sea lions, California sea lions) already use rock on the Jetties as a haul-out, mostly at the South Jetty. These animals likely prey on salmon, steelhead and sturgeon (green and white) in the MCR. It is unlikely that the quantity of haul-out space in the MCR would increase the size of marine mammal populations. The increase in haul-out area above MHHW may provide more surface area for marine mammals, but it is unlikely to increase the number of marine mammals at the MCR as this area is not a rookery. Therefore, the increase in haul-out space is unlikely to increase the magnitude, rate, or intensity of existing predation on listed species.

Dredging. The most likely adverse effect on listed species associated with dredging is entrainment. Entrainment studies of out-migrating fish carried out by Larson and Moehl (1999) at the MCR during May through October, the peak out-migration period of salmon and steelhead in the Columbia River basin, reported no entrained salmon or steelhead. The 4-year study examined 798 disposal samples. In Grays Harbor, Washington, four independent studies that monitored 798 disposal samples resulted in entrainment of 1 chum salmon over the 5-year study period (Bengston and Brown 1977, Tegelberg and Arthur 1977, Stevens 1981, and Armstrong *et al.* 1982, as cited in R2 1999).

An entrainment study carried out by R2 in 1999 examined 391 disposal samples (140 samples from the Columbia River and 251 from the Oregon Coast) and reported entrainment of two Chinook salmon at the Columbia River site. The R2 studies occurred during May through August, the peak out-migration period of salmon and steelhead in the Columbia River basin.

Buell *et al.* (1992) carried out entrainment studies on the Columbia River between RMs 102.2 and 102.5. Buell *et al.* monitored maintenance dredging of 700,000 cy between March 24 and April 10, the time of peak out-migration of salmon and steelhead in the Columbia River basin. In the Buell *et al.* study, no salmon or steelhead were entrained.

Braun (1974), as cited in Reine and Clarke (1998), reported no salmon fry entrained as a result of dredging in the Fraser River. Carlson *et al.* (2001) examined the vertical distribution of juvenile salmon in the Columbia River between RMs 32 and 43 and reported that juvenile salmon were, on average 7 to 27 feet from the bottom of the river.

Looking at the information in Larson and Moehl (1999), which examined 798 disposal samples from the MCR, approximately equal to 4 million cy of dredged material, during peak out-migration for salmon and steelhead, and the fact that they reported no entrainment of salmon or steelhead, it is unlikely that dredging of 780,000 cy spread out over a 20-year period will entrain any salmon or steelhead. Additionally, the Buell *et al.* (1992) study, which examined disposal samples for 9 days of dredging and 700,000 cy, and at depths ranging between 60 and 80 feet in the Columbia River, during the peak out-migration of salmon and steelhead, and the fact that they reported no entrainment of salmon or steelhead, it is unlikely that dredging of 780,000 cy spread out over a 20-year period will entrain any salmon or steelhead. Based on the above assessment of the literature that examined entrainment of fishes in Oregon, Washington, and British Columbia, especially the Larson and Moehl (1999) and Buell *et al.* (1992), the information on the vertical distribution of juvenile salmon in the Columbia River, the operations of dredging, *i.e.*, keeping the draghead/cutterhead below the bottom of the river, and the proposed BMPs to place the draghead/cutterhead motors in neutral if they rise 3 feet above the bottom, NMFS considers the probability of entrainment of listed species to be discountable, except for eulachon.

NMFS expects a small percentage of the approximate 1,900,000,000 to 6,500,000,000 eulachon larvae produced each year in the Columbia River basin (based on 2009 spawner biomass estimates, NMFS 2010a) to be entrained during dredging since dredging may overlap with eulachon emigration in late spring or early summer. Since eulachon larvae are dispersal migrants and may occur anywhere in the water column, NMFS considers the entrainment of larvae eulachon to be reasonably certain to occur. Entrainment will kill these eulachon larvae. Nonetheless, NMFS expects the magnitude of effect (*i.e.*, number of larvae entrained) will be small because: (1) Dredging will take place below the river bottom; (2) the dragheads or cutterheads will not be engaged if raised more than 3 feet above the river bottom; (3) the relative volume associated with dredging compared to the volume of the river flow is approximately 0.0001%; and (4) the timing of dredging will range from 3.3 to 13.3 hours per year, relative to the total outmigration period of larval eulachon of 95 to 200 days.

Dredging is likely to entrain benthic infauna. However, the magnitude and significance of effects is likely to be insignificant for listed species, as the small quantity of material dredged each year, 20,000 to 80,000 cy, represents a fraction of habitat available for benthic infauna in the MCR, *e.g.*, benthic infauna densities in the subtidal habitats in MCR ranges between 7,999 individuals to 267,283 individuals per 10.8 square feet of subtidal substrate sampled (Siipola 1994). More importantly, these areas represents a minor source of food for listed species as the primary forage items for juvenile salmon and steelhead in the MCR are marine-based, *e.g.*, marine insects, euphausiids (krill), zooplankton, crab megalopa, and fishes, Groot and Margolis (1991). Because eulachon larvae feed on plankton, their foraging habitat will not be affected by dredging. Therefore, NMFS does not expect effects associated with dredging to adversely affect behavior, fitness, migration patterns, physiology, or spatial distribution for listed species.

Increases in suspended sediment will occur during disposal. Residence time of suspended sediment in the water column is likely to be short, and increases will attenuate to background levels within minutes because the dredged material is comprised of 97% or greater sand. Dredging, especially in areas adjacent to the Jetties, will take place in areas where sediment tests have confirmed that material to be dredged is 97% or greater sand. The dredging volume will be small, between 20,000 and 80,000 cy per year, and the dredged material does not pose a risk as a source of contaminants because it consists of very little organic matter for contaminants to bind to. Based on these factors, NMFS does not expect dredging to adversely affect water quality in a manner that would meaningfully affect the behavior, fitness, migration patterns, physiology, or spatial distribution for listed species. Therefore, NMFS concludes that effects associated with dredging on listed species will be insignificant, except for eulachon.

Disposal of Dredged Materials. Disposal is likely to occur on an annual basis originating from one or more of the offloading facilities. The duration of disposal will be limited to 1 to 3 hours of disposal per year. As mentioned previously, all disposal of dredged material will be at previously evaluated and approved in-water disposal sites. NMFS has previously evaluated the effects of disposal of dredged materials at these disposal sites (NMFS 2005a), on listed fish. Using the model in NMFS 2005a to estimate the number of listed fish potentially affected by disposal, NMFS estimates that between 0.000045 to 0.00018 fish per year may be affected from disposal. Based on this estimate, NMFS concludes that effects associated with disposal of dredged materials on listed fish are discountable.

Increases in suspended sediment will occur during disposal. Residence time of suspended sediment in the water column is likely to be short, and increases will attenuate to background levels within minutes because the dredged material is comprised of 97% or greater sand. Dredging, especially in areas adjacent to the Jetties, will take place in areas where sediment tests have confirmed that material to be dredged is 97% or greater sand. The dredging volume will be small, between 20,000 and 80,000 cy per year, and the dredged material does not pose a risk as a source of contaminants because it consists of very little organic matter for contaminants to bind to. Based on these factors, NMFS does not expect dredging to adversely affect water quality in a manner that would meaningfully affect the behavior, fitness, migration patterns, physiology, or spatial distribution for listed species. Therefore, NMFS concludes that effects associated with disposal of dredged materials on listed species will be insignificant.

Barge Offloading Facilities. As described in the *Effects on Habitat* section, the installation of four barge offloading facilities and one causeway is likely to occur once, likely in the late spring or early summer prior to or during the first season of construction on the associated jetty. Effects of barge offloading facility installation and removal are discussed under the sections *Rock Placement, Pile Driving, and Dredging* as those are the components of constructing the facilities.

Pile Installation and Removal. As described in the *Effects on Habitat* section, up to 96 Z- or H-piles (12 to 16 inch diameter) could be installed as dolphins, and up to 373 sections of sheet pile installed to retain rock fill. Installation of piles is likely to happen between April and June and will be done using vibration. Piles may be removed and installed several times for a total of 1,000 pile driving or removed events. Installation and removal of piles with a vibratory hammer will introduce sound waves into the MCR area intermittently over 20 years.

Injury and death of fish from underwater noise are caused by rapid pressure changes, especially on gas-filled spaces in the bodies of fish. For this analysis, NMFS is assuming that vibratory pile driving has a similar effect on eulachon and green sturgeon as it does on salmonids, even though eulachon do not have swim bladders.

Generally, sounds from vibratory hammers are generally 10-20 dB lower than those from impact pile driving (CalTrans 2009, 4-16). While peak sound levels generated by vibratory hammers can exceed 180 dB, the sound levels rise more slowly than the sound levels generated by impact hammers (CalTrans 2009). Therefore, vibratory hammers avoid the abrupt over-and under-pressure changes exhibited by impact hammer use. General agreement does not exist on what vibratory sound exposure level (SEL) threshold value should be used for fish injury, although the likely range is 187 to 220 dB (CalTrans 2009, 4-22).

The average sound pressure levels recorded during a recent test pile program during vibratory hammering was 160 dB (peak-average); 199 dB (peak-maximum), 146 dB (SEL-average); and 181 dB (SEL-maximum) (NMFS 2010b). Therefore, given the absence of large over/under pressure changes, the understanding that injury SEL threshold values are likely in the 187 to 220 dB range, and that SEL values for vibratory hammer use are likely to be less than the discussed injury threshold, NMFS expects the proposed action would not result in the injury of fish present in the action area. Furthermore, while it is a reasonable hypothesis that SEL below 187 dB may result in behavioral responses, the data is inconclusive to determine a threshold for salmonid fishes, green sturgeon, and eulachon. Nonetheless, the data from the test pile program suggest that fishes in close proximity to the pile during installation or removal are unlikely to exhibit any behavioral responses as the reported SEL at 146 dB SEL-average is significantly below the 187 dB potential injury onset threshold. To assess potential behavioral responses in fishes, NMFS calculated the root mean square for 150 dB threshold to be at 328 feet from the source. NMFS expects few, if any, fish within a few hundred feet of the Jetties, based on the acoustic telemetry data, and therefore does not expect pile installation or removal to illicit behavioral responses in fishes.

Based on the above information, NMFS does not expect sound generated from pile installation and removal using a vibratory hammer to cause adverse effects to behavior, fitness, migration patterns, physiology, or spatial distribution of listed species, except Steller sea lions and humpback whales, which are analyzed later in this Opinion. Therefore, NMFS concludes effects associated with pile installation and removal on Pacific salmon and steelhead, green sturgeon, and eulachon will be insignificant.

Wetland and Lagoon Fill and Culvert Replacement. As described in the Effects on Habitat section, wetland (1.78 acres) and lagoon (4.71 acres) fills and culvert replacements will occur above the high tide line and will be functionally disconnected from the Columbia River as the wetland and lagoon areas are located on the landward side of North Jetty (Figure 2). The filling of the wetland and lagoon that drain into the MCR is likely to have small but insignificant effects on water quality and nutrient inputs to the Columbia River. Therefore, NMFS concludes that effects associate with wetland and lagoon fill and culvert replacement on listed species will be insignificant.

Dune Augmentation. The dune augmentation at a beach below the South Jetty will occur above mean high tide. The Corps determined that the dune augmentation actions will have immeasurable effects on listed species. Since all work will occur above

MHHW, NMFS concludes effects associated with dune augmentation on listed species will be insignificant.

Jetty Road System. As described in the *Effects on Habitat* section, the roads on top of the Jetties will be built with a mix of rock and sediment. These roads are likely to deteriorate during storm events. However, the rate of erosion and the release of road base materials through the Jetties are likely to be immeasurable as washout of the road base will occur during winter storms when waves overtop the Jetties and wave-generated suspended sediment is very high. Therefore, NMFS concludes effects associated with the jetty road system on listed species are insignificant.

Construction-Associated Leaks and Spills. As described in the *Effects on Habitat* section, the Corps will require the contractor to provide a spill prevention and management plan that will include measures to avoid and minimize the potential for leaks and spills to respond quickly to minimize damages should spills occur. Good construction practices, proper equipment maintenance, appropriate staging set-backs, and use of a Wiggins fueling system would further reduce the likelihood of leak and spill potential and exposure extent and its associated effects. NMFS has determined that spills large enough to adversely affect habitat functions cannot be reasonably expected to occur.

Therefore, NMFS concludes effects associated with the construction and contaminants on listed species are discountable.

Hydraulic and Hydrological Processes. As described in detail in the *Effects on Habitat* section, previous modeling results indicated the changes to velocities, currents, salinity, plume dynamics, and bed morphology were minimal under the much larger jetty length rebuild scenarios. Based on these previous results, no significant overall changes to the hydraulics or hydrology, and associated processes of the MCR system are likely under the new, significantly smaller proposed action. The modeling results on hydraulic and hydrological processes was run for a significantly larger project, *e.g*., restoring the South Jetty to its original length—an additional 5,000 feet in length from its present location. Those modeling results showed minor changes to velocities, currents, salinity, plume dynamics, and bed morphology, all within the range of variability. Because the current proposed action is significantly smaller, *e.g.*, no restoration of jetty lengths, the effects on velocities, currents, salinity, plume dynamics, and bed morphology are likely to be significantly less than previously determined. Although it is likely that listed species cue in on these parameters while in the MCR area, minor and intermittent changes to velocities, currents, salinity, plume dynamics, and bed morphology associated with the proposed action are within the range of natural variability and any connection to meaningful changes, positive or negative, are not possible to quantify.

Therefore, NMFS concludes that there are no hydraulic and hydrological-associated effects on listed species from repairs and rehabilitation of the Jetties.

Mitigation. The Corps estimated that a total of 38.28 acres of wetland habitats will be filled or degraded. The Corps is proposing a 2:1 mitigation ratio for wetland impacts for a total of 76.56 acres of restoration. Short-term effects associated with these activities are described above under *Habitat-Species Effects* and *Wetland and Lagoon Fill and Culvert Replacement*. In the long term, these habitat restoration actions will improve intertidal and subtidal estuarine habitats for listed species.

Steller Sea Lions

The only proposed activities NMFS anticipates will affect Steller sea lions are rock placement and pile driving, as described in detail below.

<u>Rock Placement</u>. Some Steller sea lions using haulout sites (rubble mound or concrete block) on the South Jetty are reasonably likely to be disturbed by the proposed rock placement activities. The response of Steller sea lions to the proposed rock placement may include alert behavior, approaches to the water, and flushes into the water. These potential disturbances could be caused by the movement of construction machinery and/or the noise produced by the machinery. The proposed action may also include measures to intentionally deter the Steller sea lions from using the portion of the jetty where work will occur. Such activities will be authorized under MMPA section 109(h)(1)(a), and the Steller sea lion regulations at 50 CFR 223.202(b)(2) should deterrence become necessary to protect the animals from injury during construction.

Sea lions are likely to be disturbed during the rehabilitation of the South Jetty cap and 500 feet of the jetty trunk. Steller sea lions will likely be hauling out in this area for the duration of the proposed project, *i.e*., intermittently for the next 20 years. The remaining majority of construction work will occur a significant distance from the nearest location where Steller sea lions have been observed hauling out. The number of Steller sea lions that will be incidentally or purposefully disturbed during the 20 year span of the proposed action is unknown, but all individuals that use the haulout are likely to be exposed to these activities.

The number of Steller sea lions exposed daily will vary based on weather conditions, season, and daily fluctuations of abundance at the South Jetty. Given the time of year that most of the placement will occur (spring/summer), the number of Steller sea lions affected daily could range from between 200 to 600 animals, based on past surveys (see Status of the Species). The number of Steller sea lions affected daily is likely to increase over the 20 years of project activities, because the population is currently increasing at 3% per year. It is likely that individuals will be repeatedly exposed to the rock placement activities over the 20-year period. Behaviorally, Steller sea lions may respond to rock placement by vacating the area. Some sea lions may redistribute themselves along portions of the jetty away from construction activities and to other haul out sites in the lower river and along the coast to the south and north.

Steller sea lions were flushed into the water during the repairs that were performed on the South Jetty in 2006 and 2007 (refer to NMFS No.: 2005/06359), and the effects of this proposed action are expected to be similar. During construction in 2006 and 2007, sea lions were often seen in the water close to the jetty and to a lesser extent on the jetty but appeared to be unaffected by construction activities. They often swam close to construction activities and at times appeared to feed in close proximity to construction activities. Two disturbances of pinnipeds were reported during the 2007 interim repairs. The majority of Steller sea lions occurring on the concrete block structure were far away from construction activities and undisturbed.

Based on these past responses to similar activities, NMFS finds it likely that Steller sea lion exposure to rock placement activities will change their use of the South Jetty area and the amount of time they would otherwise spend foraging in the immediate vicinity. However, there are alternative foraging areas available to the affected individuals. Repetitive, short-term displacement is likely to cause repetitive, short-term disruptions in their normal behavioral patterns at the South Jetty.

Pile Driving. As described in the proposed action and effects to the environment, approximately 24 Z- or H-piles of 12 to 16 inches in diameter could be installed as dolphins, and up to 94 sections of Z or H sheet pile (24 inch) could be installed to retain rock fill. The piles for this facility are likely to be installed as close as 600 feet from the rubble mound and 1,400 feet from the concrete block structure but as far as 6,000 feet from the concrete block structure used by Steller sea lions.

NOAA is currently developing comprehensive guidance on sound levels likely to cause injury and behavioral disruption for marine mammals in the context of the Marine Mammal Protection Act and the ESA, among other statutes. Until formal guidance is available, NMFS uses conservative exposure thresholds of sound pressure levels from broadband sounds that cause behavioral disturbance (160 dBrms re: 1µPa for impulse sound and 120 dBrms re: 1µPa for continuous sound) and injury (190 dBrms re: 1µPa for pinnipeds) (70 FR 1871). In the air, sound pressure levels greater than 100 db re:20µPa have been shown to affect behavior.

Based on these conservative thresholds, the Corps anticipates that their proposed pile driving and removal would produce sound pressure levels that are likely to disturb Steller sea lions. Underwater sound produced by the proposed vibratory pile driving and removal is anticipated to be below the injury threshold at the source. Based on conservative sound modeling, noise from vibratory installation and removal will attenuate to the 120 dB disturbance threshold within 6.2 miles (in the direction of the ocean, whereas land would be encountered on either shore of the river system prior to attenuating to the 120 dB threshold). As described for rock placement above, all individual Steller sea lions that use the South Jetty haulout are likely to be exposed to pile driving sound above the in-air and underwater disturbance thresholds of 100 dB and 120 dB, respectively, repeatedly over the 20-year period when pile driving would intermittently occur. Given the time of year that most of the pile driving would occur (spring/summer), the number of Steller sea lions affected daily could range from between 200 to 600 animals, and could increase over time because the population is growing at a rate of 3% annually (see Status of the Species).

NMFS finds it likely that Steller sea lions will be exposed to and disturbed by sound generated by pile driving activities. Steller sea lions will likely spend less time at the South Jetty haulout or foraging in the immediate vicinity. However, there are alternative foraging and haul out areas available to the affected individuals. Repetitive, short-term displacement is likely to cause repetitive, short-term disruptions in their normal behavioral patterns at the South Jetty.

Humpback Whales

The only proposed activities NMFS anticipates may adversely affect humpback whales are pile driving activities, as described in detail below.

Pile Driving. Proposed activities with potential stressors that may affect humpback whales include in-water noise from pile driving that extends out 6.2 miles into the ocean from the jetty locations. Based on the sound thresholds for marine mammals described above (see the Effects Analysis for Steller sea lions), the Corps anticipates that their proposed pile driving and removal would produce sound pressure levels that could disturb humpback whales. Sound produced by the proposed vibratory pile driving and removal is anticipated to be below the injury threshold at the source. Under-water sound produced by vibratory pile installation and removal is estimated to attenuate to the 120 dB disturbance threshold within 6.2 miles. All individual humpback whales that feed or migrate through this area up to 8.6 miles off the mouth of the Columbia River are likely to be exposed to pile driving sound above the 120 dB threshold repeatedly over the 20-year period when pile driving would intermittently occur.

As described in the Status of the Species section, we do not have fine-scale information about humpback whale use of the project area, but their occurrence in the project area is likely given their general tendency to occupy shallow, coastal waters when foraging, and the available information on their fine-scale use of a proximate location (Grays Harbor) during spring and summer months. Based on this information, humpback whales are likely to pass through and may forage in the project vicinity, within 6.2 miles of the Jetties or within approximately 8.6 miles of shore. NMFS finds it reasonable to assume that the number of humpback whales that may forage or pass through the project vicinity when pile driving would occur is best estimated by evaluating humpback whales use patterns at the most proximate location where data is available, in this case off of Grays Harbor. Given the time of year that most of the pile driving would occur (spring/summer), humpback whales may be in the project vicinity on about 50% of the days and the number of humpback whales affected could range between 0 - 19 whales per day, based on surveys off of Grays Harbor (see Status of the Species). It is likely that individuals will be exposed repeatedly to the pile driving activities over the 20 years these activities are proposed.

Exposure of humpback whales to sound at or above 120 dB threshold is likely to elicit behavioral responses within the range of previously documented responses by low-frequency hearing specialists to non-pulse sound. Southall *et al*. (2007) conducted a comprehensive literature review of the effects of sound on marine mammals and based on previous studies of low-frequency hearing specialists and their responses to non-pulse sound, they conclude that there is an increasing probability of avoidance and other behavioral effects in the 120 to 160 dB range (summarized in Table 14 from Southall *et al.* 2007). However, they caution that there is considerable variability in received levels associated with behavioral responses, and that context (*i.e*., novelty of the sound and what the animals are doing in the area) is likely as important if not more important than exposure level in predicting behavioral response.

There are no studies that document the response of low-frequency sound specialists to vibratory pile driving. Humpback whales exposed to sound from the proposed vibratory pile driving are unlikely to detect the physical presence of pile driving machinery (*i.e*., they are more likely to occur closer to the edge of the 6.2-mile radius area). For this reason, NMFS finds it reasonable to assume that of the non-pulse sound sources that have been studied, studies that have documented response to playback sound, as opposed to studies that documented response to both sound and physical presence of machinery, are most applicable to the likely response under evaluation (*i.e*., gray whales migrating: Malme *et al*. 1983, 1984, and gray whales feeding: Malme *et a*l. 1986). These studies documented responses that range from slight deviation in course and deflection around the sound (migrating whales) to avoidance of the area (feeding whales). Therefore, NMFS anticipates that humpback whales exposed to sound from the proposed pile driving in the project vicinity will respond by either a deviation in their course to deflect around the sound (in the case of whales otherwise passing through the area) or by avoiding the area (in the case of whales otherwise feeding in the area).

Exposed humpback whales are likely to be displaced and precluded from foraging in the project vicinity. However, there are alternate foraging areas available (*i.e*., areas offshore and closer to the shelf break and Grays Harbor to the north, as discussed above). Exposed humpback whales are also likely to deflect around the sound instead of passing through the area; however, the additional distance traveled is unlikely to cause a significant increase in an individual’s energy budget, and effects would therefore be non-lasting. In either case, the likely behavioral responses, even considering potential for repeat exposures of individual whales, are not anticipated to reduce the reproductive success or increase the risk of injury or mortality for any individual humpback whale.

Critical Habitat within the Action Area

The effects of the proposed action on proposed and designated critical habitat are summarized below as a subset of the habitat-related effects of the action that were discussed more fully above.

<u>Pacific Salmon and Steelhead.</u>

1. Estuarine Areas
   a. Forage – Negligible and temporary reductions in benthic invertebrates are expected at localized dredging, disposal, and rock placement sites. Effects to prey resources for listed species are

expected to be insignificant as listed species using the MCR are pelagic, not benthic feeders.

b. Free of obstruction –At the North and South jetties, multiple spur groins have been in place for decades and likely do not pose behavioral concerns, *e.g.*, affect migration patterns, for fishes, based on acoustic telemetry data. The Corps is proposing to construct 11 new spur groins that will measure between 80 and 140 feet in length. Spur groins are small lateral extensions connected to the Jetties at their base. In view of the fact that the MCR is approximately 2.5 miles wide, and that few if any salmon are likely to occur within several hundred feet of the Jetties, based acoustic telemetry data, effects associated with the new jetty spur groins on passage are likely to be discountable.

c. Natural cover – Most of the construction and staging areas will occur above MHHW. Therefore, no effects are likely to occur.

d. Water quality – Negligible, localized, and temporary increases in suspended sediment due to dredging, disposal, rock placement, and piling installation and removal are likely. Placement could occur during a limited time window on a seasonal daily basis, and the other actions are temporally limited to a few days annually or a single event basis. There is also potential for spills or leaks, but BMPs reduce the likelihood of this occurrence. Monitoring will limit the levels and durations of suspended sediment. Therefore, effects on water quality will be insignificant.

e. Water quantity – No effects are likely to occur.

2. Nearshore Marine Areas

a. Free of obstruction – No effects are expected.

b. Natural cover –Most of the construction and staging areas will occur above MHHW, therefore, no effects are likely to occur.

c. Salinity – Based on the modeling, negligible effects to salinity are likely to occur.

d. Water quality – Negligible, localized, and temporary increases in suspended sediment due to dredging, disposal, rock placement, and piling installation and removal are likely. Placement could occur during a limited time window on a seasonal daily basis, and the other actions are temporally limited to a few days annually or a single event basis. There is also potential for spills or leaks, but BMPs reduce the likelihood of this occurrence. Monitoring will limit the levels and durations of suspended sediment. Therefore, effects on water quality will be insignificant.

e. Water quantity – No effects are likely to occur.

3. Adult and Juvenile Migration Corridors

a. Substrate – The substrate in the MCR is mostly sand (Figure 21). Adult and juvenile salmon and steelhead will not be affected by changes in substrate composition associated with repairs and rehabilitations as this is a migratory corridor and they are not substrate-dependent for this behavior. Therefore, effects on migratory corridors will be insignificant.

b. Water quality – Negligible, localized, and temporary increases in suspended sediment due to dredging, disposal, rock placement, and piling installation and removal are likely. Placement could occur during a limited time window on a seasonal daily basis, and the other actions are temporally limited to a few days annually or a single event basis. There is also potential for spills or leaks, but BMPs reduce the likelihood of this occurrence. Monitoring will limit the levels and durations of suspended sediment. Therefore, effects on water quality will be insignificant.

c. Water quantity – No effects are likely to occur.

d. Water temperature – No effects are likely to occur.

e. Water velocity – Based on modeling, small localized changes will occur in the vicinity of the spur groins. However, these are not expected to have larger scale or system-wide effects that would have a meaningful affect on habitat, especially since background velocities can exceed 8 fps in the MCR.

f. Cover/shelter – No effects are likely to occur.

g. Food Resources –Negligible and temporary impacts to benthic invertebrates are expected at localized dredging, disposal, and rock placement sites. Effects to prey resources for listed species are expected to be insignificant as effects on benthic invertebrates will be minor and listed species utilizing the MCR are pelagic feeders.

h. Riparian vegetation – Most of the construction and staging areas will occur above MHHW and will not impact natural cover for listed species. Also, vegetation in rock storage and other affected areas is mostly European bunchgrass.

i. Space – No effects to behavior, fitness, migration patterns, physiology, or spatial distribution are expected.

j. Safe passage– At the North and South jetties, multiple spur groins have been in place for decades and likely do not pose behavioral concerns, *e.g.,* affect migration patterns, for fishes, based on acoustic telemetry data. The Corps is proposing to construct 11 new spur groins that will measure between 80 and 140 feet in length. Spur groins are small lateral extensions connected to the Jetties at their base. In view of the fact that the MCR is approximately 2.5 miles wide, and that few if any salmon are likely to occur within several hundred feet of the Jetties, based acoustic telemetry data, effects associated with the new jetty spur groins on passage are likely to be discountable.

4. Areas for Growth and Development to Adulthood

a. Ocean areas – (not identified) – No effects are expected.

Based on the above assessment, the effects on the PCEs noted above will not be significant at the watershed or the designation scale of critical habitat for Pacific salmon and steelhead. Additionally, in the above analysis, the long-term beneficial effects from the proposed wetland mitigation and habitat improvement projects were not incorporated. However, the Corps is proposing to restore 76.56 acres associated with wetland impacts, and 60 acres associated with in-water impacts. These habitat restoration actions in the long term will improve intertidal and subtidal estuarine habitats for listed species. Therefore, these restoration actions are expected to beneficially affect critical habitat.

Green Sturgeon. Critical habitat was designated by the NMFS for green sturgeon. The PCEs of critical habitats relevant directly or indirectly in the action area include:

- Estuarine areas
- Coastal marine areas

1. Estuarine Areas
    a. Food Resources – Negligible and temporary reductions in benthic invertebrates are expected at localized dredging, disposal, and rock placement sites. Placement could occur during a limited time window on a seasonal daily basis, and the other actions are temporally limited to a few days only annually. This is not anticipated to have any significant or long-term effect on food abundance or distribution of green sturgeon.
    b. Migratory Corridor – The substrate in the MCR is mostly sand. Adult and juvenile green sturgeon will not be affected by changes in substrate composition associated with repairs and rehabilitations as this is a migratory corridor and they are not substrate-dependent for this behavior. Therefore, effects on migratory corridors will be insignificant.
    c. Sediment Quality – Harmful levels of contaminants have not been identified at the sites, and most of the substrate is 97% or greater sands. Therefore, no effects are likely to occur.
    d. Water Flow – No effects are likely to occur.
    e. Water Quality – Negligible, localized, and temporary increases in suspended sediment due to dredging, disposal, rock placement, and piling installation and removal are likely. Placement could occur during a limited time window on a seasonal daily basis, and the other actions are temporally limited to a few days annually or a single event basis. There is also potential for spills or leaks, but BMPs reduce the likelihood of this occurrence. Monitoring will limit the levels and durations of suspended sediment. Therefore, effects on water quality will be insignificant.
    f. Water Depth – Effects will be negligible.
2. Coastal Marine Areas
    a. Food Resources – Negligible and temporary reductions in benthic invertebrates are expected at localized dredging, disposal, and rock placement sites.

b. Migratory Corridor – No effects are expected.
c. Water Quality – Negligible, localized, and temporary increases in suspended sediment due to dredging, disposal, rock placement, and piling installation and removal are likely. Placement could occur during a limited time window on a seasonal daily basis, and the other actions are temporally limited to a few days annually or a single event basis. There is also potential for spills or leaks, but BMPs reduce the likelihood of this occurrence. Monitoring will limit the levels and durations of suspended sediment. Therefore, effects on water quality will be insignificant.

Based on the above assessment, the effects on the PCEs noted above will not be significant at the watershed or the designation scale of critical habitat for green sturgeon. Additionally, in the above analysis, the long-term beneficial effects from the proposed wetland mitigation and habitat improvement projects were not incorporated. However, the Corps is proposing to restore 76.56 acres associated with wetland impacts, and 60 acres associated with in-water impacts. These habitat restoration actions in the long term will improve intertidal and subtidal estuarine habitats for listed species. Therefore, these restoration actions are expected to beneficially affect critical habitat.

Eulachon.

1. Estuarine Migration Corridors
   a. Food Resources – The proposed action is not likely to have any significant or long-term effects on food resources or distribution for eulachon as juveniles eat phytoplankton, copepod eggs, copepods and other small zooplanktons and adults eat euphausiids and copepods. The project will not affect these pelagic food resources.
   b. Migratory Corridor – At the North and South jetties, multiple spur groins have been in place for decades and likely do not pose behavioral concerns for eulachon. The Corps is proposing to construct 11 new spur groins that will measure between 80 and 140 feet in length. Spur groins are small lateral extensions connected to the Jetties at their base. In view of the fact that the MCR is approximately 2.5 miles wide, effects associated with the new jetty spur groins on migration habitat are likely to be discountable.
   c. Water Flow – No effects are likely to occur.
   d. Water Quality – Negligible, localized, and temporary increases in suspended sediment due to dredging, disposal, rock placement, and piling installation and removal are likely. Placement could occur during a limited time window on a seasonal daily basis, and the other actions are temporally limited to a few days annually or a single event basis. There is also potential for spills or leaks, but BMPs reduce the likelihood of this occurrence. Monitoring will

limit the levels and durations of suspended sediment. Therefore, effects on water quality will be insignificant.

2. Nearshore and Offshore Marine Areas
   a. Foraging habitat—Negligible are likely to occur.
   b. Water Quality— Negligible, localized, and temporary increases in suspended sediment due to dredging, disposal, rock placement, and piling installation and removal are likely. Placement could occur during a limited time window on a seasonal daily basis, and the other actions are temporally limited to a few days annually or a single event basis. There is also potential for spills or leaks, but BMPs reduce the likelihood of this occurrence. Monitoring will limit the levels and durations of suspended sediment. Therefore, effects on water quality will be insignificant.
   c. Available Prey— The proposed action is not likely to have any significant or long-term effects on food resources or distribution for eulachon as juveniles eat phytoplankton, copepod eggs, copepods and other small zooplanktons and adults eat euphausiids and copepods. The project will not affect these pelagic food resources.

Based on the above assessment, the effects on the PCEs noted above will not be significant at the watershed or the designation scale of critical habitat for eulachon. Additionally, in the above analysis, the long-term beneficial effects from the proposed wetland mitigation and habitat improvement projects were not incorporated. However, the Corps is proposing to restore 76.56 acres associated with wetland impacts, and 60 acres associated with in-water impacts. These habitat restoration actions in the long term will improve intertidal and subtidal estuarine habitats for listed species. Therefore, these restoration actions are expected to beneficially affect critical habitat.

Cumulative Effects

Cumulative effects are those effects of future State or private activities, not involving Federal activities, that are reasonably certain to occur within the action area of the Federal action subject to consultation (50 CFR 402.02).

Some types of human activities that contribute to cumulative effects are expected to have adverse effects on listed species and critical habitat PCEs, many of which are activities that have occurred in the recent past and had an effect on the environmental baseline. These can be considered reasonably certain to occur in the future because they occurred frequently in the recent past. Within the freshwater portion of the action area, non-Federal actions are likely to include human population growth, water withdrawals (*i.e.*, those pursuant to senior state water rights) and land use practices. In marine waters within the action area, state, tribal, and local government actions are likely to be in the form of legislation, administrative rules, or policy initiatives, shoreline growth management and resource permitting. Private activities include continued resource extraction, vessel traffic, development and other activities which contribute to non-point source pollution and storm water run-off. Although these factors are ongoing to some extent and likely to continue in the future, past occurrence is not a guarantee of a continuing level of activity. That will depend on whether there are economic, administrative, and legal impediments (or in the case of contaminants, safeguards). Therefore, although NMFS finds it likely that the cumulative effects of these activities will have adverse effects commensurate to those of similar past activities; it is not possible to quantify these effects.

Synthesis and Integration of Effects

Steller Sea Lion

The Eastern DPS of Steller sea lions is a large population, which over the past 30 years has increased approximately 3% per year. Steller sea lions are generalist predators, and able to respond to changes in prey abundance. There are no substantial threats to the species, and the final recovery plan identifies the need to initiate a status review and consider removing the Eastern DPS from the Federal List of Endangered Wildlife and Plants.

The South Jetty of the Columbia River is used as a haulout all year by Steller sea lions. The only proposed activities NMFS anticipates will affect Steller sea lions are rock placement and pile driving. Given the time of year that most of the rock placement and pile driving activities will occur (spring/summer) over a 20-year timeframe, the number of Steller sea lions affected daily could range from at least 200 to 600 animals. The response of Steller sea lions to these activities are expected to be similar to repairs performed on the South Jetty in 2006 and 2007 (refer to NMFS No.: 2005/06359) and include alert behavior, approaches to the water, and flushes into the water.

NMFS finds it likely that Steller sea lions will be exposed to and disturbed by sound generated by pile driving activities. Steller sea lions will likely spend less time at the South Jetty haulout or foraging in the immediate vicinity. However, there are alternative foraging and haul out areas available to the affected individuals. Repetitive, short-term displacement is likely to cause repetitive, short-term disruptions in their normal behavioral patterns at the South Jetty. There are no current threats to the species that are either part of the environmental baseline or cumulative effects in the action area that are anticipated to affect Steller sea lion in addition to the activities of the proposed action, described above.

Humpback Whale

The current abundance of humpback whales in the North Pacific is approximately 18,000 to 21,000 whales, of which 1,400 to 1,700 individuals are part of the California/Oregon stock. Humpback whales are sighted off the Washington and Oregon coasts relatively close to shore and are known to predictably forage approximately offshore of Grays Harbor, Washington during spring and summer months.

Based on the available information about summer foraging habits of humpback whales along the Washington coast, humpback whales are likely to pass through and may forage in the project vicinity, within 6.2 miles of the Jetties or within approximately 8.6 miles of shore. The potential exposure of humpback whales to sound at or above 120 dB threshold is likely to elicit behavioral responses within the range of previously documented responses by low-frequency hearing specialists to non-pulse sound. Based on review of these documented responses, NMFS anticipates that humpback whales exposed to sound from the proposed pile driving in the project vicinity will respond by either a deviation in their course to deflect around the sound (in the case of whales otherwise passing through the area) or by avoiding the area (in the case of whales otherwise feeding in the area).

Exposed humpback whales are likely to be displaced and precluded from foraging in the project vicinity. However, there are alternate foraging areas available (*i.e*., areas offshore and closer to the shelf break and Grays Harbor to the north, as discussed above). Exposed humpback whales are also likely to deflect around the sound instead of passing through the area. In both cases, the likely behavioral responses, even considering potential for repeat exposures of individual whales, are not anticipated to reduce the reproductive success or increase the risk of injury or mortality for any individual humpback whale. In addition, current threats to the species that may occur as part of the environmental baseline or cumulative effects in this area include vessel sound that is a habitat concern for low-frequency sound specialists, such as humpback whales. Effects of the action in addition to threats that are part of the environmental baseline or cumulative effects are not anticipated to appreciably reduce the species' ability to survive and recover.

Eulachon

For eulachon, NMFS expects effects to be limited to entrainment, which will kill a small number of eulachon larvae because: (1) Dredging will take place below the river bottom; (2) the dragheads or cutterheads will not be engaged if raised more than 3 feet above the river bottom; (3) the relative volume associated with dredging compared to the volume of the river flow is approximately 0.0001%; and (4) the timing of dredging will range from 3.3 to 13.3 hours per year, relative to the total outmigration period of larval eulachon of 95 to 200 days.

Therefore, it is unlikely that the proposed action will appreciably reduce the likelihood of survival and recovery of eulachon.

Critical Habitat at the Watershed and Designation Scales

As described in the *Effects to Habitat* and *Critical Habitat with the Action Area* sections, effects to critical habitat are either insignificant or discountable. The effects will not be scalable to a reduction in conservation value because they are either intermittent, short-lived, or do not meaningfully affect the PCEs or physical or biological features of critical habitat. Therefore, NMFS concludes that the effects of the proposed action on designated critical habitat for listed species considered in the Opinion will be insignificant or discountable at the watershed and designation scales.

Conclusion

After reviewing the status of Steller sea lions, humpback whales, and eulachon, the environmental baseline, the effects of the action, and cumulative effects, NMFS concludes that the proposed action will not jeopardize the continued existence of those species

Incidental Take Statement

Section 9 of the ESA and Federal regulation pursuant to section 4(d) of the ESA prohibit the take of endangered and threatened species, respectively, without a special exemption. Take is defined as to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture or collect, or to attempt to engage in any such conduct. Harm is further defined by NMFS as significant habitat modification or degradation that results in death or injury to listed species by significantly impairing essential behavioral patterns, including breeding, feeding, or sheltering. Harass is defined by Fish and Wildlife Service as an intentional or negligent actions that create the likelihood of injury to listed species to such an extent as to significantly disrupt normal behavior patterns which include, but are not limited to, breeding, feeding or sheltering. Incidental take is defined as take that is incidental to, and not the purpose of, the carrying out of an otherwise lawful activity. Under the terms of section 7(b)(4) and section 7(o)(2), taking that is incidental to and not intended as part of the agency action is not prohibited under the ESA, provided that such taking is in compliance with the terms and conditions of an incidental take statement.

Because there are no protective regulations in place for eulachon via section 4(d) of the ESA, there is no take prohibition for eulachon.

The NMFS is not including an incidental take authorization for marine mammals at this time because the incidental take of marine mammals has not been authorized under section 101(a)(5) of the Marine Mammal Protection Act and/or its 1994 Amendments. Following issuance of such regulations or authorizations, NMFS may amend this Opinion to include an incidental take statement for marine mammals, as appropriate.

Conservation Recommendations

Section 7(a) (1) of the ESA directs Federal agencies to use their authorities to further the purposes of the ESA by carrying out conservation programs for the benefit of the threatened and endangered species. The following recommendation is a discretionary measure consistent with this obligation and therefore should be carried out by the Corps:

> To improve the potential for recovery of ESA-listed species that use the MCR, the Corps should carry out management actions to reverse threats to species survival as identified in the Columbia River Estuary ESA Recovery Plan Module for Salmon and Steelhead (NMFS 2011).

Please notify NMFS if the Corps carries out this recommendation so that we will be kept informed of actions that are intended to improve the conservation of listed species or their designated critical habitats.

Reinitiation of Consultation

Reinitiation of formal consultation is required and shall be requested by the Federal agency or by NMFS where discretionary Federal involvement or control over the action has been retained or is authorized by law and: (a) If the amount or extent of taking specified in the incidental take statement is exceeded; (b) if new information reveals effects of the action that may affect listed species or designated critical habitat in a manner or to an extent not previously considered; (c) if the identified action is subsequently modified in a manner that has an effect to the listed species or designated critical habitat that was not considered in the biological opinion; or (d) if a new species is listed or critical habitat is designated that may be affected by the identified action (50 CFR 402.16).

To reinitiate consultation, contact the Oregon State Habitat Office of NMFS, and refer to the NMFS Number **2010/06104**.

NOT LIKELY TO ADVERSELY AFFECT DETERMINATIONS

Species Determinations

Blue Whales, Sei Whales, Sperm Whales, Fin Whales, Southern Resident Killer Whales, and Leatherback Sea Turtles. NMFS concurs with the Corps' "may affect, not likely to adversely affect" determinations for the following marine mammal and sea turtle species: blue whales, Sei whales, sperm whales, fin whales, Southern Resident killer whales, leatherback sea turtles. These ESA-listed species do not occur in the Columbia River, they will not be exposed to any potential stressors from the proposed activities that occur in the estuary and river proper, and no effects from activities in these areas are therefore anticipated. The above ESA-listed marine mammal and sea turtle species may occur outside of the Columbia River in the marine portion of the action area.

The proposed activity with a potential stressor in the marine portion of the action area that may affect these species is in-water noise from pile driving that extends out 6.2 miles into the ocean from the jetty locations where rock placement is proposed. Blue, fin, Sei and sperm whales and leatherback sea turtles are not generally distributed near shore. Their presence within range of in-water noise from pile driving is extremely unlikely and any effects from this activity are therefore discountable.

Southern Resident killer whales have been repeatedly observed feeding off the Columbia River plume in the vicinity of the Jetties in March and April during peak spring Chinook salmon runs (*i.e.*, in 2004: Krahn *et al*. 2004; in 2005: Zamon *et al*. 2007; in 2006: Hanson *et al*. 2008; and in 2009: Hanson *et al*. 2010). The Corps restricted the window in which piling installation will most likely be conducted (May through the summer) to avoid possible project effects that overlap with limited peak killer whale use in the project vicinity (March through April). Southern Resident killer whales can occur near shore, but their presence is likely to be infrequent and transitory, such that co-occurrence of these killer whales and proposed pile driving from May through the summer is extremely unlikely and any effects from this activity are therefore discountable.

Additionally, the proposed action is not likely to cause a measurable reduction in the quantity of salmon and other ESA-listed or proposed fish, as described above and therefore will not affect the quantity of prey available to marine mammals. The quality of prey available to marine mammals will not be adversely affected by the proposed action, because there is no causal mechanism for the proposed activities to increase the concentration of persistent organic pollutants in fish.

NMFS concurs with the Corps' determinations that effects of the action are either insignificant or discountable and therefore are not likely to adversely affect blue whales, Sei whales, sperm whales, fin whales, Southern Resident killer whales, and leatherback sea turtles.

Fishes. The NMFS concludes that the proposed action is NLAA LCR Chinook salmon, UWR Chinook salmon, UCR spring-run Chinook salmon, SR spring/summer run Chinook salmon, SR fall-run Chinook salmon, CR chum salmon, LCR coho salmon, OC coho salmon, SONCC coho salmon, SR sockeye salmon, LCR steelhead, UWR steelhead, UCR steelhead, MCR steelhead, SRB steelhead, and southern green sturgeon.

Critical Habitat Determinations

Proposed Leatherback Sea Turtle Critical Habitat. The PCEs that NMFS identified as essential for the conservation of leatherback turtles when it proposed to revise critical habit to include marine waters off the U.S. West Coast, including the action area, are: (1) A sufficient quantity and quality of their jellyfish prey; and (2) migratory pathway conditions that allow for safe and timely passage to, from, and within high use foraging areas, including areas within the action area. No effects on prey quantity or quality are anticipated. In-water noise from pile driving activities would have a discountable effect on leatherback turtle passage, given the extremely unlikely nature of leatherback turtle occurrence in the action area.

NMFS concurs with the Corps' determination that effects of the action are either insignificant or discountable and therefore are not likely to adversely affect proposed critical habitat of leatherback turtles.

Fishes. After reviewing the status of critical habitats of fish species specified above for which critical habitat is proposed or designated NMFS also concludes that the proposed action is NLAA critical habitat for those species.

MAGNUSON-STEVENS FISHERY CONSERVATION AND MANAGEMENT ACT

The consultation requirement of section 305(b) of the MSA directs Federal agencies to consult with NMFS on all actions, or proposed actions that may adversely affect EFH. Adverse effects include the direct or indirect physical, chemical, or biological alterations of the waters or substrate and loss of, or injury to, benthic organisms, prey species and their habitats, and other ecosystem components, if such modifications reduce the quality or quantity of EFH. Adverse effects on EFH may result from actions occurring within EFH or outside EFH, and may include site-specific or EFH-wide impacts, including individual, cumulative, or synergistic consequences of actions (50 CFR 600.810). Section 305(b) also requires NMFS to recommend measures that may be taken by the action agency to conserve EFH.

The Pacific Fishery Management Council (PFMC) described and identified EFH for groundfish (PFMC 2005), coastal pelagic species (PFMC 1998), and Chinook salmon, coho salmon, and Puget Sound pink salmon (PFMC 1999). The proposed action and action area for this consultation are described in the Introduction to this document. The action area includes areas designated as EFH for various life-history stages groundfish species, coastal pelagic species, and Pacific salmon (Table 13).

Table 13. Species of fish and life stages with designated EFH that may occur within the action area, activities and prey.

Groundfish Species	Life stage	Activity	Prey
Arrowtooth flounder	Adults	All	Gadids, *Theragra chalcogramma*, krill, clupeids, shrimp
	Eggs	Unknown	
	Larvae		
Big skate	Adults	All	Crustaceans, fish
Black rockfish	Juveniles	Feeding, growth to maturity	
	Adults	All	
Blue rockfish	Juveniles	All	
	Adults	All	
	Larvae	Feeding	
Bocaccio	Juveniles	Feeding	Euphausiids, copepods
Butter sole	Adults	All	Polychaetes, molluscs, fish, decapod crustaceans, amphipods, shrimp, sea stars
Cabezon	Adults	All	Fish eggs, lobsters, molluscs, small fishes, crabs
California skate	Eggs	Unknown	

Groundfish Species	Life stage	Activity	Prey
Canary rockfish	Juveniles	Feeding, growth to maturity	
Chilipepper	Adults	All	Clupeids, euphausiids, *Merluccius productus*, squids, copepods, euphausiids
	Juveniles	Feeding, growth to maturity	
Copper rockfish	Adults	All	Crustaceans, fish, shrimp, molluscs
Curlfin sole	Adults	All	Crustacean eggs, *Echiurid proboscises*, nudibranchs, polychaetes
Dusky rockfish	Adults	All	
English sole	Juveniles	Feeding, growth to maturity	Polychaetes, molluscs, cumaceans, copepods, amphipods, mysids
	Adults	All	Polychaetes, ophiuroids, molluscs, cumaceans, amphipods, crustaceans
Flathead sole	Adults	All	Polychaetes, mysids, shrimp, molluscs, clupeids, fish
Kelp greenling	Adults	All	Worms, crabs, octopi, shrimp, small fishes, brittle stars, snails
	Larvae		
Lingcod	Adults	All	Juvenile crab, demersal fish, squid, octopi
	Larvae	Feeding	Decapod larvae, copepods, euphausiids, copepod nauplii, copepod eggs, amphipods
Longnose skate	Adults	All	
Pacific cod	Juveniles		Amphipods, shrimp, copepods, crabs
	Larvae		Copepods
Pacific hake	Juveniles		Euphausiids
	Adults	All	
Pacific sanddab	Adults	All	Squids, octopi, crab larvae, clupeids
Petrale sole	Adults	All	Shrimp, *Eopsetta jordani*, euphausiids, ophiuroids, pelagic fishes
Quillback rockfish	Adults	All	Amphipods, molluscs, euphausiids, polychaetes, fish juveniles, shrimp, clupeids, crabs
Redstripe rockfish	Adults	All	Fish juveniles, squid, clupeids

Groundfish Species	Life stage	Activity	Prey
Rex sole	Adults	All	Cumaceans, euphausiids, larvacea, polychaetes
Rock sole	Adults	All	Tunicates, echinoderms, fish, molluscs, polychaetes, echiurans
Rosy rockfish	Adults	All	Crabs, shrimp
Sablefish	Adults		Octopi, clupeids, euphausiids, shrimp, rockfish
	Juveniles	Growth to Maturity	Krill, small fishes, squids, euphausiids, demersal fish, tunicates, cephalopods, amphipods, copepods
	Larvae	Feeding	
Sand sole	Adults	All	Polychaetes, clupeids, crabs, fish, mysids, shrimp, molluscs
	Juveniles	Growth to Maturity, feeding	Euphausiids, molluscs, mysids, polychaetes, shrimp
Silvergray rockfish	Adults	All	
Soupfin shark	Adults	All	Fish, invertebrates
	Juveniles	Growth to Maturity	Invertebrates, fish
Spiny dogfish	Adults	All	Pelagic fishes, invertebrates
Splitnose rockfish	Juveniles	Feeding	Copepods, cladocerans, amphipods
	Larvae		
Spotted ratfish	Adults	All	Amphipods, annelids, brittle stars, fish, algae, molluscs, squids, small crustacea, ostracods, opisthobranchs, nudibranchs
	Juveniles	Growth to Maturity	Small crustacea, squids, ostracods, ophisthobranchs, nudibranchs, molluscs, fish, brittle stars, amphipods, algae, annelids
Starry flounder	Adults	Growth to Maturity	Molluscs, fish juveniles, polychaetes, crabs
	Juveniles	Feeding	Polychaetes, copepods, amphipods
Stripetail rockfish	Adults	All	Euphausiids, copepods
	Juveniles	Growth to Maturity	Copepods
Tiger rockfish	Adults	All	Juvenile rockfish, amphipods, fish juveniles, shrimp, clupeids, crabs
Vermilion rockfish	Adults		Clupeids, juvenile rockfish, krill, octopi, squids
Widow rockfish	Juveniles	Growth to Maturity, feeding	Copepods, copepod eggs, euphausiid eggs
Yellowtail rockfish	Adults	All	Clupeids, euphausiids, tunicates, mysids, salps, squid, krill, *Merluccius productus*

Groundfish Species	**Life stage**	**Activity**	**Prey**
Coastal Pelagic Species	**Life stage**	**Activity***	**Prey**
Northern anchovy	Eggs		
	Larvae		
	Juvenile		
	Adult	All	Zooplankton
Pacific sardine	Eggs		
	Larvae		
	Juvenile		
	Adult	All	Zooplankton
Pacific mackerel	Eggs		
	Larvae		
	Juvenile		
	Adult	All	Zooplankton, micronekton
Jack mackerel	Adult		Krill, small crustacea
Market squid	Eggs		
	Larvae		
	Juvenile		
	Adult	All	Plankton, small crustacea, euphausiids, copepods

Pacific Salmon			
Coho salmon**	Juvenile		
	Adults	Feeding	
Chinook salmon	Juvenile		Plankton, insects, small fish
	Adults	Feeding	
Pink Salmon	Juvenile		Plankton, insects, small fish
	Adults	Feeding	

Based on information provided by the action agency and the analysis of effects presented in the ESA portion of this document, *Effects on Habitat*, NMFS concludes that proposed action will adversely affect EFH designated for groundfish species by reducing the quality of EFH from dredging and pile installation and removal. In the long term, the increased surface area of rock for the Columbia River Jetty System will likely have beneficial habitat effects for federally-managed rockfish species.

Essential Fish Habitat Conservation Recommendations

Although NMFS did identify adverse effects associated with the proposed action on EFH, NMFS does not propose any conservation recommendations at this time as the only conservation recommendation we would recommend would be to limit the timing for dredging and pile installation and removal. Because the MCR is a high-energy environment, dredging is already limited due to weather and wave activity in the fall through spring, and dredging and pile installation and removal outside the proposed timing poses a safety hazard to dredge and pile operators.

Statutory Response Requirement

Federal agencies are required to provide a detailed written response to NMFS' EFH conservation recommendations within 30 days of receipt of these recommendations [16 U.S.C. 1855 (b)(4)(B)]. The response must include a description of measures proposed to avoid, mitigate, or offset the adverse affects of the activity on EFH. If the response is inconsistent with the EFH conservation recommendations, the response must explain the reasons for not following the recommendations. The reasons must include the scientific justification for any disagreements over the anticipated effects of the proposed action and the measures needed to avoid, minimize, mitigate, or offset such effects.

In response to increased oversight of overall EFH program effectiveness by the Office of Management and Budget, NMFS established a quarterly reporting requirement to determine how many conservation recommendations are provided as part of each EFH consultation and how many are adopted by the action agency. Therefore, we ask that in your statutory reply to the EFH portion of this consultation, you clearly identify the number of conservation recommendations accepted.

Supplemental Consultation

The Corps must reinitiate EFH consultation with NMFS if the proposed action is substantially revised in a way that may adversely affect EFH [50 CFR 600.920(k)].

DATA QUALITY ACT DOCUMENTATION AND PRE-DISSEMINATION REVIEW

Section 515 of the Treasury and General Government Appropriations Act of 2001 (Public Law 106-554) (Data Quality Act) specifies three components contributing to the quality of a document. They are utility, integrity, and objectivity. This section of the Opinion addresses these Data Quality Act (DQA) components, documents compliance with the DQA, and certifies that this Opinion has undergone pre-dissemination review.

Utility: Utility principally refers to ensuring that the information contained in this consultation is helpful, serviceable, and beneficial to the intended users.

This ESA consultation concludes that the proposed repair and rehabilitation of the Columbia River Jetty System will not jeopardize the affected listed species. Therefore, the Corps can carry out this action in accordance with its Congressional authority. The intended user is the Corps of Engineers.

Individual copies were provided to the Corps. This consultation will be posted on the NMFS Northwest Region website (http://www.nwr.noaa.gov). The format and naming adheres to conventional standards for style.

Integrity: This consultation was completed on a computer system managed by NMFS in accordance with relevant information technology security policies and standards set out in Appendix III, 'Security of Automated Information Resources,' Office of Management and Budget Circular A-130; the Computer Security Act; and the Government Information Security Reform Act.

Objectivity:

Information Product Category: Natural Resource Plan.

Standards: This consultation and supporting documents are clear, concise, complete, and unbiased; and were developed using commonly accepted scientific research methods. They adhere to published standards including the NMFS ESA Consultation Handbook, ESA Regulations, 50 CFR 402.01, *et seq.*.

Best Available Information: This consultation and supporting documents use the best available information, as referenced in the Literature Cited section. The analyses in this Opinion contain more background on information sources and quality.

Referencing: All supporting materials, information, data and analyses are properly referenced, consistent with standard scientific referencing style.

Review Process: This consultation was drafted by NMFS staff with training in ESA implementation, and reviewed in accordance with Northwest Region ESA quality control and assurance processes.

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Oregon
John A. Kitzhaber, MD, Governor

Parks and Recreation Department
State Historic Preservation Office
725 Summer St NE, Ste C
Salem, OR 97301-1266
(503) 986-0671
Fax (503) 986-0793
www.oregonheritage.org

May 22, 2012

Ms. Joyce Casey
USACOE CENWP-PM-E
PO Box 2946
Portland, OR 97308-3946

RE: SHPO Case No. 12-0338
North Jetty, Mouth of Columbia River
FOE/dredging/repair
COE
, Clatsop County

Dear Ms. Casey,

Our office recently received the cultural resources summary about the project referenced above. I have reviewed the summary document and agree that the project will have no effect on any known cultural resources. However, though the project area is largely comprised of recently accreted land forms and areas adjacent to the jetty have been dredged previously during successive repair episodes, there are known shipwrecks in the general area and it is perceived to have a high probability for submerged historic vessels.

Please be aware, that if during development activities you or your staff encounters any cultural material (i.e., historic or prehistoric), all activities should cease immediately and agency archaeologists should be contacted to evaluate the discovery. If you have any questions regarding any future discovery or my letter, feel free to contact our office at your convenience.

Sincerely,

Dennis Griffin, Ph.D., RPA
State Archaeologist
(503) 986-0674
dennis.griffin@state.or.us

STATE OF WASHINGTON

DEPARTMENT OF ARCHAEOLOGY & HISTORIC PRESERVATION

1063 S. Capitol Way, Suite 106 • Olympia, Washington 98501
Mailing address: PO Box 48343 • Olympia, Washington 98504-8343
(360) 586-3065 • Fax Number (360) 586-3067 • Website: www.dahp.wa.gov

May 16, 2012

Ms. Joyce E. Casey
Environmental Resources Branch
Corps of Engineers, Portland District
PO Box 2946
Portland, Oregon 97208-2946

Re: MCR North Jetty Repair Project
Log No: 080709-06-COE-P

Dear Ms. Casey:

Thank you for contacting our department. We have reviewed the materials you provided for the proposed MCR North Jetty Repair Project, Cape Disappointment State Park, Pacific County, Washington.

We concur with your determination of No Historic Properties Affected.

We would appreciate receiving any correspondence or comments from concerned tribes or other parties that you receive as you consult under the requirements of 36CFR800.4(a)(4).

In the event that archaeological or historic materials are discovered during project activities, work in the immediate vicinity must stop, the area secured, and the concerned tribes and this department notified.

These comments are based on the information available at the time of this review and on the behalf of the State Historic Preservation Officer in conformance with Section 106 of the National Historic Preservation Act and its implementing regulations 36CFR800. Should additional information become available, our assessment may be revised.

Thank you for the opportunity to comment and a copy of these comments should be included in subsequent environmental documents.

Sincerely,

Robert G. Whitlam, Ph.D.
State Archaeologist
(360) 586-3080
Email: rob.whitlam@dahp.wa.gov

DEPARTMENT OF THE ARMY
CORPS OF ENGINEERS, PORTLAND DISTRICT
PO BOX 2946
PORTLAND OR 97208-2946

REPLY TO
ATTENTION OF

DEC 1 5 2010

Planning, Program and Project
Management Division

Dr. Kim Kratz
National Marine Fisheries Service
Oregon State Habitat Office
1201 NE Lloyd Boulevard, Suite 11 00
Portland, OR 97232

Dear Dr. Kratz:

The Portland District Corps of Engineers (Corps) has completed the Biological Assessment (BA) and Essential Fish Habitat (EFH) Assessment reports and is requesting entering into consultation for the Major Rehabilitation of the Jetty System at the Mouth of the Columbia River (MCR). The Biological Assessment evaluates the potential impacts of the Corps' activities with regards to several federally listed marine and anadromous fish, mammal, and turtle species that are present in the proposed action area. The Corps also requests a Conference Opinion regarding effects to proposed critical habitat for leatherback turtles. Additionally, prior to construction activities, an incidental harassment authorization (IHA) for marine mammals at the South Jetty will be obtained. Based on this BA, the Corps has concluded that proposed actions will have minor adverse effects on all listed salmon species, eulachon, green sturgeon, and Stellar sea lions.

The EFH Assessment evaluates the potential impacts of the Corps' activities on five coastal pelagic species, numerous Pacific Coast groundfish species, and coho and Chinook salmon. Based on the assessment, the Corps has concluded that the proposed Jetty Major Rehabilitation will have a minor adverse effect on EFH for groundfish, pelagic fish, and salmon.

If you have any questions or need additional information, please contact Barbara Cisneros at 503-808-4784 or Barbara.G.Cisneros@usace.army.mil.

Sincerely,

Joyce E. Casey

Joyce E. Casey
Chief, Environmental Resources Branch

Enclosures

United States Department of the Interior

FISH AND WILDLIFE SERVICE

Oregon Fish and Wildlife Office
2600 SE 98th Avenue, Suite 100
Portland, Oregon 97266
Phone: (503)231-6179 FAX: (503)231-6195

Reply To: 8330.10082(11)
File Name: MCR_major jetty rehabilitation_informal.doc
TAILS: 13420-2011-I-0082
TS Number: 11-491
Doc Type: Final

FEB 23 2011

Ms. Joyce E. Casey
Chief, Environmental Resources Branch
Portland District, Corps of Engineers
P.O. Box 2946
Portland, Oregon 97208-2946

Subject: Major Rehabilitation of the Jetty System at the Mouth of the Columbia River Navigation Channel, Clatsop County Oregon and Pacific County, Washington (USFWS Number: 13420-2011-I-0082)

Dear Ms. Casey:

This is in response to your letter received on February 8, 2011, transmitting a Biological Assessment (BA) and request for concurrence on the proposed rehabilitation of the North and South Jetties and Jetty A at the mouth of the Columbia River (MCR) navigation channel, Clatsop County Oregon and Pacific County, Washington. Of interest to the Fish and Wildlife Service (Service) is your evaluation of the impacts to listed bull trout (*Salvelinus confluentus*) and critical habitat, marbled murrelet (*Brachyramphus marmoratus*), and western snowy plover (*Charadrius alexandrinus nivosus*). The BA submitted for this proposed action includes your determination that the proposed action "may affect but is not likely to adversely affect" the above species and critical habitat. Our review and comments regarding these determinations are provided pursuant to section 7 of the Endangered Species Act of 1973, as amended (16 U.S.C. 1536 et seq.).

Consultation History

The Service has coordinated with the Corps on this evolving preferred alternative since 2005. Previously, the Corps submitted an earlier version of this BA proposing a larger jetty rebuild. That BA was withdrawn in January of 2008 due to significant changes in the proposed action. On February 10, 2010, the Service sent comments to the Corps based on a revised environmental assessment (CENWP-PM-E-10-03) received in our office January 14, 2010. The current proposal constitutes a new proposed action with a smaller project footprint and was determined to be the preferred alternative.

Proposed Action

The North and South Jetties and Jetty A have badly deteriorated areas where degradation has accelerated in recent years due to increased storm activity and loss of sand shoal material upon which the jetties are constructed. The purpose of this proposal is to perform modifications and repairs to the jetties at the mouth of the Columbia River that would strengthen the jetty structures, extend their functional life, and maintain deep-draft navigation. Scheduled repairs addressing the existing loss of cross sections and the addition of engineering features designed to minimize future cross section instability are planned. New groins will be constructed primarily on existing relic stone and the head capping will be placed on relic as well as jetty stone that is above MLLW. An armor stone cap of stone or equivalent concrete armor will be placed on the head the jetties. Detailed descriptions of the repair schedule, placement, and rock tonnage are provided in the BA and are incorporated here by reference.

The proposed jetty repair would be conducted by marine and/or land access activities which would include stone placement from both land and water. This includes the construction of haul roads and access ramps, placement of mooring dolphins for barges delivering stone to the jetties, and construction of equipment and rock storage areas. Placement by water could occur via the use of a jack-up barge on the South Jetty, and regular dredging and disposal of infill is expected to occur at off-loading facilities. The duration of the construction schedule is 20 years, with a 50-year operational lifetime for the MCR jetty system. Jetty rehabilitation work would occur throughout the year, where weather and other conditions allow for safe operation.

Conclusion

Based upon the information in the biological assessment, we concur with your determination that the proposed action **"may affect but is not likely to adversely affect"** bull trout and proposed critical habitat for the following reasons: 1) it is unlikely bull trout will be within the action area; and 2) the primary constituent elements of critical habitat are not likely to be degraded to an extent that is measureable or permanent.

Based upon the information in the biological assessment, we concur with your determination that the proposed action **"may affect but is not likely to adversely affect"** marbled murrelet for the following reasons: 1) conservation measures will be implemented to reduce potential noise disturbance by haul trucks through nesting habitat at Cape Disappointment State Park; 2) abundant foraging habitat is available adjacent to the activity and any disturbance would be minor and temporary; and 3) effects to prey resources would be temporary and would not impact resources known to be limiting factors to murrelet populations.

Based upon the information in the biological assessment, we concur with your determination that the proposed action **"may affect but is not likely to adversely affect"** the western snowy plover because it is unlikely to occur within the action area, and therefore exposure to effects of the proposed action is low.

Conservation Recommendations

Section 7(a)(1) of the Act directs Federal agencies to utilize their authorities to further the purposes of the Act by carrying out conservation programs for the benefit of endangered and threatened species. Conservation recommendations are discretionary agency activities to minimize or avoid adverse effects of a proposed action on listed species or critical habitat, and to help implement recovery plans or to develop information. The Service recommends that the following conservation measures be implemented as a means of furthering the conservation of western snowy plovers:

1. The construction activities are proposed in the vicinity of areas known to have historical winter and breeding snowy plover populations, and are directly adjacent to the Columbia River South Jetty Snowy Plover Management Area (SPMA). During this 20-year project timeframe, the Oregon Park and Recreation Department (OPRD) will be implementing a management plan for plovers within the SPMA to restore sufficient habitat for snowy plover nesting and brood rearing to occur, reduce the amount of predators present, and keep human disturbance to a minimum. If snowy plovers attempt to nest adjacent to this activity, they could experience disturbance effects. Therefore, the Corps should survey for plover presence during the nesting season (March 15 through September 15) in areas of suitable habitat. This will help determine if snowy plovers are nesting in any given year during the life of this project. Surveys should be conducted with the Service Breeding Window Survey Protocol and coordinated with OPRD and the Service. Monitoring of plovers should be conducted a minimum of once every two weeks during the nesting season. Nesting surveys could cease after July 15, if plovers are not observed. Should plovers be observed, the Corps should immediately contact the Service and determine the next steps.

2. The Corps should consider using the heavy equipment that will already be in place at the south jetty staging area to restore and enhance nesting habitat on Clatsop Spit by removing European beach grass (*Ammophila arenaria*) or other invasive species. This area has been identified as a SPMA and is an important area for restoration of suitable habitat under the Oregon State Parks Habitat Conservation Plan for the western snowy plover.

3. The Corps should work with the OPRD to identify and prioritize specific areas for habitat creation. The Corps should consider the beneficial use of dredging material from the off-loading facilities to cover and eliminate European beach grass, especially if there is an opportunity for dune augmentation at the SPMA.

4. All garbage should be contained or removed regularly from the project site to minimize the risk of attracting additional predators, such as corvids, to the area.

If you have any questions or need more information, please Kathy Roberts of my staff at (503) 231-6179.

Sincerely,

Paul Henson, PhD
State Supervisor

WALLA WALLA COST ENGINEERING TECHNICAL CENTER OF EXPERTISE

COST AGENCY TECHNICAL REVIEW

CERTIFICATION STATEMENT

For

NWP – MCR Jetties
Major Rehabilitation

The MCR Jetties Major Rehabilitation project as presented by Portland District has undergone a successful Cost Agency Technical Review (Cost ATR), performed by the Walla Walla District Cost Engineering Technical Center of Expertise (Cost TCX) team. The Cost ATR included study of the project scope, report, cost estimates, schedules, escalation, and risk-based contingencies. This certification signifies the products meet the quality standards as prescribed in ER 1110-2-1150 Engineering and Design for Civil Works Projects and ER 1110-2-1302 Civil Works Cost Engineering.

As of June 13, 2012, the Cost TCX certifies the estimated total project cost of:

FY 2014 Price Level: $238,547,000
Fully Funded Amount: $257,201,000

It remains the responsibility of the District to correctly reflect these cost values within the Final Report and to implement effective project management controls and implementation procedures including risk management throughout the life of the project.

Glenn R. Matlock (signature)

Glenn R. Matlock, PE, CCE
Chief, Cost Engineering
Walla Walla District

US Army Corps of Engineers®

Date 13 June 2012

APPENDIX E

RECOMMENDED PLAN
COST ENGINEERING PACKAGE

Table of Contents

**** TOTAL PROJECT COST SUMMARY ****

PROJECT: MCR Major Rehabilitation
LOCATION: Mouth of Columbia River

DISTRICT: NWP Portland District PREPARED: 6/8/2012
POC: CHIEF, COST ENGINEERING, Mike Moran

This Estimate reflects the scope and schedule in report; MCR Major Rehabilitation Report June 2012

WBS Structure		ESTIMATED COST				PROJECT FIRST COST (Constant Doller Basis)				TOTAL PROJECT COST (FULLY FUNDED)				
						Program Year (Budget EC): 2014 Effective Price Level Date: 1 OCT 13								
WBS NUMBER	Civil Works Feature & Sub-Feature Description	COST ($K)	CNTG ($K)	CNTG (%)	TOTAL ($K)	ESC (%)	COST ($K)	CNTG ($K)	TOTAL ($K)	Spent Thru: 8-Jun-12 ($K)		COST ($K)	CNTG ($K)	FULL ($K)
A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
10	Contract 1, Jetty A Season 1, Year 2015	$18,887	$5,836	31%	$24,723	2.5%	$19,356	$5,981	$25,337			$19,957	$6,167	$26,124
10	Contract 2, NJ Season 1, Year 2015	$20,172	$6,233	31%	$26,405	2.5%	$20,674	$6,388	$27,062			$21,316	$6,587	$27,902
10	Contract 2, NJ Season 2, Year 2016	$15,929	$4,922	31%	$20,851	2.5%	$16,325	$5,044	$21,369			$17,135	$5,295	$22,430
10	Contract 2, NJ Season 3, Year 2017	$12,526	$3,871	31%	$16,397	2.5%	$12,838	$3,967	$16,804			$13,717	$4,239	$17,956
10	Contract 3, SJ Season 1, Year 2017	$23,145	$7,152	31%	$30,297	2.5%	$23,720	$7,330	$31,050			$25,346	$7,832	$33,177
10	Contract 3, SJ Season 2, Year 2018	$18,872	$5,831	31%	$24,703	2.5%	$19,341	$5,976	$25,317			$21,038	$6,501	$27,539
10	Contract 4, SJ Season 1, Year 2019	$20,242	$6,255	31%	$26,497	2.5%	$20,746	$6,410	$27,156			$22,972	$7,098	$30,070
10	Contract 4, SJ Season 2, Year 2020	$22,746	$7,029	31%	$29,775	2.5%	$23,312	$7,203	$30,515			$26,278	$8,120	$34,398
	CONSTRUCTION ESTIMATE TOTALS:	$152,519	$47,128		$199,647	$0	$156,311	$48,300	$204,611			$167,759	$51,838	$219,597
01	LANDS AND DAMAGES		-			-								
30	PLANNING, ENGINEERING & DESIGN	$16,666	$5,150	31%	$21,816	3.7%	$17,282	$5,340	$22,622			$18,790	$5,806	$24,596
31	CONSTRUCTION MANAGEMENT	$8,335	$2,576	31%	$10,911	3.7%	$8,643	$2,671	$11,314			$9,938	$3,071	$13,009
	PROJECT COST TOTALS:	$177,520	$54,854	31%	$232,373		$182,236	$56,311	$238,547			$196,487	$60,714	$257,201

CHIEF, COST ENGINEERING, Mike Moran

PROJECT MANAGER, Eric Bluhm

CHIEF, REAL ESTATE,

CHIEF, PLANNING,Laura Hicks

CHIEF, ENGINEERING, Lance Helwig

~~CHIEF, OPERATIONS, James Mahar~~ for

CHIEF, CONSTRUCTION, Karen Garmire

CHIEF, CONTRACTING, Ralph Banse-fay

CHIEF, PM-PB, ~~xxxx~~ Don Erickson

for
CHIEF, DPM, Kevin Brice

ESTIMATED FEDERAL COST:	100%	**$257,201**
ESTIMATED NON-FEDERAL COST:		
ESTIMATED TOTAL PROJECT COST:		**$257,201**

O&M OUTSIDE OF TOTAL PROJECT COST:

**** TOTAL PROJECT COST SUMMARY ****

**** CONTRACT COST SUMMARY ****

PROJECT: MCR Major Rehabilitation
LOCATION: Mouth of Columbia River
This Estimate reflects the scope and schedule in report; MCR Major Rehabilitation Report June 2012

DISTRICT: NWP Portland District PREPARED: 6/8/2012
POC: CHIEF, COST ENGINEERING, Mike Moran

WBS Structure		ESTIMATED COST				PROJECT FIRST COST (Constant Doller Basis)				TOTAL PROJECT COST (FULLY FUNDED)				
		Estimate Prepared: 8-Jun-12 Effective Price Level: 8-Jun-12				Program Year (Budget EC): 2014 Effective Price Level Date: 1 OCT 13								
				RISK BASED										
WBS NUMBER	Civil Works Feature & Sub-Feature Description	COST ($K)	CNTG ($K)	CNTG (%)	TOTAL ($K)	ESC (%)	COST ($K)	CNTG ($K)	TOTAL ($K)	Mid-Point Date	INFLATED (%)	COST ($K)	CNTG ($K)	FULL ($K)
A	*B*	*C*	*D*	*E*	*F*	*G*	*H*	*I*	*J*	*P*	*L*	*M*	*N*	*O*
	CONTRACT 1 (2015 Jetty A)													
10	Contract 1, Jetty A Season 1, Year 2015	$18,887	$5,836	31%	$24,723	2.5%	$19,356	$5,981	$25,337	2015Q4	3.1%	$19,957	$6,167	$26,124
	CONSTRUCTION ESTIMATE TOTALS:	$18,887	$5,836	31%	**$24,723**		$19,356	$5,981	$25,337			$19,957	$6,167	$26,124
01	LANDS AND DAMAGES													
30	PLANNING, ENGINEERING & DESIGN													
2.0%	Project Management	$378	$117	31%	$495	3.7%	$392	$121	$513	2014Q3	1.8%	$399	$123	$522
1.0%	Planning & Environmental Compliance	$189	$58	31%	$247	3.7%	$196	$61	$257	2014Q3	1.8%	$200	$62	$261
5.0%	Engineering & Design	$944	$292	31%	$1,236	3.7%	$979	$302	$1,281	2014Q3	1.8%	$997	$308	$1,305
0.5%	Engineering Tech Review ITR & VE	$94	$29	31%	$123	3.7%	$97	$30	$128	2014Q3	1.8%	$99	$31	$130
0.5%	Contracting & Reprographics	$94	$29	31%	$123	3.7%	$97	$30	$128	2014Q3	1.8%	$99	$31	$130
1.0%	Engineering During Construction	$189	$58	31%	$247	3.7%	$196	$61	$257	2015Q4	6.9%	$209	$65	$274
0.5%	Planning During Construction	$94	$29	31%	$123	3.7%	$97	$30	$128	2015Q4	6.9%	$104	$32	$136
0.5%	Project Operations	$94	$29	31%	$123	3.7%	$97	$30	$128	2014Q3	1.8%	$99	$31	$130
31	CONSTRUCTION MANAGEMENT													
3.5%	Construction Management	$661	$204	31%	$865	3.7%	$685	$212	$897	2015Q4	6.9%	$732	$226	$959
1.0%	Project Operation:	$189	$58	31%	$247	3.7%	$196	$61	$257	2015Q4	6.9%	$209	$65	$274
1.0%	Project Management	$189	$58	31%	$247	3.7%	$196	$61	$257	2015Q4	6.9%	$209	$65	$274
	CONTRACT COST TOTALS:	$22,002	$6,799		**$28,800**		$22,586	$6,979	$29,566			$23,316	$7,205	**$30,520**

**** TOTAL PROJECT COST SUMMARY ****

**** CONTRACT COST SUMMARY ****

PROJECT: MCR Major Rehabilitation
LOCATION: Mouth of Columbia River
This Estimate reflects the scope and schedule in report; MCR Major Rehabilitation Report June 2012

DISTRICT: NWP Portland District PREPARED: 6/8/2012
POC: CHIEF, COST ENGINEERING, Mike Moran

WBS Structure		ESTIMATED COST				PROJECT FIRST COST (Constant Doller Basis)				TOTAL PROJECT COST (FULLY FUNDED)				
		Estimate Prepared: Effective Price Level:			habilitation Rep	Program Year (Budget EC): 2014 Effective Price Level Date: 1 OCT 13								
WBS NUMBER	Civil Works Feature & Sub-Feature Description	COST ($K)	CNTG ($K)	CNTG (%)	TOTAL ($K)	ESC (%)	COST ($K)	CNTG ($K)	TOTAL ($K)	Mid-Point Date	INFLATED (%)	COST ($K)	CNTG ($K)	FULL ($K)
A	*B*	*C*	*D*	*E*	*F*	*G*	*H*	*I*	*J*	*P*	*L*	*M*	*N*	*O*
	CONTRACT 2 (2015-2017 N. Jetty)													
10	Contract 2, NJ Season 1, Year 2015	$20,172	$6,233	31%	$26,405	2.5%	$20,674	$6,388	$27,062	2015Q4	3.1%	$21,316	$6,587	$27,902
10	Contract 2, NJ Season 2, Year 2016	$15,929	$4,922	31%	$20,851	2.5%	$16,325	$5,044	$21,369	2016Q4	5.0%	$17,135	$5,295	$22,430
10	Contract 2, NJ Season 3, Year 2017	$12,526	$3,871	31%	$16,397	2.5%	$12,838	$3,967	$16,804	2017Q4	6.9%	$13,717	$4,239	$17,956
	CONSTRUCTION ESTIMATE TOTALS:	$48,627	$15,026	31%	**$63,653**		$49,836	$15,399	$65,236			$52,168	$16,120	$68,288
01	LANDS AND DAMAGES													
30	PLANNING, ENGINEERING & DESIGN													
2.0%	Project Management	$973	$301	31%	$1,274	3.7%	$1,009	$312	$1,321	2014Q3	1.8%	$1,027	$317	$1,345
1.0%	Planning & Environmental Compliance	$486	$150	31%	$636	3.7%	$504	$156	$660	2014Q3	1.8%	$513	$159	$672
5.0%	Engineering & Design	$2,431	$751	31%	$3,182	3.7%	$2,521	$779	$3,300	2014Q3	1.8%	$2,567	$793	$3,360
0.5%	Engineering Tech Review ITR & VE	$243	$75	31%	$318	3.7%	$252	$78	$330	2014Q3	1.8%	$257	$79	$336
0.5%	Contracting & Reprographics	$243	$75	31%	$318	3.7%	$252	$78	$330	2014Q3	1.8%	$257	$79	$336
1.0%	Engineering During Construction	$486	$150	31%	$636	3.7%	$504	$156	$660	2016Q4	11.0%	$559	$173	$732
0.5%	Planning During Construction	$243	$75	31%	$318	3.7%	$252	$78	$330	2016Q4	11.0%	$280	$86	$366
0.5%	Project Operations	$243	$75	31%	$318	3.7%	$252	$78	$330	2014Q3	1.8%	$257	$79	$336
31	CONSTRUCTION MANAGEMENT													
3.5%	Construction Management	$1,702	$526	31%	$2,228	3.7%	$1,765	$545	$2,310	2016Q4	11.0%	$1,958	$605	$2,563
1.0%	Project Operation:	$486	$150	31%	$636	3.7%	$504	$156	$660	2016Q4	11.0%	$559	$173	$732
1.0%	Project Management	$486	$150	31%	$636	3.7%	$504	$156	$660	2016Q4	11.0%	$559	$173	$732
	CONTRACT COST TOTALS:	$56,649	$17,505		**$74,154**		$58,155	$17,970	$76,124			$60,960	$18,837	**$79,797**

****** TOTAL PROJECT COST SUMMARY ******

PROJECT: MCR Major Rehabilitation
LOCATION: Mouth of Columbia River
This Estimate reflects the scope and schedule in report; MCR Major Rehabilitation Report June 2012

DISTRICT: NWP Portland District PREPARED: 6/8/2012
POC: CHIEF, COST ENGINEERING, Mike Moran

WBS Structure		ESTIMATED COST				PROJECT FIRST COST (Constant Doller Basis)				TOTAL PROJECT COST (FULLY FUNDED)				
		Estimate Prepared: Effective Price Level:			'RACTING, Ra	Program Year (Budget EC): Effective Price Level Date:			2014 1 OCT 13					
WBS NUMBER	Civil Works Feature & Sub-Feature Description	COST ($K)	CNTG ($K)	CNTG (%)	TOTAL ($K)	ESC (%)	COST ($K)	CNTG ($K)	TOTAL ($K)	Mid-Point Date	INFLATED (%)	COST ($K)	CNTG ($K)	FULL ($K)
A	*B*	*C*	*D*	*E*	*F*	*G*	*H*	*I*	*J*	*P*	*L*	*M*	*N*	*O*
	CONTRACT 3 (2017-1018 S. Jetty)													
10	Contract 3, SJ Season 1, Year 2017	$23,145	$7,152	31%	$30,297	2.5%	$23,720	$7,330	$31,050	2017Q4	6.9%	$25,346	$7,832	$33,177
10	Contract 3, SJ Season 2, Year 2018	$18,872	$5,831	31%	$24,703	2.5%	$19,341	$5,976	$25,317	2018Q4	8.8%	$21,038	$6,501	$27,539
	CONSTRUCTION ESTIMATE TOTALS:	$42,017	$12,983	31%	**$55,000**		$43,062	$13,306	$56,368			$46,384	$14,333	$60,716
01	LANDS AND DAMAGES													
30	PLANNING, ENGINEERING & DESIGN													
2.0%	Project Management	$840	$260	31%	$1,100	3.7%	$871	$269	$1,140	2016Q2	8.9%	$949	$293	$1,242
1.0%	Planning & Environmental Compliance	$420	$130	31%	$550	3.7%	$436	$135	$570	2016Q2	8.9%	$474	$147	$621
5.0%	Engineering & Design	$2,101	$649	31%	$2,750	3.7%	$2,179	$673	$2,852	2016Q2	8.9%	$2,373	$733	$3,106
0.5%	Engineering Tech Review ITR & VE	$210	$65	31%	$275	3.7%	$218	$67	$285	2016Q2	8.9%	$237	$73	$310
0.5%	Contracting & Reprographics	$210	$65	31%	$275	3.7%	$218	$67	$285	2016Q2	8.9%	$237	$73	$310
1.0%	Engineering During Construction	$420	$130	31%	$550	3.7%	$436	$135	$570	2018Q1	16.1%	$505	$156	$662
0.5%	Planning During Construction	$210	$65	31%	$275	3.7%	$218	$67	$285	2018Q1	16.1%	$253	$78	$331
0.5%	Project Operations	$210	$65	31%	$275	3.7%	$218	$67	$285	2016Q2	8.9%	$237	$73	$310
31	CONSTRUCTION MANAGEMENT													
3.5%	Construction Management	$1,471	$455	31%	$1,926	3.7%	$1,525	$471	$1,997	2018Q1	16.1%	$1,770	$547	$2,317
1.0%	Project Operation:	$420	$130	31%	$550	3.7%	$436	$135	$570	2018Q1	16.1%	$505	$156	$662
1.0%	Project Management	$420	$130	31%	$550	3.7%	$436	$135	$570	2018Q1	16.1%	$505	$156	$662
	CONTRACT COST TOTALS:	$48,949	$15,125		**$64,074**		$50,250	$15,527	$65,777			$54,430	$16,819	**$71,249**

****** TOTAL PROJECT COST SUMMARY ******

PROJECT: MCR Major Rehabilitation
LOCATION: Mouth of Columbia River
This Estimate reflects the scope and schedule in report; MCR Major Rehabilitation Report June 2012

DISTRICT: NWP Portland District PREPARED: 6/8/2012
POC: CHIEF, COST ENGINEERING, Mike Moran

WBS Structure		**ESTIMATED COST**				**PROJECT FIRST COST (Constant Doller Basis)**				**TOTAL PROJECT COST (FULLY FUNDED)**				
		Estimate Prepared: Effective Price Level:				Program Year (Budget EC): 2014 Effective Price Level Date: 1 OCT 13								
WBS NUMBER	Civil Works Feature & Sub-Feature Description	COST ($K)	CNTG ($K)	CNTG (%)	TOTAL ($K)	ESC (%)	COST ($K)	CNTG ($K)	TOTAL ($K)	Mid-Point Date	INFLATED (%)	COST ($K)	CNTG ($K)	FULL ($K)
A	***B***	***C***	***D***	***E***	***F***	***G***	***H***	***I***	***J***	***P***	***L***	***M***	***N***	***O***
	CONTRACT 4 (2019-2020 S. Jetty)													
10	Contract 4, SJ Season 1, Year 2019	$20,242	$6,255	31%	$26,497	2.5%	$20,746	$6,410	$27,156	2019Q4	10.7%	$22,972	$7,098	$30,070
10	Contract 4, SJ Season 2, Year 2020	$22,746	$7,029	31%	$29,775	2.5%	$23,312	$7,203	$30,515	2020Q4	12.7%	$26,278	$8,120	$34,398
	CONSTRUCTION ESTIMATE TOTALS:	$42,988	$13,283	31%	**$56,272**		$44,057	$13,614	$57,671			$49,250	$15,218	$64,469
01	LANDS AND DAMAGES													
30	PLANNING, ENGINEERING & DESIGN													
2.0%	Project Management	$840	$260	31%	$1,100	3.7%	$871	$269	$1,140	2018Q1	16.1%	$1,011	$312	$1,323
1.0%	Planning & Environmental Compliance	$420	$130	31%	$550	3.7%	$436	$135	$570	2018Q1	16.1%	$505	$156	$662
5.0%	Engineering & Design	$2,101	$649	31%	$2,750	3.7%	$2,179	$673	$2,852	2018Q1	16.1%	$2,529	$781	$3,310
0.5%	Engineering Tech Review ITR & VE	$210	$65	31%	$275	3.7%	$218	$67	$285	2018Q1	16.1%	$253	$78	$331
0.5%	Contracting & Reprographics	$210	$65	31%	$275	3.7%	$218	$67	$285	2018Q1	16.1%	$253	$78	$331
1.0%	Engineering During Construction	$420	$130	31%	$550	3.7%	$436	$135	$570	2019Q3	22.2%	$532	$164	$697
0.5%	Planning During Construction	$210	$65	31%	$275	3.7%	$218	$67	$285	2019Q3	22.2%	$266	$82	$348
0.5%	Project Operations	$210	$65	31%	$275	3.7%	$218	$67	$285	2018Q1	16.1%	$253	$78	$331
31	CONSTRUCTION MANAGEMENT													
3.5%	Construction Management	$1,471	$455	31%	$1,926	3.7%	$1,525	$471	$1,997	2019Q3	22.2%	$1,864	$576	$2,440
1.0%	Project Operation:	$420	$130	31%	$550	3.7%	$436	$135	$570	2019Q3	22.2%	$532	$164	$697
1.0%	Project Management	$420	$130	31%	$550	3.7%	$436	$135	$570	2019Q3	22.2%	$532	$164	$697
	CONTRACT COST TOTALS:	$49,920	$15,425		**$65,346**		$51,245	$15,835	$67,080			$57,781	$17,854	**$75,635**

MCR JETTIES MAJOR REHABILITATION

COST ESTIMATE

Basis of Estimate

The basis for the estimate is given in scoping documents provided by the Product Development Team.

Estimate References

ER 1110-2-1302 (Civil Works Cost Engineering)
EP 1110-1-8 (Construction Equipment Ownership and Operating Expense Schedule)
ETL 1110-2-573 (Construction Cost Estimating Guide for Civil Works)

Overtime

It is anticipated that the contractor, based on required production rates and past experience, will work 6 days per week, 10 hours per shift, one shift per day.

Construction Windows

Typical weather restricts stone placement to June through September of each year. There are no in water work restrictions for placing stones.

Acquisition Strategy

The rehabilitation of the jetties will be accomplished using multi-year construction contracts, with base and optional items. For computing the Total Project Cost (TPCS) beginning in 2015, four contracts were assumed including Jetty A (2015), North Jetty (2015-2017), South Jetty (2017-2018), and South Jetty (2019-2020).

Subcontracting Plan

The estimate assumes a dredging subcontractor. All other activities to be performed by the prime contractor.

General Estimating Information

Sources of Historical Data. The 2005 MCR North Jetty repair project and the 2006 MCR South Jetty repair project were among the sources of historical data used in the preparation of this estimate.

Hazardous, Toxic and Radioactive Waste (HTRW) Remediation. No HTRW remediation will be necessary for this job.

Computation of Quantities. Quantities were computed by Coastal Engineering personnel.

Equipment/Labor Availability. Equipment of the appropriate size would likely be available from the Portland, OR area, though the large stone handling crane may need to be obtained from Seattle, WA.

Effective Dates for Labor, Equipment, Material Pricing. The effective date for all pricing is April 2012.

Equipment Rates. Equipment rates were obtained from the 2011 MII equipment region 8 database, which is derived from the equipment methodology in EP 1110-1-8.

Labor Rates. Labor rates were updated using recent Davis-Bacon rates for Clatsop County, OR and Pacific County, WA. Payroll tax and insurance rates were computed within MII. An overtime percentage was applied assuming the contractor will work six 10-hour days per week. Hourly travel costs were added for all crafts, as allowed by the latest AGC union labor agreements.

Overhead, Profit and Bond. Prime Contractor home office overhead was calculated utilizing a rule-of-thumb percentage of 10% and job office overhead was detailed out for each construction year. Profit was included as this is a budget estimate. Bond was determined using the Class B rating in MII.

A dredging subcontractor was utilized and all overhead, profit, and bond costs are included. Dredging costs are based on bid abstract information obtained from the 2006 North Coast clamshell dredging contract information for Baker Bay.

Functional Costs. Functional costs (i.e., Lands and Damages, Planning, Engineering and Design, and Construction Management) were not included as part of the construction cost but were included in the TPCS.

Total Project Costs. TPCS will show the overall project cost including contingencies, escalation, and associated administrative costs.

Contingencies. Contingencies will be developed using the Project Cost and Schedule Risk Analysis. No contingencies were added to the MII estimate.

Escalation. Escalation will be based upon the USACE Engineering Manual 1110-2-1304 Civil Works Construction Cost Index System (CWCCIS) and included in the Total Project Cost Summary (TPCS).

Specific Estimating Details

Transport of Stone to Jetty. A transportation study was completed to compare the costs of transporting stone with barges versus trucks. Typically barging is the less expensive option especially when transporting from the more distant quarries.

The methods described below for transport of the stone are those assumed in the estimate. Several stone suppliers were contacted but and provided market pricing based on assumed parameters for the project. Assumptions include a minimum density of 165 #/cf and the stone would be delivered the most economical way to the jetty and unloaded by the contractor. The actual methods used by the contractor will likely vary. Currently it is assumed stone and haul road material for jetty rehabilitation will be transported to the jetty from the quarries via a combination of highway trucks and barges. Stones will be transported in the nearest port and then barged to the project site.

Off-loading facilities will be constructed at the beginning of the initial season of jetty construction; one near the South Jetty Parking Lot D, and one near the North Jetty and Jetty A. Stones would be unloaded at the off-loading sites and transported to the staging areas near the jetty. Stone would then be re-loaded onto off-highway trucks when ready to be placed at the jetty. From the staging area, stone will be transported out to the jetties where stone is being placed by land-based equipment.

It is possible that stone may be transported from as far away as British Columbia or Northern California. If this is the case, it is likely that transportation will be by barge.

The barges would require a 20 foot draft. The barge un-loading sites would be dredged in order to meet this depth.

Jetty Stone. Quantities were given and vary depending on unit weight of the stone and the reach of the jetties the stone is to be placed. Quantities have also been increase by 10% to account for losses due to variations in stone size, shapes, and over placement outside the neat lines.

Land Based Production. Production is based on using equipment similar to what was used for the recent jetty repairs. A crane would be used to place stone that is outside the reach of the capabilities of an excavator. Assumptions for which piece of equipment to used was based on typical jetty cross-sections, stone size and distance from the equipment to where the stone is to be placed. Lifting tables and diagrams for the assumed equipment were used to determine equipment capabilities.

Assumed production rates are 100 tons/hour as an average for both the crane and excavator. The limiting factor for production is the rate the crane can place stone, while during operation with the excavator, it is the delivery rate of the stone that determines production. Historical production rates were used in determining assumed rates.

Use off-highway dump trucks to transport stone, and a dozer and front-end loader to maintain the haul road. The production rate includes time for stone placement, moving equipment, and maintenance/repairs. A separate blade and operator crew are included for maintaining the storage areas.

Weigh Scales. Scales and a scale house for weighing off-highway trucks will be needed onsite. Scales need to be 100-ton capacity. The quote obtained for the South Jetty Repairs was used. This item includes work to prepare the foundation and to set the scales. The scale house is 10 feet x 16 feet x 8 feet and of wood frame construction. It is assumed the scale house is built off-site and transported to the site. All utilities are included.

Fences and Gates. Construct a fence around the contractor's yard area, stone storage areas, and selected locations as required to direct traffic. Assume 6-foot high temporary chain link fence with a double gate with 11-foot leaves. The fence and gate will be removed at end of the individual contracts.

Jetty Haul Roads. This item consists of constructing an access road on top of the jetty, to provide a suitable smooth surface for heavy equipment. Chink rock will be used to fill in the larger holes, and then quarry run material. A 1' layer of ¾" material is included for haul road maintenance items throughout the construction period.

Haul Road Turnout. Turnouts will likely be necessary and are assumed every 500' of jetty construction beginning once the jetty extends into the ocean. The turnouts will be constructed by trucks dumping armor stone matching the *in situ* stone and rearranging stones to produce a well-keyed mass. Quarry waste will be used as haul road material on top of the jettystone. Stone in the turnouts will be used to complete the jetty rehabilitation; therefore, material costs are covered in the "Stone" items.

Quantities for each turnout: Turnout volume = 30 x 40 x 30 x 0.5/27 = 670 cy x 2.2 ton/cy = 1,474 ton less 30% voids (442 ton) = 1,031 say 1,100 ton. Turnouts are assumed to be rebuilt at the beginning of every construction season.

Design Quantities

JETTY "A" Schedule Repairs Hold Length

Year	From Sta	To Sta	Re-Work** (5 to 15 tons) (tons)	Small Armor (3 to 15 tons) (tons)	Medium Armor (10 to 20 tons) (tons)	Large Armor (4 to 18 tons) (tons)	Super Armor (16 to 33 tons) (tons)	Total New Armor + Existing Stone Re-work for Each Repair Campaign (tons)
2015	48+00	60+00	4,823	32,150				36,973
	69+00	73+00	1,608			10,717		12,324
	85+00	89+00	1,608			10,717		12,324
	74+00	84+00	4,019			26,792		30,810
		TOTAL	12,056	32,150		48,225		
				TOTAL NEW REPAIR ARMOR on jetty			80,375	92,431

NORTH JETTY Schedule Repairs Hold Length

Year	From Sta	To Sta	Re-Work** (5 to 15 tons) (tons)	Small Armor (6 to 18 tons) (tons)	Medium Armor (10 to 20 tons) (tons)	Large Armor (8 to 24 tons) (tons)	Super Armor (16 to 33 tons) (tons)	Total New Armor + Existing Stone Re-work for Each Repair Campaign (tons)
2015	20+00	30+00	5,360	35,733				41,093
	30+00	45+00	8,040	53,599				61,639
2016	45+00	54+00	4,824	32,160				36,983
	55+00	63+00	2,144	14,293				16,437
	64+00	71+00	3,752	25,013				28,765
	72+00	76+00	2,144	14,293				16,437
2017	77+00	85+00	4,288	11,435		17,152		32,874
	99+00	101+00	3,000			17,200		20,200
		TOTAL	33,552	186,525		34,352		
					TOTAL NEW REPAIR ARMOR on jetty		220,877	254,429

SOUTH JETTY Base Condition - REVISED 12 APR 2012

Year	From Sta	To Sta	Re-Work** (5 to 15 tons) (tons)	Small Armor (6 to 15 tons) (tons)	Medium Armor (10 to 20 tons) (tons)	Large Armor (13 to 26 tons) (tons)	Super Armor (16 to 33 tons) (tons)	Total New Armor + Existing Stone Re-work for Each Repair Campaign (tons)
2017	167+00	175+00	5,146	17,152	17,152			39,449
	182+00	195+00	8,361	27,872	27,872			64,105
2018	197+00	215+00	9,262	30,873	30,873			71,008
	215+00	222+00	4,052		15,008	12,006		31,066
2019	223+00	246+00	11,835		39,449	39,449		90,733
2020	258+00	290+00	12,973			36,224	50,261	99,459
		TOTAL	51,629	75,896	130,353	87,680	50,261	
				TOTAL NEW REPAIR ARMOR on jetty			344,191	395,820

MCR Major Rehabilitation - PREFERRED PLAN

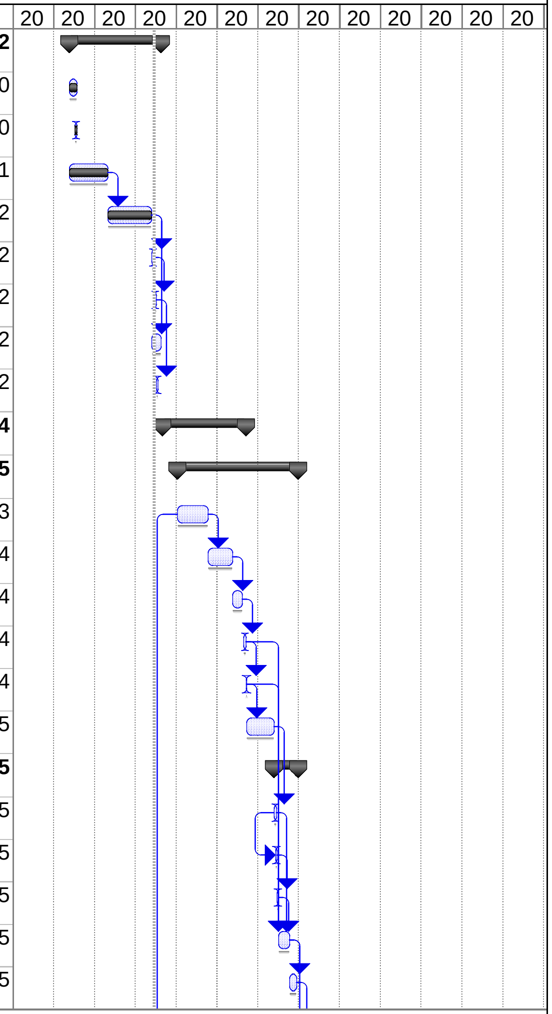
Estimated by	Phil Ohnstad
Designed by	CENWP-EC
Prepared by	CENWP-EC-CC
Preparation Date	6/8/2012
Effective Date of Pricing	6/8/2012
Estimated Construction Time	Days

Description	LaborCost	EQCost	MatlCost	ProjectCost
Project Cost Summary Report	**9,939,432**	**24,428,799**	**75,480,278**	**152,518,581**
10 BREAKWATERS AND SEAWALLS	**9,939,432**	**24,428,799**	**75,480,278**	**152,518,581**
10 001 Contract 1 JETTY A Scheduled Repairs Hold Length	**1,265,018**	**2,789,214**	**8,599,126**	**18,886,667**
1000104 AA Contract 1, Jetty A Season 1, Year 2015	**1,265,018**	**2,789,214**	**8,599,126**	**18,886,667**
10 002 Contract 2 NORTH JETTY Scheduled Repairs Hold Length	**3,225,560**	**7,689,805**	**22,673,823**	**48,627,013**
1000201 BB Contract 2, NJ Season 1, Year 2015	**1,526,283**	**3,345,728**	**9,584,691**	**20,172,152**
1000201 CC Contract 2, NJ Season 2, Year 2016	**952,581**	**2,584,962**	**7,722,757**	**15,928,822**
1000201 DD Contract 2, NJ Season 3, Year 2017	**746,696**	**1,759,114**	**5,366,374**	**12,526,039**
10 003 Contract 3 SOUTH JETTY Base Condition	**2,814,415**	**6,898,880**	**22,712,464**	**42,016,674**
1000303 AA Contract 3, SJ Season 1, Year 2017	**1,670,764**	**3,749,054**	**12,546,831**	**23,144,916**
1000303 BB Contract 3, SJ Season 2, Year 2018	**1,143,651**	**3,149,826**	**10,165,633**	**18,871,758**
10 004 Contract 4 SOUTH JETTY Base Condition	**2,634,439**	**7,050,900**	**21,494,865**	**42,988,228**
1000403 DD Contract 4, SJ Season 1, Year 2019	**1,417,303**	**3,394,306**	**10,684,313**	**20,242,187**
1000403 EE Contract 4, SJ Season 2, Year 2020	**1,217,136**	**3,656,593**	**10,810,553**	**22,746,041**

MCR Jetty Major Rehab Preferred Plan

Mon 6/11/12

ID		Task Name	Duration	Start	Finish
1		**MCR Long Term Plan**	**586 days**	**Mon 5/24/10**	**Mon 8/20/12**
2		Main Report and Appendices (ATR Draft)	50 days	Mon 5/24/10	Fri 7/30/10
3		PDT Responses to ATR/NWD Comments	15 days	Mon 7/12/10	Fri 7/30/10
4		IEPR	246 days	Mon 5/24/10	Mon 5/2/11
5		Moffett and Nichol independent Task Order	280 days	Tue 5/3/11	Mon 5/28/12
6		Final Report Sent to NWD for Review	15 days	Tue 5/29/12	Mon 6/18/12
7		Prepare FONSI - District Engineer Signs	15 days	Tue 6/19/12	Mon 7/9/12
8		Revised Environmental Assessment	60 days	Tue 5/29/12	Mon 8/20/12
9		HQUSACE & ASA (CW) Approval	10 days	Tue 7/10/12	Mon 7/23/12
10		**FY14 Construction Base Contract**	**535 days**	**Mon 9/3/12**	**Fri 9/19/14**
65		**Contract 1, Jetty A Construction Contract 2015**	**772.5 days**	**Tue 1/15/13**	**Thu 12/31/15**
66		DDR	196 days	Tue 1/15/13	Tue 10/15/13
67		Plans and Specs	157 days	Wed 10/16/13	Thu 5/22/14
68		Contract Procurement	62 days	Fri 5/23/14	Mon 8/18/14
69		Off Loading Facility Dredging (60,000 CY)	20 days	Fri 8/29/14	Sat 9/20/14
70		Construct Off Loading Facility (1 EA)	4 days	Mon 9/22/14	Thu 9/25/14
71		Rock Delivery	175 days	Fri 9/26/14	Thu 5/28/15
72		**Jetty A Sta 40+00 to 80+00**	**154.5 days**	**Fri 5/29/15**	**Thu 12/31/15**
73		Mobilization	15 days	Fri 5/29/15	Thu 6/18/15
74		Jetty Crest Haul Road	10 days	Wed 6/10/15	Tue 6/23/15
75		Re-Work Exising Relic Stone (12,056 TN)	12 days	Tue 6/23/15	Wed 7/8/15
76		Jetty Stone Placement (80,375 TN)	80 days	Wed 7/8/15	Thu 10/15/15
77		Site Mitigation	45 days	Thu 10/15/15	Thu 12/17/15



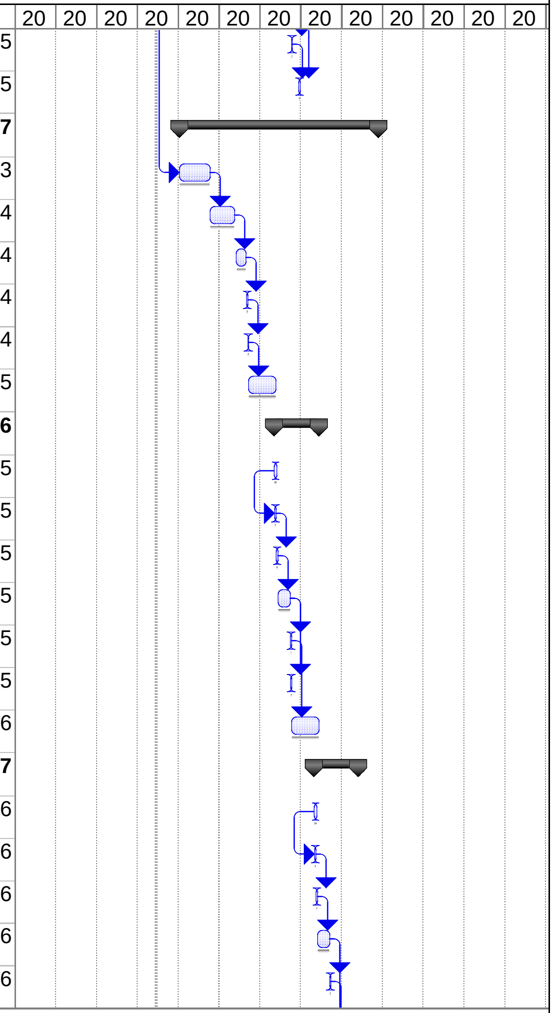
Project: MCR Major Rehab Preferred Plan Schedule
Date: Mon 6/11/12

Task
Split
Progress
Milestone
Summary
Project Summary
External Tasks
External MileTask
Split

MCR Jetty Major Rehab Preferred Plan

Mon 6/11/12

ID	Indicators	Task Name	Duration	Start	Finish
78		Remove Off Load Facilities	4 days	Thu 10/15/15	Wed 10/21/15
79		Demobillization	10 days	Thu 12/17/15	Thu 12/31/15
80		**Contract 2, North Jetty 2015, 2016, 2017**	**1271.25 days**	**Tue 1/15/13**	**Wed 11/29/17**
81		DDR	196 days	Tue 1/15/13	Tue 10/15/13
82		Plans and Specs	157 days	Wed 10/16/13	Thu 5/22/14
83		Contract Procurement	62 days	Fri 6/6/14	Mon 9/1/14
84		Off Loading Facility Dredging (30,000 CY)	10 days	Sat 9/6/14	Thu 9/18/14
85		Construct Off Loading Facility (1 EA)	4 days	Thu 9/18/14	Wed 9/24/14
86		Rock Delivery	175 days	Wed 9/24/14	Wed 5/27/15
87		**2015 North Jetty Sta 20+00 to 45+00**	**288 days**	**Mon 5/11/15**	**Wed 6/15/16**
88		Mobilization	20 days	Mon 5/11/15	Fri 6/5/15
89		Jetty Crest Haul Road	10 days	Sat 5/16/15	Thu 5/28/15
90		Re-Work Exising Relic Stone (13,400 TN)	14 days	Thu 5/28/15	Mon 6/15/15
91		Jetty Stone Placement (89,332 TN)	89 days	Mon 6/15/15	Sat 10/3/15
92		Off Loading Facility Dredging (30,000 CY)	10 days	Sat 10/3/15	Wed 10/14/15
93		Demobilization	10 days	Mon 10/5/15	Fri 10/16/15
94		Rock Delivery	175 days	Thu 10/15/15	Wed 6/15/16
95		**2016 North Jetty Sta 45+00 to76+00**	**284.25 days**	**Mon 5/2/16**	**Fri 6/2/17**
96		Mobilization	20 days	Mon 5/2/16	Fri 5/27/16
97		Jetty Crest Haul Road	10 days	Sat 5/7/16	Thu 5/19/16
98		Re-Work Exising Relic Stone (12,864 TN)	12 days	Thu 5/19/16	Fri 6/3/16
99		Jetty Stone Placement (85,759 TN)	86 days	Fri 6/3/16	Mon 9/19/16
100		Off Loading Facility Dredging (30,000 CY)	10 days	Mon 9/19/16	Fri 9/30/16



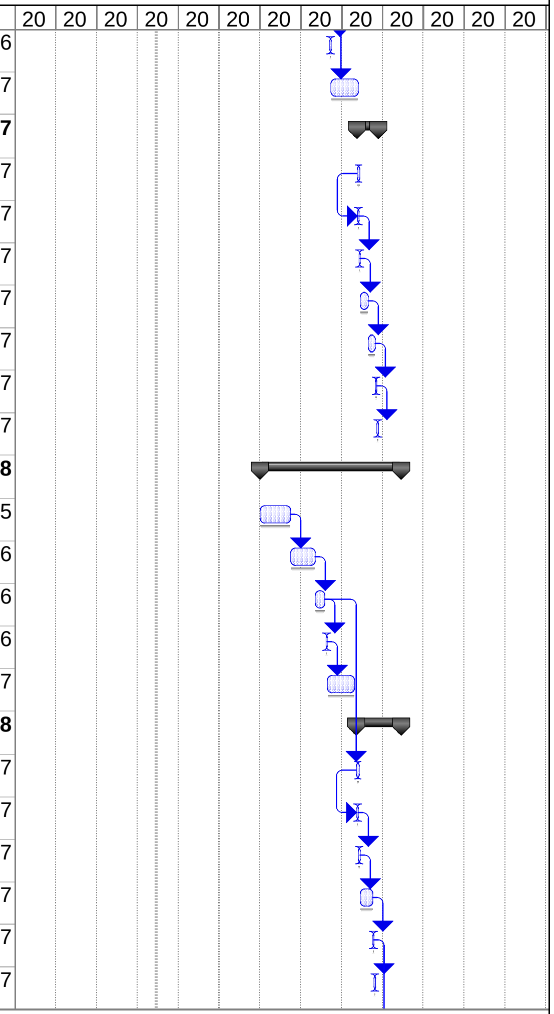
Project: MCR Major Rehab Preferred Plan Schedule
Date: Mon 6/11/12

Legend			
Task		Project Summary	
Split		External Tasks	
Progress		External MileTask	
Milestone		Split	
Summary			

MCR Jetty Major Rehab Preferred Plan

Mon 6/11/12

ID	Task Name	Duration	Start	Finish
101	Demobilization	10 days	Mon 9/19/16	Mon 10/3/16
102	Rock Delivery	175 days	Fri 9/30/16	Fri 6/2/17
103	**2017 North Jetty Sta 77+00 to101+00**	**137.25 days**	**Mon 5/22/17**	**Wed 11/29/17**
104	Mobilization	20 days	Mon 5/22/17	Fri 6/16/17
105	Jetty Crest Haul Road	10 days	Sat 5/27/17	Thu 6/8/17
106	Re-Work Exising Relic Stone (7,288 TN)	8 days	Thu 6/8/17	Mon 6/19/17
107	Jetty Stone Placement (58,400 TN)	58 days	Mon 6/19/17	Wed 8/30/17
108	Site Mitigation	45 days	Wed 8/30/17	Wed 11/1/17
109	Remove Off Load Facilities	10 days	Wed 11/1/17	Wed 11/15/17
110	Demobilization	10 days	Wed 11/15/17	Wed 11/29/17
111	**Contract 3, South Jetty 2017, 2018**	**904.63 days**	**Mon 1/5/15**	**Fri 6/22/18**
112	DDR	196 days	Mon 1/5/15	Mon 10/5/15
113	Plans and Specs	157 days	Tue 10/6/15	Wed 5/11/16
114	Contract Procurement	62 days	Thu 5/12/16	Fri 8/5/16
115	Off Loading Facility Dredging (30,000 CY)	10 days	Wed 8/17/16	Sun 8/28/16
116	Rock Delivery	175 days	Mon 8/29/16	Fri 4/28/17
117	**2017 South Jetty Sta 167+00 to 195+00**	**289.63 days**	**Mon 5/15/17**	**Fri 6/22/18**
118	Mobilization	20 days	Mon 5/15/17	Fri 6/9/17
119	Jetty Crest Haul Road	10 days	Sat 5/20/17	Thu 6/1/17
120	Re-Work Exising Relic Stone (13,507 TN)	14 days	Thu 6/1/17	Mon 6/19/17
121	Jetty Stone Placement (90,047 TN)	90 days	Mon 6/19/17	Mon 10/9/17
122	Off Loading Facility Dredging (30,000 CY)	10 days	Mon 10/9/17	Fri 10/20/17
123	Demobilization	10 days	Fri 10/20/17	Fri 11/3/17



Project: MCR Major Rehab Preferred Plan Schedule
Date: Mon 6/11/12

Task
Split
Progress
Milestone
Summary
Project Summary
External Tasks
External MileTask
Split

MCR Jetty Major Rehab Preferred Plan

ID	Task Name	Duration	Start	Finish
124	Rock Delivery	175 days	Fri 10/20/17	Fri 6/22/18
125	**2018 South Jetty Sta 45+00 to76+00**	**114.5 days**	**Mon 5/9/16**	**Fri 10/14/16**
126	Mobilization	20 days	Mon 5/9/16	Fri 6/3/16
127	Jetty Crest Haul Road	10 days	Sat 5/14/16	Thu 5/26/16
128	Re-Work Exising Relic Stone (13,314 TN)	13 days	Thu 5/26/16	Sat 6/11/16
129	Jetty Stone Placement (88,760 TN)	89 days	Sat 6/11/16	Fri 9/30/16
130	Demobilization	10 days	Fri 9/30/16	Fri 10/14/16
131	**Contract 4, South Jetty 2019, 2020**	**1014.5 days**	**Mon 2/6/17**	**Fri 12/25/20**
132	DDR	196 days	Mon 2/6/17	Mon 11/6/17
133	Plans and Specs	157 days	Tue 11/7/17	Wed 6/13/18
134	Contract Procurement	62 days	Thu 6/14/18	Fri 9/7/18
135	Off Loading Facility Dredging (30,000 CY)	10 days	Wed 9/19/18	Sun 9/30/18
136	Rock Delivery	175 days	Mon 10/1/18	Fri 5/31/19
137	**2019 South Jetty Sta 223+00 to 246+00**	**276.25 days**	**Mon 5/6/19**	**Tue 5/26/20**
138	Mobilization	20 days	Mon 5/6/19	Fri 5/31/19
139	Jetty Crest Haul Road	10 days	Sat 5/11/19	Thu 5/23/19
140	Re-Work Exising Relic Stone (11,835 TN)	12 days	Thu 5/23/19	Fri 6/7/19
141	Jetty Stone Placement (78,898 TN)	78 days	Fri 6/7/19	Thu 9/12/19
142	Off Loading Facility Dredging (30,000 CY)	10 days	Thu 9/12/19	Tue 9/24/19
143	Demobilization	10 days	Tue 9/24/19	Tue 10/8/19
144	Rock Delivery	175 days	Tue 9/24/19	Tue 5/26/20
145	**2020 South Jetty Sta 258+00 to 290+00**	**169.5 days**	**Mon 5/4/20**	**Fri 12/25/20**
146	Mobilization	20 days	Mon 5/4/20	Fri 5/29/20

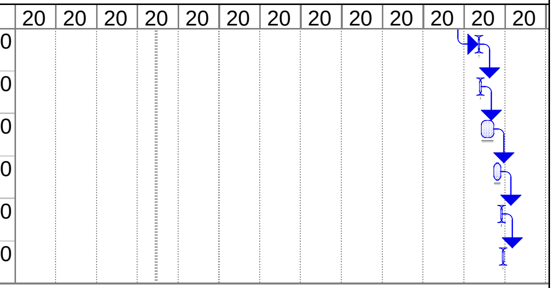
Project: MCR Major Rehab Preferred Plan Schedule
Date: Mon 6/11/12

Task
Split
Progress
Milestone
Summary
Project Summary
External Tasks
External MileTask
Split

MCR Jetty Major Rehab Preferred Plan

Mon 6/11/12

ID		Task Name	Duration	Start	Finish
147		Jetty Crest Haul Road	10 days	Sat 5/9/20	Thu 5/21/20
148		Re-Work Exising Relic Stone (12,973 TN)	13 days	Thu 5/21/20	Sat 6/6/20
149		Jetty Stone Placement (88,486 TN)	89 days	Sat 6/6/20	Fri 9/25/20
150		Site Mitigation	45 days	Fri 9/25/20	Fri 11/27/20
151		Remove Off Load Facilities	10 days	Fri 11/27/20	Fri 12/11/20
152		Demobilization	10 days	Fri 12/11/20	Fri 12/25/20



Project: MCR Major Rehab Preferred Plan Schedule
Date: Mon 6/11/12

Task | Split | Progress | Milestone | Summary | Project Summary | External Tasks | External MileTask | Split

US Army Corps
of Engineers®

Mouth of the Columbia River (MCR) Jetties
Major Rehabilitation – Preferred Plan
Project Cost and Schedule Risk Analysis Report

Prepared for:

U.S. Army Corps of Engineers,
Portland District

Prepare: February 25, 2010

U.S. Army Corps of Engineers
Cost Engineering Directory of Expertise, Walla Walla

Revised by

U.S. Army Corps of Engineers,
Portland District

Revision 120608a Updated June 8, 2012

REVISIONS

INITIAL REPORT:

Published 2/25/2010 The Cost Schedule Risk Analysis, CSRA, recommended a contingency of 29% on a total construction cost of $386 Million. Synopsis of the Project report: Base condition involved a "fix-as-fails" approach where each jetty was allowed to degrade to as low as 20 percent of the originally authorized cross section and therefore breaches were forecasted. The plan was to perform scheduled repairs with engineering features on the North Jetty and the South Jetty. Planned FOR Jetty A: immediate rehabilitation. 18 years was the estimate duration of the plans.

Revision on 4/24/2012:

Independent External Peer Review commented the previous strategy was an unrealistic assumption. The Project strategy changed. As a result, the Portland District changed the base condition to reflect the most likely future jetty maintenance strategy, one that did not allow breaches: by using interim repair with the jetty head receding. The project plan became: North Jetty Schedule Repair hold length; South Jetty base condition; Jetty A Schedule Repair hold length. CSRA was updated to match the new project scope, construction effort and risks elements. CSRA recommended contingency of 29% on a total construction cost of $160 Million. The new scope reduced the project life / duration to 7 years and reduced quantities being considered. Construction activities, materials, sources, methods and assumptions remained the same, therefore the risk elements only had minor changes. The net result for the CSRA was the same contingency percentage.

Revision on 6/8/2012

Since the Initial Report, The Corps of Engineers has continued to develop the format, documentation, and expectations for the Risk Analysis Report. This revision attempts to incorporate and address these current expectations. In additional, further review comments and project engineering and cost details have been updated and are revised in the CSRA with this current data.

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EXECUTIVE SUMMARY

Under the auspices of the US Army Corps of Engineers (USACE), Portland District, this report presents a recommendation for the total project cost and schedule contingencies for the Mouth of the Columbia River (MCR) Jetties Major Rehabilitation, Preferred Plan. In compliance with Engineer Regulation (ER) 1110-2-1302 CIVIL WORKS COST ENGINEERING, dated September 15, 2008, a formal risk analysis study was conducted for the development of contingency on the total project cost. The purpose of this risk analysis study was to establish project contingencies by identifying and measuring the cost and schedule impact of project uncertainties with respect to the estimated total project cost.

The MCR Jetties Rehabilitation Project scope changed early in 2012. IEPR comments led to a revised base condition. The previous FY 11 base condition involved a "fix-as-fails" approach where each jetty was allowed to degrade to as low as 20 percent of the originally authorized cross section and therefore breaches were forecasted. An Independent Expert Panel Review IEPR comment stated that this was an unrealistic assumption. As a result, the Portland District changed the base condition to reflect the most likely future jetty maintenance strategy, one that did not allow breaches: interim repair, with the jetty head receding. The current project considers work through 2020 instead of 2032 with an estimated project cost in the range of $152 million (without contingency nor escalation) instead of $386 million previously.

Specific to the current MCR Jetties Rehabilitation Project, the most likely total project cost (at price level) is estimated at approximately $152 Million. Based on the revised results of the Cost Schedule Risk Analysis, the recommended contingency value is $47 Million, or 31%. This contingency includes $43 Million (28%) for cost growth potential due to risk analyzed in the base cost estimate and $4 Million (3%) for cost growth potential due to risk analyzed in the baseline schedule.

Portland District revised the risk analysis performed by Walla Walla Cost Dx risk analysis using the *Monte Carlo* technique, producing the aforementioned contingencies and identifying key risk drivers.

The following table ES-1 portrays the development of contingencies. The contingency is based on an 80% confidence level, as per USACE Civil Works guidance.

Table ES-1. Contingency Analysis Table

Most Likely Cost Estimate	$152,519,000	
Confidence Level	**Value ($$)**	**Contingency (%)**
5%	$172,842,000	13%
50%	$190,033,000	25%
80%	**$199,411,000**	**31%**
95%	$208,549,000	37%

The following table ES-2 portrays the full costs of the recommended alternative based on the anticipated contracts. The costs are intended to address the congressional request of estimates to implement the project. The contingency is based on an 80% confidence level, as per accepted USACE Civil Works guidance.

Table ES-2. Cost Summary

MCR Jetties Major Rehabilitation		COST ($1,000)	CNTG ($1,000)	TOTAL ($1,000)
10	BREAKWATER AND SEAWALLS	167,759	51,838	219,597
30	PLANNING, ENGINEERING AND DESIGN	18,790	5,806	24,596
31	CONSTRUCTION MANAGEMENT	9,938	3,071	13,009
	TOTAL PROJECT COSTS	**196,487**	**60,714**	**257,201**
	Schedule Completion with Contingency	**31 Oct 2020**	**40 months**	**29 Feb 2024**

Notes:
1) Recommended contingency of 31%.
2) Costs exclude O&M and Life Cycle Cost estimates.

KEY FINDINGS/OBSERVATIONS RECOMMENDATIONS

The key cost risk drivers identified through sensitivity analysis were the following Risk Elements. These 6 Risk Elements together contributed to 78% of the statistical cost variance.

COST VARIANCE

- Risk CA-1 Incomplete Acquisition Strategy: The details of the acquisition plan in terms of the technique to let the contracts has not been fully developed. This contributed 21% of the statistical cost variance.

- Risk CON-1 Stone Quarry Site/Material Availability and Delivery: The availability and supply of stone and cranes could be an issue, depending on when the construction occurs and how much is being demanded concurrently. The sheer volume required for this project could overwhelm the local market for supply of stone of this size and quantity. This contributed 17% of the statistical cost variance.

- Risk STL-VEQ (South Jetty) Variation in Estimated Quantities: Due to the fact that the project is at a feasibility level, the quantities of stone estimated could change positively or negatively. This contributed 14% of the statistical cost variance.

- Risk PR-5 Unexpected Escalation on Stone: There could be an unusual demand on stone, causing an unexpected spike in pricing. This contributed 11% of the statistical cost variance.

- Risk PR-7 Market Conditions and Bidding Climate: There is inherent risk of cost fluctuations created by the contractors available to perform this work, as well as the effects on the market by escalation, especially due to the length of the project. This contributed 9% of the statistical cost variance.

- Risk CA-2 Numerous Separate Contracts: There are 4 separate construction contracts planned. Numerous contracts for the project may increase the costs of contracting, and lead to less favorable contract markups, and lack of efficiencies, increasing the construction costs. This contributed 6% of the statistical cost variance.

SCHEDULE VARIANCE

The key schedule risk drivers identified through sensitivity analysis were the following Risk Elements. These 4 Risk Elements together contributed to 74% of the statistical schedule variance.

- Risk TL-1 Variation in Estimated Quantities: The Project is at a feasibility level, the quantities of stone estimated could change positively or negatively. Fluctuations in quantities may delay project completion. This contributed 46% of the statistical schedule variance.

- Risk RE-5 Agency Actions Take Longer than Expected: NMFS has completed their BIOP for the project, but it requires a separate consultation for 71 habitat improvements. This contributed 11% of the statistical schedule variance.

- Risk PR-2 Adequacy of Project Funding: The current working estimate and schedule assumes obtaining outlays in an anticipated schedule and funding profile. If the timing and outlay amounts differ from the plan, it could alter the scope and scheme of implementation thereby delaying the project completion. This contributed 10% of the statistical schedule variance.

- Risk PPM-8 Unplanned Work that Must Be Accommodated: If reviews or results of models require work to be performed that has not been planned, it could impact schedule. This contributed 8% of the statistical schedule variance.

Recommendations, as detailed within the main report, include the implementation of cost and schedule contingencies, further iterative study of risks throughout the project life-cycle, potential mitigation throughout the PED phase, and proactive monitoring and control of risk identified in this study.

MAIN REPORT

1.0 PURPOSE

Under the auspices of the US Army Corps of Engineers (USACE), Portland District, this report presents a recommendation for the total project cost and schedule contingencies for the Mouth of the Columbia River (MCR) Jetties Major Rehabilitation Preferred Plan.

2.0 BACKGROUND

The Mouth of the Columbia River (MCR) Jetties Major Rehabilitation (MCR Jetties Rehab) project consists of three major components: 1) North Jetty, 2) South Jetty, and 3) Jetty A. The project is currently in the feasibility stage, although the project was previously authorized. The current working estimate value without contingency is approximately $152 Million. The project is anticipated to be 7 years in duration, with the rehabilitation occurring in several phases. The priority is for schedule repair to the jetties to reduce the chance of breach. The repairs do not include the jetty heads nor spur groins. Weather conditions typically restrict work to between June and September. No HTRW or cultural resource issues are anticipated for the work.

As a part of this effort, Portland District requested that the USACE Cost Engineering Directory of Expertise for Civil Works (Cost Engineering Dx) provide an agency technical review (ATR) of the cost estimate and schedule for Recommended Project Plan. That tasking also included providing a risk analysis study to establish the resulting contingencies. The work was updated to the current information with Revision 120608a.

3.0 REPORT SCOPE

The scope of the risk analysis report is to calculate and present the cost and schedule contingencies at the 80 percent confidence level using the risk analysis processes, as mandated by U.S. Army Corps of Engineers (USACE) Engineer Regulation (ER) 1110-2-1150, Engineering and Design for Civil Works, ER 1110-2-1302, Civil Works Cost Engineering, and Engineer Technical Letter 1110-2-573, Construction Cost Estimating Guide for Civil Works. The report presents the contingency results for cost risks for all project features. The study and presentation does not include consideration for life cycle costs.

3.1 Project Scope

The formal process included extensive involvement of the PDT for risk identification and the development of the risk register. The analysis process evaluated the most likely Micro Computer Aided Cost Estimating System (MCACES) cost estimate, schedule, and funding profiles using Crystal Ball software to conduct a *Monte Carlo* simulation and statistical sensitivity analysis, per the guidance in Engineer Technical Letter (ETL) CONSTRUCTION COST ESTIMATING GUIDE FOR CIVIL WORKS, dated September 30, 2008.

The project technical scope, estimates and schedules were developed and presented by the Portland District. Consequently, these documents serve as the basis for the risk analysis.

The scope of this study addresses the identification of problems, needs, opportunities and potential solutions that are viable from an economic, environmental, and engineering viewpoint.

3.2 USACE Risk Analysis Process

The risk analysis process for this study follows the USACE Headquarters requirements as well as the guidance provided by the Cost Engineering Dx. The risk analysis process reflected within this report uses probabilistic cost and schedule risk analysis methods within the framework of the Crystal Ball software. Furthermore, the scope of the report includes the identification and communication of important steps, logic, key assumptions, limitations, and decisions to help ensure that risk analysis results can be appropriately interpreted.

Risk analysis results are also intended to provide project leadership with contingency information for scheduling, budgeting, and project control purposes, as well as to provide tools to support decision making and risk management as the project progresses through planning and implementation. To fully recognize its benefits, cost and schedule risk analysis should be considered as an ongoing process conducted concurrent to, and iteratively with, other important project processes such as scope and execution plan development, resource planning, procurement planning, cost estimating, budgeting and scheduling.

In addition to broadly defined risk analysis standards and recommended practices, this risk analysis was performed to meet the requirements and recommendations of the following documents and sources:

- Cost and Schedule Risk Analysis Process guidance prepared by the USACE Cost Engineering Dx.

- Engineer Regulation (ER) 1110-2-1302 CIVIL WORKS COST ENGINEERING, dated September 15, 2008.

- Engineer Technical Letter (ETL) CONSTRUCTION COST ESTIMATING GUIDE FOR CIVIL WORKS, dated September 30, 2008.

4.0 METHODOLOGY / PROCESS

The Portland cost engineer facilitated a risk identification and qualitative analysis meeting the Portland PDT on February 17, 2010. The initial risk identification meeting also included qualitative analysis to produce a risk register that served as the framework for the risk analysis. The Portland cost engineer assisted in the creation of the cost and schedule risk analysis models, and obtained the assistance of the Walla Walla Cost Dx to complete the analysis and the report.

The initial cost and schedule risk models were completed and results reported on March 27, 2010. As a result of changes to the technical scope, planning documents, and estimate updates, as well as changes recommended through the Agency Technical Review (ATR) process, revisions and iterations of the cost and schedule risk model took place between March 27, 2010 and November 15, 2010. The results were completed and reported on February 25, 2011.

After February 2011, until April 2012, IEPR comments led to a revised base condition. The current project considers work through 2020 instead of 2032 with an estimated project cost in the range of $152 million (without contingency nor escalation) instead of $386 million previously. The Cost Schedule Risk Analysis was revised to include the current plan, data, and information. to match the current project. This revision is noted as "Revision 120608a".

The risk analysis process for this study is intended to determine the probability of various cost outcomes and quantify the required contingency needed in the cost estimate to achieve any desired level of cost confidence.

Contingency is an amount added to an estimate to allow for items, conditions or events for which the occurrence or impact is uncertain and that experience suggests will likely result in additional costs being incurred or additional time being required. The amount of contingency included in project control plans depends, at least in part, on the project leadership's willingness to accept risk of project overruns. The less risk that project leadership is willing to accept the more contingency should be applied in the project control plans. The risk of overrun is expressed, in a probabilistic context, using confidence levels.

The Cost Dx guidance for cost and schedule risk analysis generally focuses on the 80-percent level of confidence (P80) for cost contingency calculation. It should be noted that use of P80 as a decision criteria is a risk averse approach (whereas the use of P50 would be a risk neutral approach, and use of levels less than 50 percent would be risk seeking). Thus, a P80 confidence level results in greater contingency as compared to a P50 confidence level. The selection of contingency at a particular confidence level is ultimately the decision and responsibility of the project's District and/or Division management.

The risk analysis process uses *Monte Carlo* techniques to determine probabilities and contingency. The *Monte Carlo* techniques are facilitated computationally by a commercially available risk analysis software package (Crystal Ball) that is an add-in to Microsoft Excel. The level of detail recreated in the schedule is sufficient for risk analysis purposes that reflect the established risk register.

The primary steps, in functional terms, of the risk analysis process are described in the following subsections. Risk analysis results are provided in Section 6.

4.1 Identify and Assess Risk Factors

Identifying the risk factors via the PDT is considered a qualitative process that results in establishing a risk register that serves as the document for the quantitative study using the Crystal Ball risk software. Risk factors are events and conditions that may influence or drive uncertainty in project performance. They may be inherent characteristics or conditions of the project or external influences, events, or conditions such as weather or economic conditions. Risk factors may have either favorable or unfavorable impacts on project cost and schedule.

Checklists or historical databases of common risk factors are sometimes used to facilitate risk factor identification. However, key risk factors are often unique to a project and not readily derivable from historical information. Therefore, input from the entire PDT was obtained using creative processes such as brainstorming or other facilitated risk assessment meetings.

Formal PDT meetings were held for the purposes of identifying and assessing risk factors. The formal meeting conducted on February 17, 2010 included personnel with the following Titles and related functions:

No.	Section	Title
1	CENWP-PM-F	Project Manager
2	CENWP-PM-F	Chief, Project Management
3	CENWP-EC-CC	Cost Engineer
4	CENWP-EC-HY	Hydraulic Engineer
5	CENWP-EC-HY	Chief, Hydraulic Design
6	CENWD-RBT	Division Construction Chief
7	CENWP-EC-CC	Senior Cost Engineering
8	CENWP-EC-CC	Supervisory Geologist, Chief Cost Engineering & Construction Services
9	CENWW-EC-X	Cost Engineer/Risk Facilitator

The initial formal meetings focused primarily on risk factor identification using brainstorming techniques, but also included some facilitated discussions based on risk factors common to projects of similar scope and geographic location. Subsequent meetings focused primarily on risk factor assessment and quantification.

Agency Technical Review (ATR) of the cost estimate and schedule products also identified additional risks for consideration. These risks were: CON-6 (Consideration for Post-Award Contract Modifications), which represents the inherent risk of contract modifications during construction due to differing site conditions and engineering changes, and EST-5 (Productivity of Contractor Labor and Equipment), which represents the risk that contractors may be more or less efficient than currently reflected in the baseline estimate and schedule. These risks were added based on historical experience with projects of this nature.

4.2 Quantify Risk Factor Impacts

The quantitative impacts of risk factors on project plans were analyzed using a combination of professional judgment, empirical data and analytical techniques. Risk factor impacts were quantified using probability distributions (density functions) because risk factors are entered into the Crystal Ball software in the form of probability density functions.

Similar to the identification and assessment process, risk factor quantification involved multiple project team disciplines and functions. However, the quantification process relied more extensively on collaboration between cost engineering and risk analysis team members with lesser inputs from other functions and disciplines. This process used an iterative approach to estimate the following elements of each risk factor:

- Maximum possible value for the risk factor
- Minimum possible value for the risk factor
- Most likely value (the statistical mode), if applicable
- Nature of the probability density function used to approximate risk factor uncertainty
- Mathematical correlations between risk factors
- Affected cost estimate and schedule elements

The resulting product from the PDT discussions is captured within a risk register as presented in Section 6 for both cost and schedule risk concerns. Note that the risk register records the PDT's risk concerns, discussions related to those concerns, and potential impacts to the current cost and schedule estimates. The concerns and discussions support the team's decisions related to event likelihood, impact, and the resulting risk levels for each risk event.

4.3 Analyze Cost Estimate and Schedule Contingency

Contingency is analyzed using the Crystal Ball software, an add-in to the Microsoft Excel format of the cost estimate and schedule. *Monte Carlo* simulations are performed by applying the risk factors (quantified as probability density functions) to the appropriate estimated cost and schedule elements identified by the PDT. Contingencies are calculated by applying only the moderate and high level risks identified for each option (i.e., low-level risks are typically not considered, but remain within the risk register to serve historical purposes as well as support follow-on risk studies as the project and risks evolve).

For the cost estimate, the contingency is calculated as the difference between the P80 cost forecast and the baseline cost estimate. Each option-specific contingency is then allocated on a civil works feature level based on the dollar-weighted relative risk of each feature as quantified by *Monte Carlo* simulation. Standard deviation is used as the feature-specific measure of risk for contingency allocation purposes. This approach results in a relatively larger portion of all the project feature cost contingency being allocated to features with relatively higher estimated cost uncertainty.

5.0 PROJECT ASSUMPTIONS

The following data sources and assumptions were used in quantifying the costs associated with the with- and without-project conditions.

a. The MII MCACES (Micro-Computer Aided Cost Estimating Software) file "MCR Preferred Plan 120608.mlp" was the basis for the cost and schedule risk analyses revision 120608a.

b. The cost comparisons and risk analyses performed and reflected within this report are based on design scope and estimates that are at the feasibility level.

c. The schedule was analyzed for impact to the project cost in terms of both uncaptured escalation (variance from OMB factors and the local market) and monthly recurring costs (unavoidable fixed contract costs and/or languishing federal administration costs incurred throughout delay).

d. Per the CWCCIS Historical State Adjustment Factors in EM 1110-2-1304, State Adjustment Factor for Oregon is 1.07, meaning that historical inflation is up to 7% higher than the national average.

e. Per the data in the estimate, the Job Office Overhead (JOOH) amount for the Contract Cost comprises approximately 5.7% of the Project Cost at Baseline. Thus, the assumed monthly recurring rate for this project is 5.7%. For the P80 schedule, this comprises approximately 3% of the total contingency due to the accrual of residual fixed costs associated with delay.

f. The Cost Dx guidance generally focuses on the eighty-percent level of confidence (P80) for cost contingency calculation. For this risk analysis, the eighty-percent level of confidence (P80) was used. It should be noted that the use of P80 as a decision criteria is a moderately risk averse approach, generally resulting in higher cost contingencies. However, the P80 level of confidence also assumes a small degree of risk that the recommended contingencies may be inadequate to capture actual project costs.

g. Only high and moderate risk level impacts, as identified in the risk register, were considered for the purposes of calculating cost contingency. Low level risk impacts should be maintained in project management documentation, and reviewed at each project milestone to determine if they should be placed on the risk "watch list" for further monitoring and evaluation.

6.0 RESULTS

The cost and schedule risk analysis results are provided in the following sections. In addition to contingency calculation results, sensitivity analyses are presented to provide decision makers with an understanding of variability and the key contributors to the cause of this variability.

6.1 Risk Register

A risk register is a tool commonly used in project planning and risk analysis. The actual risk register is provided in CSRA Attachment A. The complete risk register includes low level risks, as well as additional information regarding the nature and impacts of each risk.

It is important to note that a risk register can be an effective tool for managing identified risks throughout the project life cycle. As such, it is generally recommended that risk registers be updated as the designs, cost estimates, and schedule are further refined, especially on large projects with extended schedules. Recommended uses of the risk register going forward include:

- Documenting risk mitigation strategies being pursued in response to the identified risks and their assessment in terms of probability and impact.
- Providing project sponsors, stakeholders, and leadership/management with a documented framework from which risk status can be reported in the context of project controls.
- Communicating risk management issues.
- Providing a mechanism for eliciting feedback and project control input.
- Identifying risk transfer, elimination, or mitigation actions required for implementation of risk management plans.

6.2 Cost Contingency and Sensitivity Analysis

Table 1 provides the raw construction cost contingencies calculated for the P80 confidence level and rounded to the nearest thousand. The construction cost contingencies for the P50 and P100 confidence levels are also provided for illustrative purposes only.

Contingency was quantified as approximately $47 Million at the P80 confidence level (31% of the baseline cost estimate). For comparison, the cost contingency at the P50 and P100 confidence levels was quantified as 25% and 49% of the baseline cost estimate, respectively.

Table 1. Project Cost Contingency Summary

Risk Analysis Forecast	Baseline Estimate	Project Contingency[1,2] ($)	Total Contingency (%)
50% Confidence Level			
Project Cost	$190,033,000	$37,514,000	25%
80% Confidence Level			
Project Cost	$199,411,000	$46,892,000	31%
100% Confidence Level			
Project Cost	$231,528,000	$79,009,000	52%

Notes:
1) These figures combine uncertainty in the baseline cost estimates and schedule.
2) A P100 confidence level is an abstract concept for illustration only, as the nature of risk and uncertainty (specifically the presence of “unknown unknowns”) makes 100% confidence a theoretical impossibility.

6.2.1 Sensitivity Analysis

Sensitivity analysis generally ranks the relative impact of each risk/opportunity as a percentage of total cost uncertainty. The Crystal Ball software uses a statistical measure (contribution to variance) that approximates the impact of each risk/opportunity contributing to variability of cost outcomes during *Monte Carlo* simulation.

Key cost drivers identified in the sensitivity analysis can be used to support development of a risk management plan that will facilitate control of risk factors and their potential impacts throughout the project lifecycle. Together with the risk register, sensitivity analysis results can also be used to support development of strategies to eliminate, mitigate, accept or transfer key risks.

6.2.2 Sensitivity Analysis Results

The risks/opportunities considered as key or primary cost drivers are ranked in order of importance in contribution to variance bar charts. Opportunities that have a potential to reduce project cost and are shown with a negative sign; risks are shown with a positive sign to reflect the potential to increase project cost. A longer bar in the sensitivity analysis chart represents a greater potential impact to total project cost.

Figure 1 presents a sensitivity analysis for cost growth risk from the high level cost risks identified in the risk register. Likewise, Figure 2 presents a sensitivity analysis for schedule growth risk from the high level schedule risks identified in the risk register.

6.3 Schedule and Contingency Risk Analysis

Table 2 provides the schedule duration contingencies calculated for the P80 confidence level. The schedule duration contingencies for the P50 and P100 confidence levels are also provided for illustrative purposes.

Schedule duration contingency was quantified as 40 months based on the P80 level of confidence. These contingencies were used to calculate the projected monthly recurring cost impact of project delays that are included in the Table 1 presentation of total cost contingency. The schedule contingencies were calculated by applying the high level schedule risks identified in the risk register for each option to the durations of critical path and near critical path tasks.

The schedule was not resource loaded and contained open-ended tasks and non-zero lags (gaps in the logic between tasks) that limit the overall utility of the schedule risk analysis. These issues should be considered as limitations in the utility of the schedule contingency data presented. Schedule contingency impacts presented in this analysis are based solely on projected monthly recurring costs.

Table 2. Schedule Duration Contingency Summary

Risk Analysis Forecast	Schedule Duration (months)	Contingency[1] (months)	Contingency (%)
50% Confidence Level			
Total Project Duration	131	31.2	31%
80% Confidence Level			
Total Project Duration	139	40.0	40%
100% Confidence Level			
Total Project Duration	165	66.0	66%

Notes:
1) The schedule was not resource loaded and contained open-ended tasks and non-zero lags (gaps in the logic between tasks) that limit the overall utility of the schedule risk analysis. These issues should be considered as limitations in the utility of the schedule contingency data presented in Table 2.
2) A P100 confidence level is an abstract concept for illustration only, as the nature of risk and uncertainty (specifically the presence of "unknown unknowns") makes 100% confidence a theoretical impossibility.

Figure 1. Cost Sensitivity Analysis

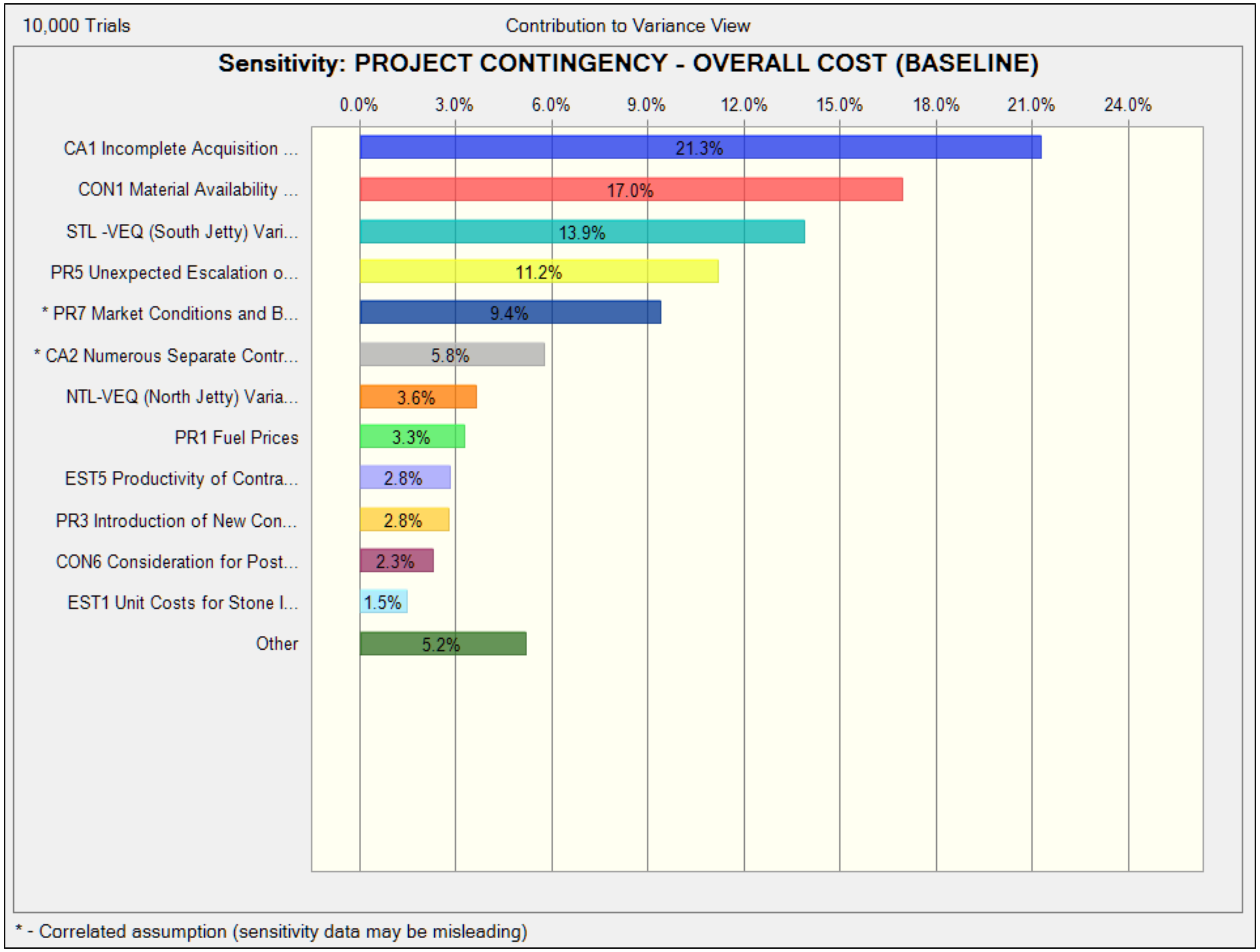
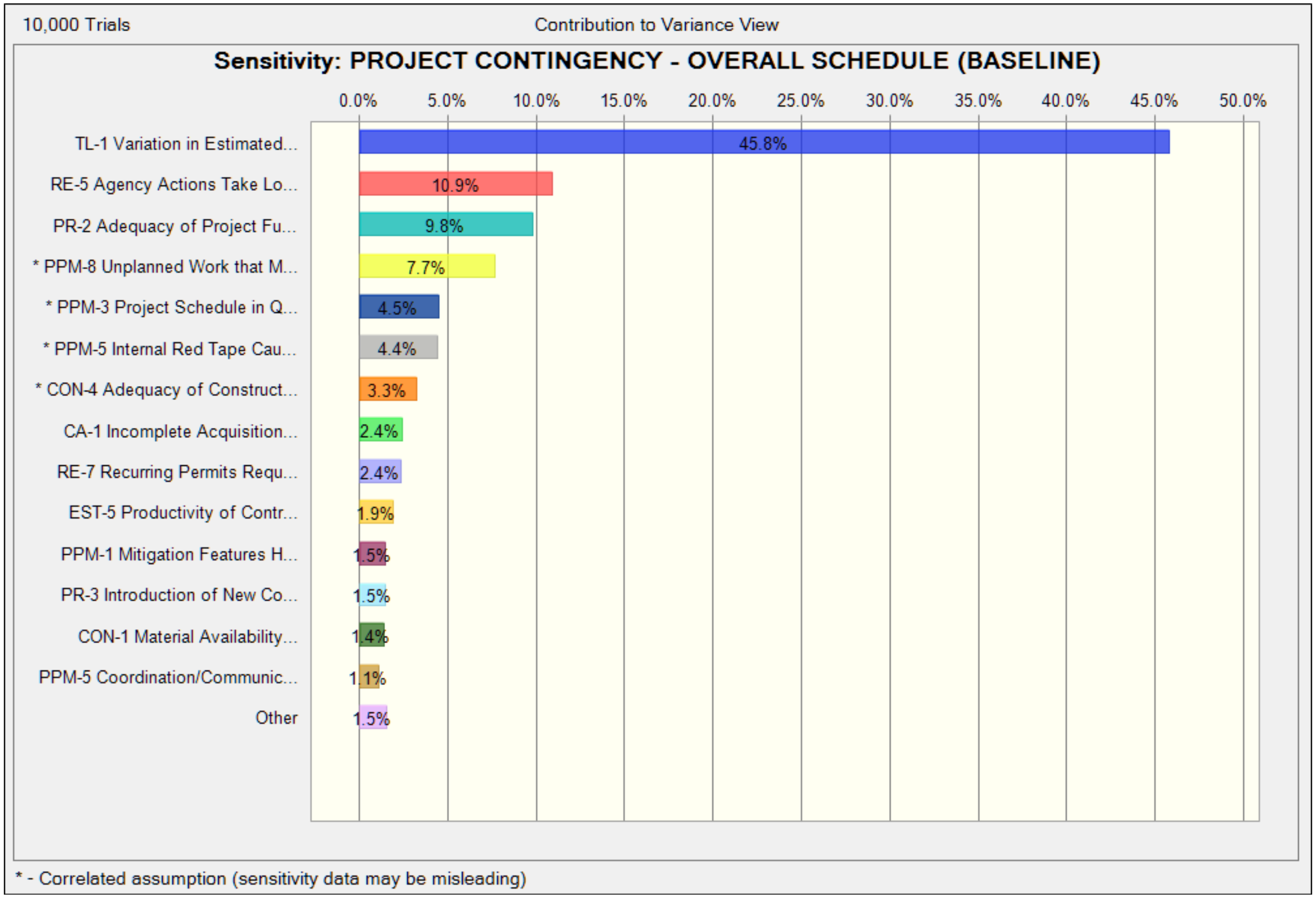


Figure 2. Schedule Sensitivity Analysis



7.0 MAJOR FINDINGS/OBSERVATIONS/RECOMMENDATIONS

This section provides a summary of significant risk analysis results that are identified in the preceding sections of the report. Risk analysis results are intended to provide project leadership with contingency information for scheduling, budgeting, and project control purposes, as well as to provide tools to support decision making and risk management as projects progress through planning and implementation. Because of the potential for use of risk analysis results for such diverse purposes, this section also reiterates and highlights important steps, logic, key assumptions, limitations, and decisions to help ensure that the risk analysis results are appropriately interpreted.

7.1 Major Findings/Observations

Total project cost comparison summaries are provided in Table 3 and Figure 3. Additional major findings and observations of the risk analysis are listed below.

1. The key cost risk drivers identified through sensitivity analysis were Risks CA-1 Incomplete Acquisition Strategy, CON-1 Stone Quarry Site/Material Availability and Delivery, STL-VEQ (South Jetty) Variation in Estimated Quantities, PR-5 Unexpected Escalation on Stone, PR-7 Market Conditions and Bidding Climate, CA-2 Numerous Separate Contracts These 6 risk elements together contribute over 78 percent of the statistical cost variance.

2. The key schedule risk drivers identified through sensitivity analysis were Risks TL-1 Variation in Estimated Quantities, RE-5 Agency Actions Take Longer than Expected, PR-2 Adequacy of Project Funding, and PPM-8 Unplanned Work that Must Be Accommodated. These 4 risk elements together contribute 74 percent of the statistical schedule variance.

3. Operation and maintenance activities were not included in the cost estimate or schedules. Therefore, a full lifecycle risk analysis could not be performed. Risk analysis results or conclusions could be significantly different if the necessary operation and maintenance activities were included.

Table 3. Project Cost Comparison Summary

Confidence Level	Project Cost ($)	Contingency ($)	Contingency (%)
P0	$151,892,000	($627,000)	-0.4%
P5	$172,394,000	$19,875,000	13.0%
P10	$176,093,000	$23,574,000	15.5%
P15	$178,607,000	$26,088,000	17.1%
P20	$180,759,000	$28,240,000	18.5%
P25	$182,512,000	$29,993,000	19.7%
P30	$184,219,000	$31,700,000	20.8%
P35	$185,813,000	$33,294,000	21.8%
P40	$187,292,000	$34,773,000	22.8%
P45	$188,664,000	$36,145,000	23.7%
P50	$190,033,000	$37,514,000	24.6%
P55	$191,402,000	$38,883,000	25.5%
P60	$192,718,000	$40,199,000	26.4%
P65	$194,240,000	$41,721,000	27.4%
P70	$195,759,000	$43,240,000	28.4%
P75	$197,473,000	$44,954,000	29.5%
P80	**$199,411,000**	**$46,892,000**	**30.7%**
P85	$201,604,000	$49,085,000	32.2%
P90	$204,328,000	$51,809,000	34.0%
P95	$208,549,000	$56,030,000	36.7%
P100	$231,528,000	$79,009,000	51.8%

Figure 3. Project Cost Summary

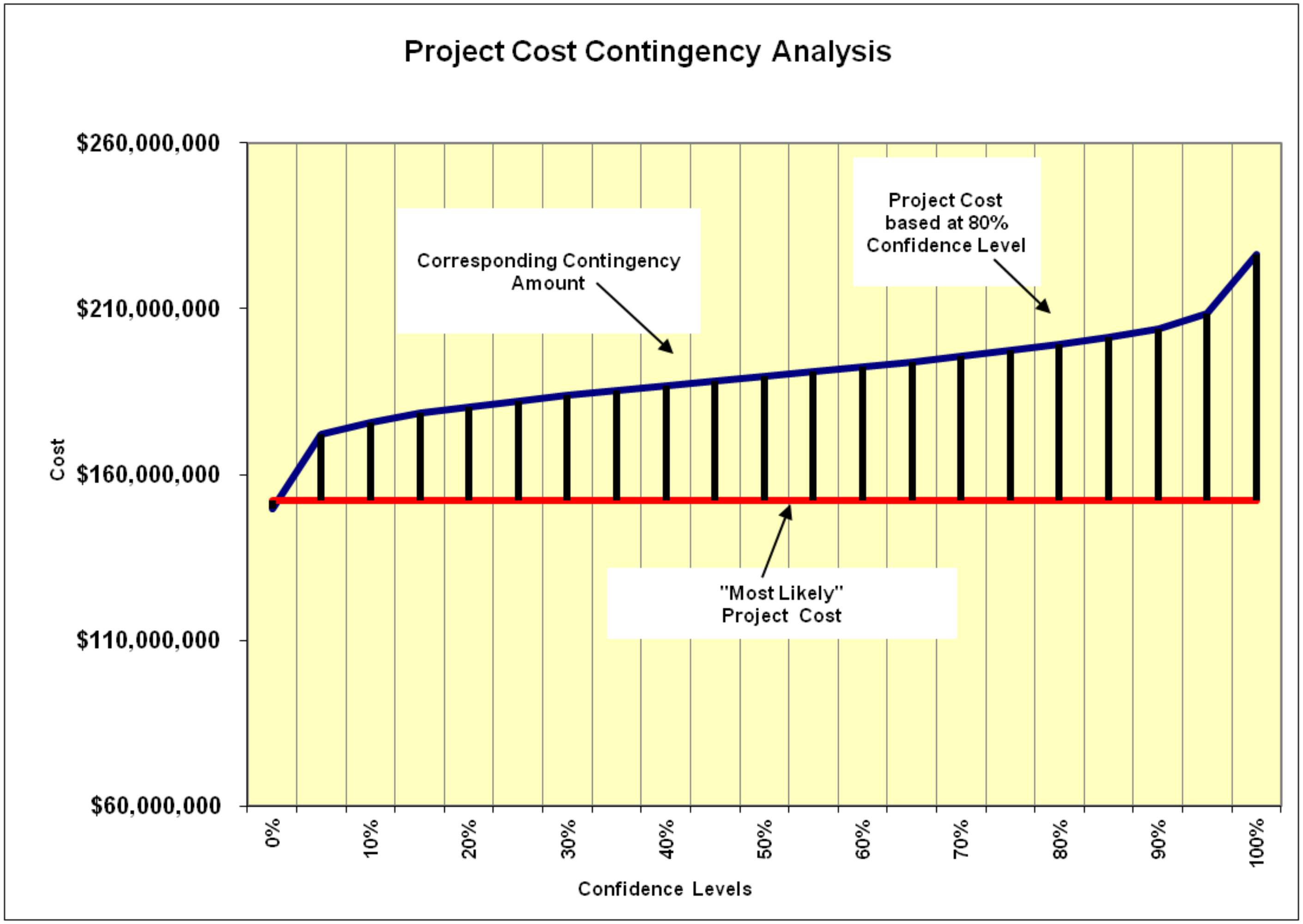
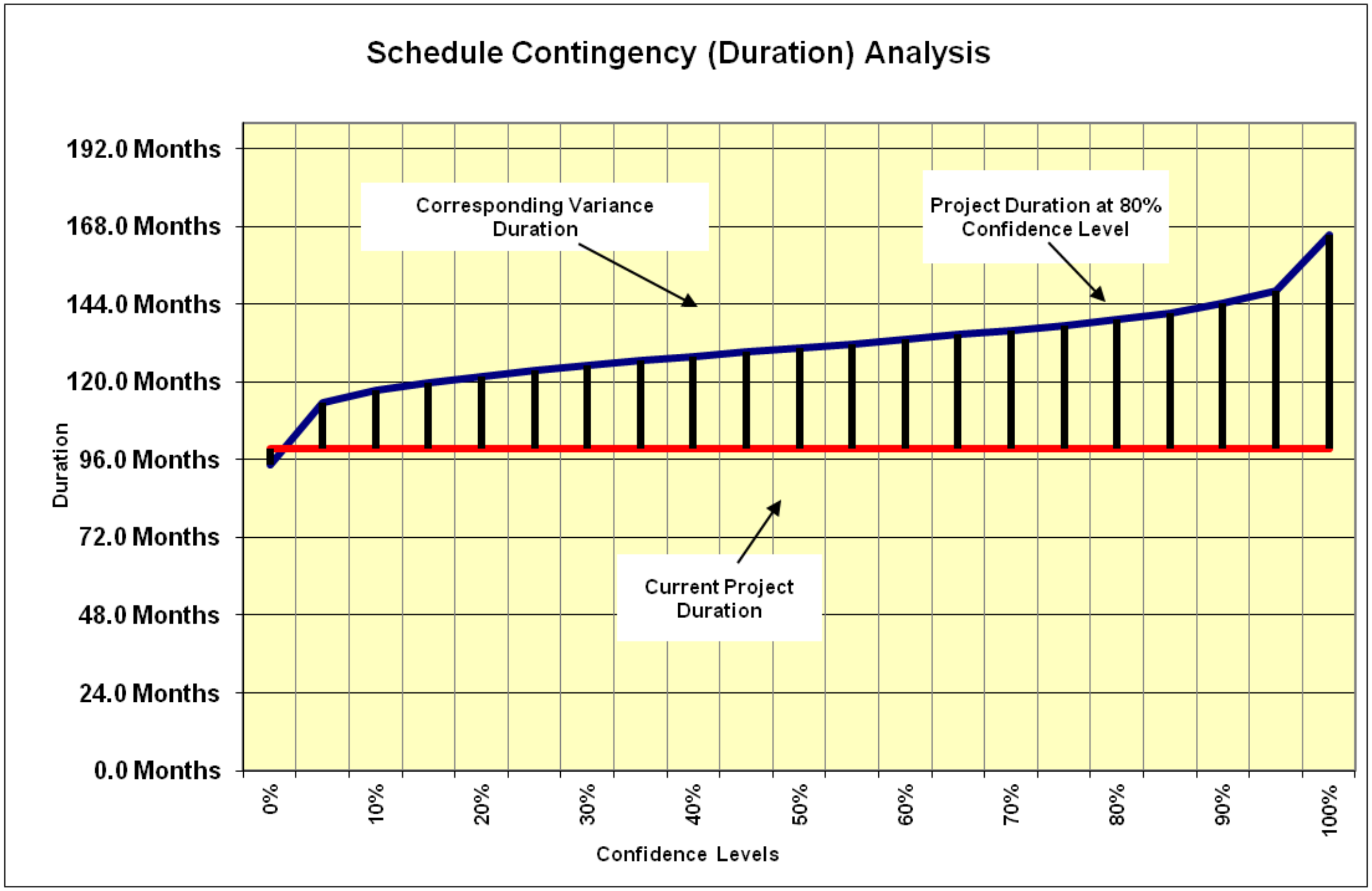


Figure 4. Project Duration Summary



7.2 Recommendations

Risk Management is an all-encompassing, iterative, and life-cycle process of project management. The Project Management Institute's (PMI) *A Guide to the Project Management Body of Knowledge (PMBOK® Guide)*, *4th edition*, states that "project risk management includes the processes concerned with conducting risk management planning, identification, analysis, responses, and monitoring and control on a project." Risk identification and analysis are processes within the knowledge area of risk management. Its outputs pertinent to this effort include the risk register, risk quantification (risk analysis model), contingency report, and the sensitivity analysis.

The intended use of these outputs is implementation by the project leadership with respect to risk responses (such as mitigation) and risk monitoring and control. In short, the effectiveness of the project risk management effort requires that proactive management of risks does not conclude with the study completed in this report.

The Cost and Schedule Risk Analysis (CSRA) produced by the PDT identifies issues that require the development of subsequent risk response and mitigation plans. This section provides a list of recommendations for continued management of the risks identified and analyzed in this study. Note that this list is not all inclusive and should not substitute a formal risk management and response plan.

<u>1. Key Cost Risk Drivers</u>: The key cost risk drivers identified through sensitivity analysis were Risks CA-1 Incomplete Acquisition Strategy, CON-1 Stone Quarry Site/Material Availability and Delivery, STL-VEQ (South Jetty) Variation in Estimated Quantities, PR-5 Unexpected Escalation on Stone, PR-7 Market Conditions and Bidding Climate, CA-2 Numerous Separate Contracts These 6 risk elements together contribute over 78 percent of the statistical cost variance.

a. <u>Risk CA-1 Incomplete Acquisition Strategy</u>: The details of the acquisition plan in terms of the technique to let the contracts has not been fully developed. This contributed 21% of the statistical cost variance. Project leadership should take proactive measures to obtain decisions regarding acquisition strategy, as well as communication to management regarding the impact of those decisions on cost performance. Project leadership should develop the acquisition strategy to maximize competition and cost control, and so that current working estimates can capture the probable costs.

b. <u>Risk CON-1 Stone Quarry Site/Material Availability and Delivery</u>: The availability and supply of stone and cranes could be an issue, depending on when the construction occurs and how much is being demanded concurrently. The sheer volume required for this project could overwhelm the local market for supply of stone of this size and quantity. This contributed 17% of the statistical cost variance. Project leadership should conduct market research to determine the regional trends regarding the availability of quarry stone to meet the requirements in parallel to the general market research being conducted. The PDT may also consider changing the engineering requirements or methodologies to increase competition and/or the likelihood of equipment being available.

c. Risk STL-VEQ (South Jetty) Variation in Estimated Quantities: Due to the fact that the project is at a feasibility level, the quantities of stone estimated could change positively or negatively. This contributed 14% of the statistical cost variance. Project leadership should focus the PDT on the engineering details of the recommended plan, improve survey data of actual conditions and geometry of relic stone, and structure and continue engineering efforts to establish detail of design cross section to increase confidence of estimated quantities.

d. Risk PR-5 Unexpected Escalation on Stone: There could be an unusual demand on stone, causing an unexpected spike in pricing. This contributed 11% of the statistical cost variance. External Risk Item are which is generated, caused, or controlled exclusively outside the PDT's sphere of influence. Project leadership should monitor this element and periodically evaluate its effect upon the success of the project.

e. Risk PR-7 Market Conditions and Bidding Climate: There is inherent risk of cost fluctuations created by the contractors available to perform this work, as well as the effects on the market by escalation, especially due to the length of the project. This contributed 9% of the statistical cost variance. External Risk Item are which is generated, caused, or controlled exclusively outside the PDT's sphere of influence. Project leadership should monitor this element and periodically evaluate its effect upon the success of the project.

f. Risk CA-2 Numerous Separate Contracts: There are 4 separate construction contracts planned. Numerous contracts for the project may increase the costs of contracting, and lead to less favorable contract markups, and lack of efficiencies, increasing the construction costs. This contributed 6% of the statistical cost variance. Project leadership should provide resources to support the contracting and administration efforts and look for ways to expand favorable effects and efficiencies to subsequent contracts.

2. Key Schedule Risk Drivers: The key schedule risk drivers identified through sensitivity analysis were Risks TL-1 Variation in Estimated Quantities, RE-5 Agency Actions Take Longer than Expected, PR-2 Adequacy of Project Funding, and PPM-8 Unplanned Work that Must Be Accommodated. These 4 risk elements together contribute 74 percent of the statistical schedule variance.

a. Risk TL-1 Variation in Estimated Quantities: Project leadership should conduct further research and/or survey to validate the quantities estimated within the project scoping documents.

b. Risk RE-5 Agency Actions Take Longer than Expected: Project leadership should coordinate with NMFS and support their process to consultations.

c. Risk PR-2 Adequacy of Project Funding: Project leadership should attempt to develop accurate funding profile projections to capture probable funding requirements. Project leadership may also ensure that the acquisition strategy plan is suited to likely funding scenarios. Ultimately, this is an external risk, and its impacts must be communicated to management.

d. Risk PPM-8 Unplanned Work that Must Be Accommodated: Project leadership should attempt to keep the PDT and reviewers focused on the goals of the project. Leadership should match and monitor schedule and resources for timely design work progression.

3. Risk Management: Project leadership should use of the outputs created during the risk analysis effort as tools in future risk management processes. The risk register should be updated at each major project milestone. The results of the sensitivity analysis may also be used for response planning strategy and development. These tools should be used in conjunction with regular risk review meetings.

4. Risk Analysis Updates: Project leadership should review risk items identified in the original risk register and add others, as required, throughout the project life-cycle. Risks should be reviewed for status and reevaluation (using qualitative measure, at a minimum) and placed on risk management watch lists if any risk's likelihood or impact significantly increases. Project leadership should also be mindful of the potential for secondary (new risks created specifically by the response to an original risk) and residual risks (risks that remain and have unintended impact following response).

CSRA ATTACHMENT A

Cost Schedule Risk Analysis

MCR Jetties Rehabilitation Feasibility Report

Revised 06/08/2012

Feasibility Report Estimate Level

PDT Members

Project Manager COE:	✓
Chief, Project Management	✓
Techincal Lead:	✓
Cost Engineer	✓
Hydraulic Engineer	✓
Chief, Hydraulic Design	✓
Division Construction Chief	✓
Cost Engineering	✓
Supervisory Geologist, Construction	✓
Cost Engineer/Risk Facilitator	✓

EVENTS

Date	Comment
2/17/2010	Meeting Develop Risk Registar
3/27/2010	Draft CSRA Rpt
2/25/2011	Revised CSRA Rpt
4/23/2012	Meetings Update Risk Registar

MCR Jetties Rehabilitation Feasibility Report - Cost and Schedule Risk Analysis Revised 06/08/12

Contingency on Base Estimate	80% Confidence Project Cost	
Baseline Estimate Cost (Most Likely) ->	**$152,519,000**	
Baseline Estimate Cost Contingency Amount ->	$42,784,412	28.1%
Baseline Estimate Construction Cost (80% Confidence) ->	**$195,303,412**	

Contingency on Schedule	80% Confidence Project Schedule	
Project Schedule Duration (Most Likely) ->	**99.3 Months**	
Schedule Contingency Duration ->	40.0 Months	40.3%
Project Schedule Duration (80% Confidence) ->	**139.3 Months**	
Project Schedule Contingency Amount (80% Confidence) ->	**$4,107,655**	2.7%

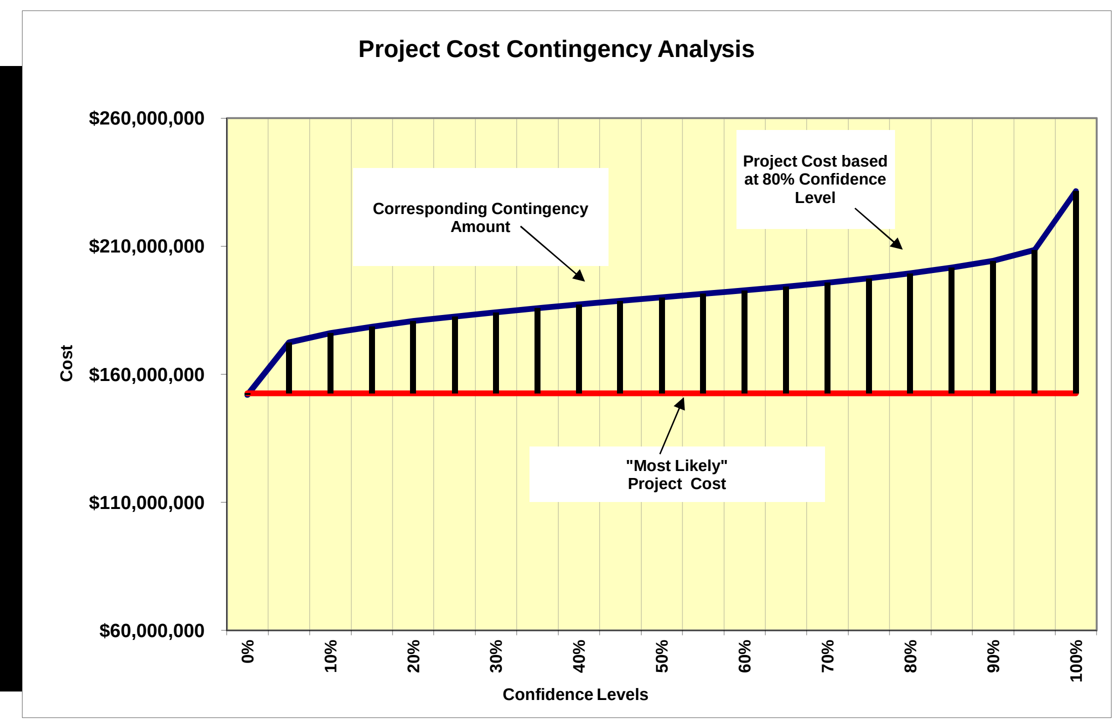
Project Contingency	80% Confidence Project Cost	
Project Contingency Amount (80% Confidence) ->	**$46,892,067**	30.7%
Project Contingency Percentage (80% Confidence) ->	**31%**	

Project Cost (80% Confidence) ->	**$199,411,067**

- PROJECT CONTINGENCY DEVELOPMENT -

Contingency Analysis

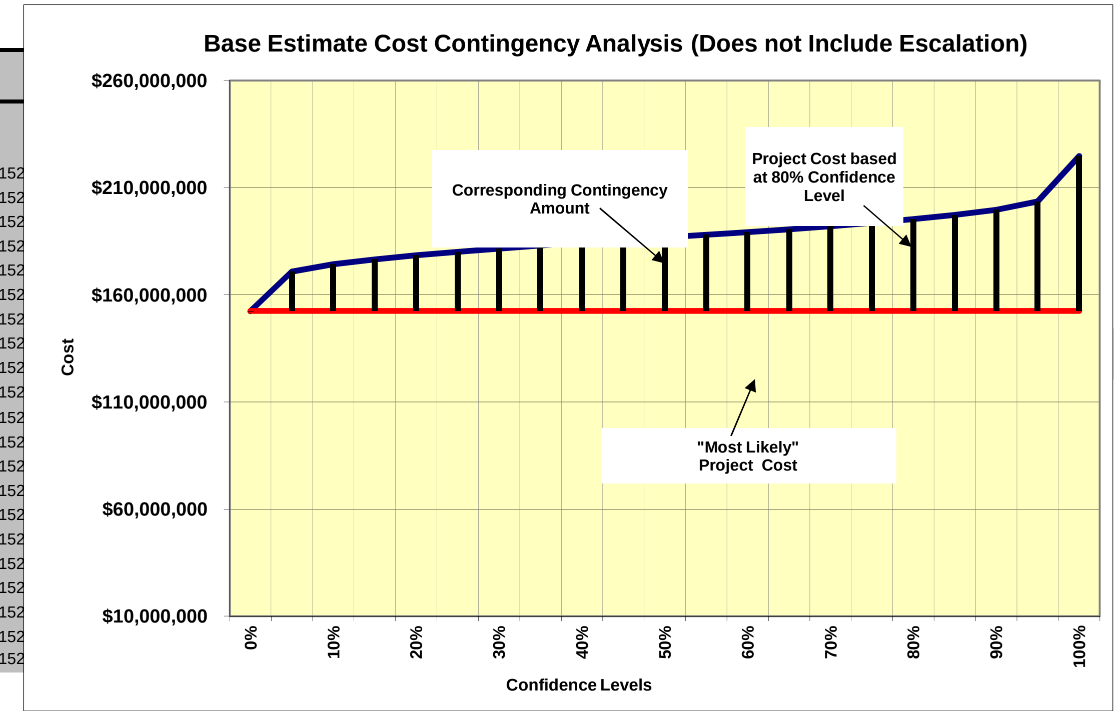
Most Likely Cost Estimate	$152,519,000						
		Contingency Amounts					%
Confidence Level	Project Cost	All Jetties	Overall	North Jetty	South Jetty	Jetty A	Contingency
0%	$151,892,316	($626,684)	($626,684)	$0	$0	$0	-0.41%
5%	$172,394,030	$19,875,030	$19,875,030	$0	$0	$0	13.03%
10%	$176,092,967	$23,573,967	$23,573,967	$0	$0	$0	15.46%
15%	$178,606,976	$26,087,976	$26,087,976	$0	$0	$0	17.10%
20%	$180,758,742	$28,239,742	$28,239,742	$0	$0	$0	18.52%
25%	$182,512,343	$29,993,343	$29,993,343	$0	$0	$0	19.67%
30%	$184,219,191	$31,700,191	$31,700,191	$0	$0	$0	20.78%
35%	$185,813,143	$33,294,143	$33,294,143	$0	$0	$0	21.83%
40%	$187,292,121	$34,773,121	$34,773,121	$0	$0	$0	22.80%
45%	$188,663,633	$36,144,633	$36,144,633	$0	$0	$0	23.70%
50%	$190,033,063	$37,514,063	$37,514,063	$0	$0	$0	24.60%
55%	$191,402,350	$38,883,350	$38,883,350	$0	$0	$0	25.49%
60%	$192,717,581	$40,198,581	$40,198,581	$0	$0	$0	26.36%
65%	$194,240,013	$41,721,013	$41,721,013	$0	$0	$0	27.35%
70%	$195,758,510	$43,239,510	$43,239,510	$0	$0	$0	28.35%
75%	$197,472,777	$44,953,777	$44,953,777	$0	$0	$0	29.47%
80%	**$199,411,067**	**$46,892,067**	**$46,892,067**	**$0**	**$0**	**$0**	**30.75%**
85%	$201,603,687	$49,084,687	$49,084,687	$0	$0	$0	32.18%
90%	$204,328,305	$51,809,305	$51,809,305	$0	$0	$0	33.97%
95%	$208,549,053	$56,030,053	$56,030,053	$0	$0	$0	36.74%
100%	$231,528,466	$79,009,466	$79,009,466	$0	$0	$0	51.80%



- BASE CONTINGENCY DEVELOPMENT - cost

Contingency Analysis

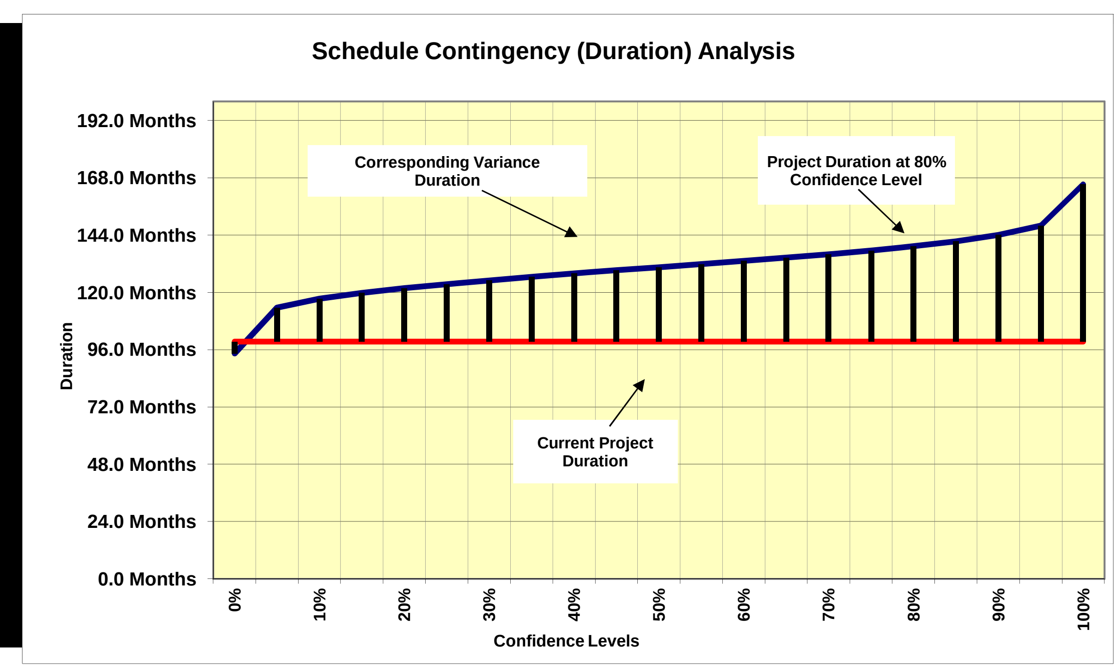
Most Likely Cost Estimate	$152,519,000							
		Contingency Amounts					%	
Confidence Level	Project Cost	All Jetties	Overall	North Jetty	South Jetty	Jetty A	Contingency	
0%	$152,394,688	($124,312)	($124,312)	$0	$0	$0	-0.08%	152
5%	$170,925,374	$18,406,374	$18,406,374	$0	$0	$0	12.07%	152
10%	$174,241,637	$21,722,637	$21,722,637	$0	$0	$0	14.24%	152
15%	$176,508,872	$23,989,872	$23,989,872	$0	$0	$0	15.73%	152
20%	$178,455,272	$25,936,272	$25,936,272	$0	$0	$0	17.01%	152
25%	$180,032,811	$27,513,811	$27,513,811	$0	$0	$0	18.04%	152
30%	$181,577,770	$29,058,770	$29,058,770	$0	$0	$0	19.05%	152
35%	$183,027,291	$30,508,291	$30,508,291	$0	$0	$0	20.00%	152
40%	$184,351,358	$31,832,358	$31,832,358	$0	$0	$0	20.87%	152
45%	$185,590,912	$33,071,912	$33,071,912	$0	$0	$0	21.68%	152
50%	$186,830,499	$34,311,499	$34,311,499	$0	$0	$0	22.50%	152
55%	$188,066,767	$35,547,767	$35,547,767	$0	$0	$0	23.31%	152
60%	$189,234,940	$36,715,940	$36,715,940	$0	$0	$0	24.07%	152
65%	$190,618,366	$38,099,366	$38,099,366	$0	$0	$0	24.98%	152
70%	$191,991,435	$39,472,435	$39,472,435	$0	$0	$0	25.88%	152
75%	$193,548,293	$41,029,293	$41,029,293	$0	$0	$0	26.90%	152
80%	$195,303,412	$42,784,412	$42,784,412	$0	$0	$0	28.05%	152
85%	$197,283,351	$44,764,351	$44,764,351	$0	$0	$0	29.35%	152
90%	$199,727,096	$47,208,096	$47,208,096	$0	$0	$0	30.95%	152
95%	$203,556,982	$51,037,982	$51,037,982	$0	$0	$0	33.46%	152
100%	$224,754,522	$72,235,522	$72,235,522	$0	$0	$0	47.36%	152



- SCHEDULE CONTINGENCY (DURATION) DEVELOPMENT -

Contingency Analysis

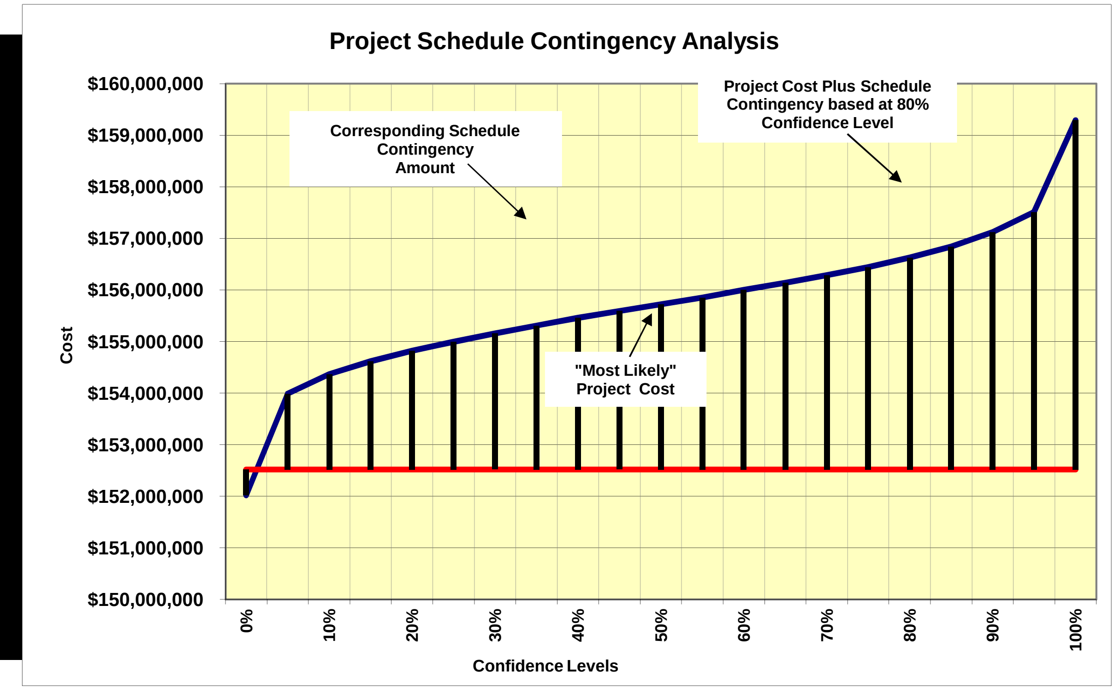
Most Likely Schedule Duration	99.3 Months						
Confidence Level	Project Duration	All Jetties	Overall	North Jetty	South Jetty	Jetty A	Contingency
0%	94.4 Months	-4.9 Months	-4.9 Months	0.0 Months	0.0 Months	0.0 Months	-4.92%
5%	113.6 Months	14.3 Months	14.3 Months	0.0 Months	0.0 Months	0.0 Months	14.40%
10%	117.4 Months	18.0 Months	18.0 Months	0.0 Months	0.0 Months	0.0 Months	18.15%
15%	119.8 Months	20.4 Months	20.4 Months	0.0 Months	0.0 Months	0.0 Months	20.57%
20%	121.8 Months	22.4 Months	22.4 Months	0.0 Months	0.0 Months	0.0 Months	22.58%
25%	123.5 Months	24.1 Months	24.1 Months	0.0 Months	0.0 Months	0.0 Months	24.31%
30%	125.1 Months	25.7 Months	25.7 Months	0.0 Months	0.0 Months	0.0 Months	25.89%
35%	126.5 Months	27.1 Months	27.1 Months	0.0 Months	0.0 Months	0.0 Months	27.31%
40%	128.0 Months	28.6 Months	28.6 Months	0.0 Months	0.0 Months	0.0 Months	28.83%
45%	129.3 Months	29.9 Months	29.9 Months	0.0 Months	0.0 Months	0.0 Months	30.12%
50%	130.5 Months	31.2 Months	31.2 Months	0.0 Months	0.0 Months	0.0 Months	31.39%
55%	131.8 Months	32.5 Months	32.5 Months	0.0 Months	0.0 Months	0.0 Months	32.70%
60%	133.2 Months	33.9 Months	33.9 Months	0.0 Months	0.0 Months	0.0 Months	34.14%
65%	134.6 Months	35.3 Months	35.3 Months	0.0 Months	0.0 Months	0.0 Months	35.50%
70%	136.0 Months	36.7 Months	36.7 Months	0.0 Months	0.0 Months	0.0 Months	36.93%
75%	137.5 Months	38.2 Months	38.2 Months	0.0 Months	0.0 Months	0.0 Months	38.47%
80%	139.3 Months	40.0 Months	40.0 Months	0.0 Months	0.0 Months	0.0 Months	40.27%
85%	141.4 Months	42.1 Months	42.1 Months	0.0 Months	0.0 Months	0.0 Months	42.35%
90%	144.1 Months	44.8 Months	44.8 Months	0.0 Months	0.0 Months	0.0 Months	45.10%
95%	147.9 Months	48.6 Months	48.6 Months	0.0 Months	0.0 Months	0.0 Months	48.94%
100%	165.3 Months	66.0 Months	66.0 Months	0.0 Months	0.0 Months	0.0 Months	66.40%



- SCHEDULE CONTINGENCY (AMOUNT) DEVELOPMENT -

Contingency Analysis $s from delay

Most Likely Cost Estimate	$152,519,000						
Confidence Level	Project Cost	All Jetties	Overall	North Jetty	South Jetty	Jetty A	Contingency
0%	$152,016,628	($502,372)	($502,372)	$0	$0	$0	-0.33%
5%	$153,987,656	$1,468,656	$1,468,656	$0	$0	$0	0.96%
10%	$154,370,329	$1,851,329	$1,851,329	$0	$0	$0	1.21%
15%	$154,617,104	$2,098,104	$2,098,104	$0	$0	$0	1.38%
20%	$154,822,469	$2,303,469	$2,303,469	$0	$0	$0	1.51%
25%	$154,998,531	$2,479,531	$2,479,531	$0	$0	$0	1.63%
30%	$155,160,421	$2,641,421	$2,641,421	$0	$0	$0	1.73%
35%	$155,304,852	$2,785,852	$2,785,852	$0	$0	$0	1.83%
40%	$155,459,763	$2,940,763	$2,940,763	$0	$0	$0	1.93%
45%	$155,591,721	$3,072,721	$3,072,721	$0	$0	$0	2.01%
50%	$155,721,564	$3,202,564	$3,202,564	$0	$0	$0	2.10%
55%	$155,854,583	$3,335,583	$3,335,583	$0	$0	$0	2.19%
60%	$156,001,641	$3,482,641	$3,482,641	$0	$0	$0	2.28%
65%	$156,140,647	$3,621,647	$3,621,647	$0	$0	$0	2.37%
70%	$156,286,075	$3,767,075	$3,767,075	$0	$0	$0	2.47%
75%	$156,443,485	$3,924,485	$3,924,485	$0	$0	$0	2.57%
80%	$156,626,655	$4,107,655	$4,107,655	$0	$0	$0	2.69%
85%	$156,839,336	$4,320,336	$4,320,336	$0	$0	$0	2.83%
90%	$157,120,209	$4,601,209	$4,601,209	$0	$0	$0	3.02%
95%	$157,511,070	$4,992,070	$4,992,070	$0	$0	$0	3.27%
100%	$159,292,944	$6,773,944	$6,773,944	$0	$0	$0	4.44%



MCR Jetties Rehabilitation Feasibility Report - Cost and Schedule Risk Analysis Revised 06/08/12

Risk Level

Likelihood of Occurrence	Negligible	Marginal	Significant	Critical	Crisis
Very Likely	Low	Moderate	High	High	High
Likely	Low	Moderate	High	High	High
Unlikely	Low	Low	Moderate	Moderate	High
Very Unlikely	Low	Low	Low	Low	High

Impact or Consequence of Occurrence

Overall Project Scope
See Preferred Plan report for scope.

Cost Impacts
For the MCR Jetties Project, any cost impact of $3 Million or higher should be considered at least "Significant."
Anything over $1.5 Million should be considered at least "Marginal."

Schedule Impacts
For the MCR Jetties Project, any schedule impact of 6 months or greater should be considered at least "Significant."
Anything over 3 months should be considered at least "Marginal."

Risk No.	Risk/Opportunity Event	Concerns	PDT Discussions	UPDATE NOTE:	Project Cost			Project Schedule			Variance Distribution	Correlation to Other(s)	Responsibility/POC
					Likelihood*	Impact*	Risk Level*	Likelihood*	Impact*	Risk Level*			
Contract Risks (Internal Risk Items are those that are generated, caused, or controlled within the PDT's sphere of influence.)													
	PROJECT & PROGRAM MGMT												
PPM-1	Mitigation Features Have not Been Fully Defined	There currently is some cost included for mitigation needs for North Jetty and Jetty A. Total losses that will determine the mitigation plan have not been established, nor the mitigation configuration.	PDT further investigated mitigation requirements. Key PDT members more comfortable with feasibility-level assumptions.	Assumptions modifed to delete items associated with the spur groins and coordinated with Environmental Assessment.	Very Likely	Marginal	MODERATE	Likely	Marginal	MODERATE	Triangular	LD-1	Environmental
PPM-2	Concerns Regarding Trestle Bay Configuration	There is uncertainty as to the ultimate requirements regarding mitigation for Trestle Bay. This may or may not be captured in the estimate.	PDT resolved this issue.		Unlikely	Marginal	LOW	Unlikely	Marginal	LOW	Uniform	TL-5	Environmental
PPM-3	Project Schedule in Question	If the model changes the requirements for configuration in cross-sections, stone size and type, etc., it could alter the currently contemplated schedule. PDT acknowledges that the schedule is not complete.	Upon comprehensive district review, PDT more confident in feasibility level design assumptions.	The MCR jetty system is in a continual state of degredation and the current assumption is to capture a project time period for construction of 2015-2020 in lieu of 2014-2032	Very Likely	Marginal	MODERATE	Very Likely	Marginal	MODERATE	Triangular	CON-4	Project Manager
PPM-4	Issues with Multiple Local Agencies	There are several issues that are in question with respect to local agencies, such as NOAA, DLCD, WDOE, DEQ, NMFS, etc. There are issues with mitigation features, as well as constructability and feasibility of certain features (e.g. the offloading facility)	PDT has conducted several outreach meetings with local agenices and now has a better understanding of their expectations.		Very Likely	Marginal	MODERATE	Very Likely	Marginal	MODERATE	Yes-No		Project Manager
PPM-5	Coordination/Communication Difficulties	There has been some issues and challenges with communication internally, and with external agencies and stakeholders. This is contributed to by the turnover and length of the project formulation.	PDT coordination both internally and externally has improved significantly.		Likely	Marginal	MODERATE	Likely	Marginal	MODERATE	Triangular		Project Manager
PPM-6	Internal Red Tape Causing Delays in Obtaining Approvals and Decisions	The changes to the requirements for reviews (such as ATRs, IEPRs, etc.) has an impact on the performance of the study and the project.	Project's significance will help PDT acquire necessary resources to meet new review requirements.		Likely	Negligible	LOW	Likely	Marginal	MODERATE	Uniform	PPM-8	District Management
PPM-7	Pressure To Deliver on an Accelerated Schedule	There is the possibility that management may pressure the PDT to deliver the project sooner, possibly sacrificing quality. This has already occurred with the environmental aspects of the project.	Could affect both cost and schedule.		Unlikely	Negligible	LOW	Unlikely	Marginal	LOW	Uniform		District Management
PPM-8	Unplanned Work that Must Be Accommodated	If the reviews or the results of models require work to be performed that has not been planned, it could impact cost and schedule.	High priority project; therefore, schedule risk is moderate.		Very Likely	Marginal	MODERATE	Very Likely	Marginal	MODERATE	Uniform	PPM-6	District Management
PPM-9	Product Development by Several Sources	Aspects of the project (e.g. the physical modeling) is being handled outside the District. There is also possibility that some of the PED activities will be performed by AEs. Trying to queue into their workload management cycles could impact the overall schedule.	Could affect schedule.	Added an A/E firm into developing a model and updating the report, creating another layer of coorination activity for the project.	Very Unlikely	Negligible	LOW	Unlikely	Marginal	LOW	Triangular		Project Manager
	CONTRACT ACQUISITION RISKS												
CA-1	Incomplete Acquisition Strategy	The details of the acquisition plan in terms of the technique to let the contracts has not been fully developed.	Key PDT members discussed and decided this risk could be managed with early contracting involvement with project schedule, contingent upon funding.	6/8/12 Cost Impact upgraded to Sign Impact due to resulting High (>$3M) amts of Hi/Low range Upgraded Shedudle Impact level to Significant since High range > 3 mo	Very Likely	Significant	HIGH	Very Likely	Significant	HIGH	Triangular		TASB
CA-2	Numerous Separate Contracts	There could be anywhere from 8 to 18 separate contracts.	Same as above.	Shortening the project time line has decreased the number of construction contracts to 4. High range value greater than $3m so Significant Impact Level	Very Likely	Marginal	MODERATE	Very Likely	Marginal	MODERATE	Triangular		TASB

Risk No.	Risk/Opportunity Event	Concerns	PDT Discussions	UPDATE NOTE:	Project Cost			Project Schedule			Variance Distribution	Correlation to Other(s)	Responsibility/POC
					Likelihood*	Impact*	Risk Level*	Likelihood*	Impact*	Risk Level*			
	TECHNICAL RISKS												
TL-1	Variation in Estimated Quantities	Due to the fact that the project is at a feasibility level, the quantities of stone estimated could change positively or negatively.	Could affect cost and schedule.		Likely	Significant	HIGH	Likely	Significant	HIGH	Triangular		Technical Lead
TL-2	Changes in the Cross-Section Designs	Due to the fact that the project is at a feasibility level, the cross section designs could change.	PDT has a higher level of comfort with feasibility-level design assumptions.		Likely	Marginal	MODERATE	Unlikely	Marginal	LOW	Yes-No		Technical Lead
TL-3	Stone Sizing	There may be some changes in the stone size, as required by the model or in design, as it proceeds. The PDT is fairly confident in the assumptions made at this point. However, due to the size of this project, cost changes are possible.	Could impact costs.		Likely	Marginal	MODERATE	Very Unlikely	Negligible	LOW	Triangular		Technical Lead
TL-4	Spur Groins	There is some uncertainty as to the stone sizing, the cross-sections, and the methodology for the contemplated spur groins.	Could impact costs.	Spur Groins have been deleted from the preferred plan.	Likely	Marginal	MODERATE	Very Unlikely	Negligible	LOW	Triangular		Technical Lead
TL-5	Incomplete Studies Regarding Trestle Bay Mitigation	There is a need to accomplish some erosion control and stabilization on the Trestle Bay (Inner Bay) side on the South Jetty. Currently, there are no complete studies for this, and it is now being considered as part of the base (without) project conditions.	PDT resolved this issue.		Unlikely	Negligible	LOW	Unlikely	Negligible	LOW	Triangular	PPM-2	Environmental
TL-6	Wetland Delineations	Wetland delineations for the project are not finalized for any of the jetties.	This risk is very likely to become an issue with minor impacts to cost and schedule.		Very Likely	Negligible	LOW	Very Likely	Negligible	LOW	Triangular		Environmental
NTL-VEQ	NTL-VEQ (North Jetty) Variation in Est. Quantities	Due to the fact that the project is at a feasibility level, the quantities of stone estimated could change positively or negatively.	Could affect cost and schedule.	6/8/12 added back into overall. At this stage of the project this is the apporate way to account for this element since N, S, & A make up the project.	Likely	Significant	HIGH	Likely	Significant	HIGH	Triangular		Technical Lead
NTL-3	NTL3 Stone Sizing (North Jetty)	There may be some changes in the stone size, as required by the model or in design, as it proceeds. The PDT is fairly confident in the assumptions made at this point. However, due to the size of this project, cost changes are possible.	Could impact costs.	6/8/12 added back into overall. At this stage of the project this is the apporate way to account for this element since N, S, & A make up the project.	Likely	Marginal	MODERATE	Very Unlikely	Negligible	LOW	Triangular		Technical Lead
STL-VEQ	STL -VEQ (South Jetty) Variation in Estimated Quantities	Due to the fact that the project is at a feasibility level, the quantities of stone estimated could change positively or negatively.	Could affect cost and schedule.	6/8/12 added back into overall. At this stage of the project this is the apporate way to account for this element since N, S, & A make up the project.	Likely	Significant	HIGH	Likely	Significant	HIGH	Triangular		Technical Lead
STL-3	STL3 Stone Sizing (South Jetty)	There may be some changes in the stone size, as required by the model or in design, as it proceeds. The PDT is fairly confident in the assumptions made at this point. However, due to the size of this project, cost changes are possible.	Could impact costs.	6/8/12 added back into overall. At this stage of the project this is the apporate way to account for this element since N, S, & A make up the project.	Likely	Marginal	MODERATE	Very Unlikely	Negligible	LOW	Triangular		Technical Lead
ATL-VEQ	ATL-VEQ (A Jetty) Variation in Estimated Quantities	Due to the fact that the project is at a feasibility level, the quantities of stone estimated could change positively or negatively.	Could affect cost and schedule.	6/8/12 added back into overall. At this stage of the project this is the apporate way to account for this element since N, S, & A make up the project. Total $ impact <$3M on high reevalt to Marginal impact	Likely	Marginal	MODERATE	Likely	Significant	HIGH	Triangular		Technical Lead
ATL-3	ATL3 Stone Sizing (A Jetty)	There may be some changes in the stone size, as required by the model or in design, as it proceeds. The PDT is fairly confident in the assumptions made at this point. However, due to the size of this project, cost changes are possible.	Could impact costs.	6/8/12 added back into overall. At this stage of the project this is the apporate way to account for this element since N, S, & A make up the project. High $ Impact <$1.5M re-ranked to Negligible impact	Likely	Negligible	LOW	Very Unlikely	Negligible	LOW	Triangular		Technical Lead
	LANDS AND DAMAGES RISKS												
LD-1	Mitigation Needs Undefined	Because the mitigation measures have not been fully defined, the real estate requirements also have not been defined.	Could affect cost and schedule.	Mitigation quantities updated to match EA but are still not very defined.	Very Likely	Marginal	MODERATE	Unlikely	Negligible	LOW	Uniform	PPM-1	Real Estate
LD-2	Roadway Repair Requirements	There may be requirements to repair roadways due to the wear caused by project transportation requirements.	This would be nominal cost, but would accrue over 18 years.	The construction timeline has been reduced to 6 years but the scope of work is still unknown.	Very Likely	Marginal	MODERATE	Very Unlikely	Negligible	LOW	Triangular		Project Manager
LD-3	Lands and Damages Not Included in Estimate	Lands, Relocations, and Damages (LERDs) have not been captured in the baseline cost estimate. Upland site restoration besides wetland and waters mitigation may be challenging given the need for repeated access over a long construction schedule.	Could impact project costs.		Likely	Marginal	MODERATE	Likely	Negligible	LOW	Triangular		Cost Engineering
	REGULATORY AND ENVIRONMENTAL RISKS												
RE-1	Potential Barging Windows	There is a possibility that barging window (limitations) could be induced resulting from studies occurring for ongoing projects of a similar nature.	Could affect cost and schedule.		Unlikely	Marginal	LOW	Unlikely	Marginal	LOW	Yes-No	CON-2	Environmental

Risk No.	Risk/Opportunity Event	Concerns	PDT Discussions	UPDATE NOTE:	Project Cost			Project Schedule			Variance Distribution	Correlation to Other(s)	Responsibility/POC
					Likelihood*	Impact*	Risk Level*	Likelihood*	Impact*	Risk Level*			
RE-2	Impact to Wetland by Culvert Design	The ultimate culvert design may have some impacts on the wetland. The drain field and culvert repair for the North Jetty lagoon fill are not finalized. Some level of hydrologic and/or hydraulic analyses are needed to determine if there will be impacts to adjacent wetlands. If impacts are anticipated, this will increase the amount of mitigation needed, which could increase cost.	With proper design, it is unlikely there would be additional impacts. This may have marginal impact on budget due to increased mitigation costs, but should not have a significant impact to schedule. The need for a simple hydrologic evaluation is very likely, and could have a marginal impact on budget and not likely to have an impact on schedule.		Likely	Marginal	MODERATE	Unlikely	Negligible	LOW	Uniform		Environmental
RE-3	Project in a Coastal Zone	This project will require clearances from local agencies due to the fact that it is in a Coastal Zone. PDT will have to obtain a consistency determination by the Coastal Zone Management (DLCD).	Could affect cost (if methodology in offloading is required) and schedule.		Likely	Marginal	MODERATE	Unlikely	Marginal	LOW	Uniform		Project Manager
RE-4	Status of Permits	There may be some challenges in obtaining permits due to increased requirements by outside agencies, such as NMFS, that incur extra costs.	Could affect costs.		Unlikely	Marginal	LOW	Unlikely	Marginal	LOW	Triangular		Project Manager
RE-5	Agency Actions Take Longer than Expected	NMFS has not completed their BIOP for the project, and the PDT has no control over the completion of that effort, which could delay implementation.	Could impact schedule.	Biop complete but are required to have a separate consultation for 71 habitat improvements.	Likely	Marginal	MODERATE	Likely	Significant	HIGH	Uniform	RE-6	Project Manager
RE-6	Requirements Added by NMFS	Due to the extensive nature of this rehab, there is the potential that additional mitigation could be required.	Could affect cost and schedule.		Likely	Marginal	MODERATE	Unlikely	Marginal	LOW	Uniform	RE-5	Project Manager
RE-7	Recurring Permits Required	The project is very likely to require new permits every 5 years.	Could impact schedule.		Very Likely	Negligible	LOW	Likely	Marginal	MODERATE	Yes-No		Project Manager
	CONSTRUCTION RISKS												
CON-1	Stone Quarry Site/Material Availability and Delivery	The availability and supply of stone (and cranes) could be an issue, depending on when the construction occurs and how much is being demanded concurrently. The sheer volume required for this project could overwhelm the local market for supply of stone of this size and quantity.	The cost estimator, the design engineer, resident engineer, and PM agreed that based on the current revised construction schedule, this risk was moderate for both cost and schedule.	6/8/12 Upgraded cost impact to Significant since High range turns out to be >$3M	Likely	Significant	HIGH	Likely	Marginal	MODERATE	Triangular		Cost Engineering
CON-2	Concerns with the Offloading Facility	There is only one off-loading facility for each of the jetties. This could present a contract sequence/strategy plan such that the resource is properly managed under separate contracts, even working separable features of work.	This could affect cost and schedule.		Unlikely	Marginal	LOW	Unlikely	Marginal	LOW	Yes-No		Project Manager
CON-3	Transportation/haul routes constricted or unusable during periods of time	There may be some transportation routes that are unusable or shut-down at certain times of year. Also, there is constricted access, especially for the amount of traffic anticipated.	This risk and assumption is reflected in the cost estimate.		Unlikely	Marginal	LOW	Unlikely	Marginal	LOW	Triangular		Technical Lead
CON-4	Adequacy of Construction Schedule	The construction schedule is very preliminary in nature.	The cost estimator, the design engineer, resident engineer, and PM agreed that based on the current revised construction schedule, this risk was moderate for both cost and schedule.	The schedule overall duration has been shortened and thus reduces the schedule risk.	Unlikely	Marginal	LOW	Very Likely	Marginal	MODERATE	Triangular	PPM-3	Technical Lead
CON-5	Critical Fabrication and Delivery	If the project required concrete armor units, there would be potential risk in securing fabrication and ensuring timely delivery.	PDT does not feel that the quantities would present a huge risk that could not be supported by the market.	Market research has indicated a single stone supplier will be able to furnish 200,000 tons of rock per construction season.	Unlikely	Marginal	LOW	Unlikely	Marginal	LOW	Triangular		Cost Engineering
CON-6	Consideration for Post Award Cost Modifications	There is inherent risk of cost growth following award of construction contracts due to post-award contract modifications due to differing site conditions, user-directed changes, or engineering changes during construction. This risk was added during the ATR of the cost estimate, schedule, and risk analysis.	Historically, this risk always adds at least moderate cost growth to contract cost. Since this contract is largely constrained by work windows, it is likely that modifications would be structured in ways to minimize schedule impacts or accelerate work such that modifications did not affect contract schedule.	6/8/12 Upgraded cost impact to Significant since High range turns out to be >$3M	Likely	Significant	HIGH	Unlikely	Negligible	LOW	Triangular		Construction
	ESTIMATE AND SCHEDULE RISKS												
EST-1	Unit Costs for Stone In Question	The latest estimate had lower costs for stone than the previous version. The PDT feels that the unit prices for stone may be on the optimistic side.	Design engineer accounted for this risk factor within project model.		Likely	Marginal	MODERATE	Very Unlikely	Negligible	LOW	Triangular		Cost Engineering
EST-2	Special Equipment Assumptions	The latest estimate includes a smaller crane than that of another similar project. This may be too optimistic. This project requires several pieces of specialized equipment for transportation and placement. There may be issues related to assumptions in the design/estimate, as well as availability issues.	PDT discussions regarding constructibility issues have lessened this cost risk.		Likely	Marginal	MODERATE	Very Unlikely	Negligible	LOW	Triangular		Cost Engineering
EST-3	Estimate Excludes Contingency and Escalation	At this time, the current working estimate does not include contingency and escalation. This will be captured by the risk analysis.	This will not impact costs or schedule, as impacts will be captured by the risk analysis.		Very Unlikely	Negligible	LOW	Very Unlikely	Negligible	LOW	Triangular		Cost Engineering

Risk No.	Risk/Opportunity Event	Concerns	PDT Discussions	UPDATE NOTE:	Project Cost			Project Schedule			Variance Distribution	Correlation to Other(s)	Responsibility/POC
					Likelihood*	Impact*	Risk Level*	Likelihood*	Impact*	Risk Level*			
EST-4	Schedule Depicts Logical Construction Sequencing, Phasing, and Parallel Activities	Due to the size of this job, there is considerable opportunity for issues or opportunities with the sequencing, phasing, and parallel activities.	The most critical issues with schedule relate to site access (road replacement) and the annual work windows. Due to the work window, even minor delays could significantly delay the project, pushing work off to the following year, and necessitating rework in subsequent years. Could positively or negatively affect cost and/or schedule. Key PDT members decided this is a moderate risk to cost and schedule.		Likely	Marginal	MODERATE	Likely	Marginal	MODERATE	Triangular		Technical Lead
EST-5	Productivity of Contractor Labor and Equipment	The estimate captures assumptions regarding contractor's productivity rates for labor and equipment built into the crews and assemblies in the estimate. However, actual productivity during construction could vary. This risk was added during the ATR of the cost estimate, schedule, and risk analysis.	Variance in the assumed producitivity rates could affect the construction contract costs and schedule.		Unlikely	Significant	MODERATE	Unlikely	Significant	MODERATE	Triangular		Cost Engineering
	Programmatic Risks (External Risk Items outside the PDT's sphere of												
PR-1	Fuel Prices	There is potential for significant increase in fuel prices, especially due to the length of the project.	About 80 percent of project costs are related to stone procurement. Key PDT members decided this is a marginal cost risk.		Likely	Marginal	MODERATE	Very Unlikely	Negligible	LOW	Min. Extreme		Cost Engineering
PR-2	Adequacy of Project Funding	The current working estimate and schedule assumes obtaining outlays in an anticipated schedule and funding profile. The issue is that if the timing and outlay amounts differ from the plan, it could alter the scope and scheme of implementation.	Could affect cost and schedule.		Likely	Significant	HIGH	Likely	Significant	HIGH	Uniform		Project Manager
PR-3	Introduction of New Constraints/Requirements	Due to the length of the project, there is the possibility of new regulatory or mitigation requirements being applied.	Key PDT members reassesed and base on communciations with regulatory agencies, decided this is a moderate cost and schedule risk.		Likely	Marginal	MODERATE	Likely	Marginal	MODERATE	Triangular		Project Manager
PR-4	Local Communities Pose Objections	Due to the length of the project, there is the possibility of objections growing from the local communities.	Feedback during EA public meeting was favorable; therefore, it's reasonable to rate schedule risk as moderate.	The EA is being revised and sent out for another round of public comments. The risk to cost and schedule remains moderate.	Likely	Marginal	MODERATE	Likely	Marginal	MODERATE	Uniform		Project Manager
PR-5	Unexpected Escalation on Stone	There could be an unusual demand on stone, causing an unexpected spike in pricing.	Key PDT members decided this cost risk is moderate based on excess capacity of quarries.	High range value greater than $3m so Significant Impact Level	Likely	Significant	HIGH	Unlikely	Marginal	LOW	Triangular		Cost Engineering
PR-6	Unanticipated Repairs Necessary on Jetties	A breach or failure on any of the jetties could tie up resources for the completion of this project.	This is not seen as a risk that would impact this project, as emergency repairs would be funded separately.		Very Likely	Negligible	LOW	Very Unlikely	Negligible	LOW	Yes-No		Project Manager
PR-7	Market Conditions and Bidding Climate	There is inherent risk of cost fluctuations created by the contractors available to perform this work, as well as the effects on the market by escalation, especially due to the length of the project.	Key PDT members decided this cost risk is moderate based on excess capacity of quarries.	6/8/12 Upgraded cost impact to Significant since High range turns out to be >$3M	Likely	Significant	HIGH	Very Unlikely	Negligible	LOW	Triangular		Cost Engineering

*Likelihood, Impact, and Risk Level to be verified through market research and analysis (conducted by cost engineer).

1. Risk/Opportunity identified with reference to the Risk Identification Checklist and through deliberation and study of the PDT.
2. Discussions and Concerns elaborates on Risk/Opportunity Events and includes any assumptions or findings (should contain information pertinent to eventual study and analysis of event's impact to project).
3. Likelihood is a measure of the probability of the event occurring -- **Very Unlikely**, **Unlikely**, **Moderately Likely**, **Likely**, **Very Likely.** The likelihood of the event will be the same for both Cost and Schedule, regardless of impact.
4. Impact is a measure of the event's effect on project objectives with relation to scope, cost, and/or schedule -- **Negligible**, **Marginal**, **Significant**, **Critical**, or **Crisis.** Impacts on Project Cost may vary in severity from impacts on Project Schedule.
5. Risk Level is the resultant of Likelihood and Impact **Low**, **Moderate**, or **High**. Refer to the matrix located at top of page.
6. Variance Distribution refers to the behavior of the individual risk item with respect to its potential effects on Project Cost and Schedule. For example, an item with clearly defined parameters and a solid most likely scenario would probably follow a triangular or normal distribution. A risk item for which the PDT has little data or probability of modeling with respect to effects on cost or schedule (i.e. "anyone's guess") would probably follow a uniform or discrete uniform distribution.
7. The responsibility or POC is the entity responsible as the Subject Matter Expert (SME) for action, monitoring, or information on the PDT for the identified risk or opportunity.
8. Correlation recognizes those risk events that may be related to one another. Care should be given to ensure the risks are handled correctly without a "double counting."
9. Affected Project Component identifies the specific item of the project to which the risk directly or strongly correlates.
10. Project Implications identifies whether or not the risk item affects project cost, project schedule, or both. The PDT is responsible for conducting studies for both Project Cost and for Project Schedule.
11. Results of the risk identification process are studied and further developed by the Cost Engineer, then analyzed through the Monte Carlo Analysis Method for Cost (Contingency) and Schedule (Escalation) Growth.

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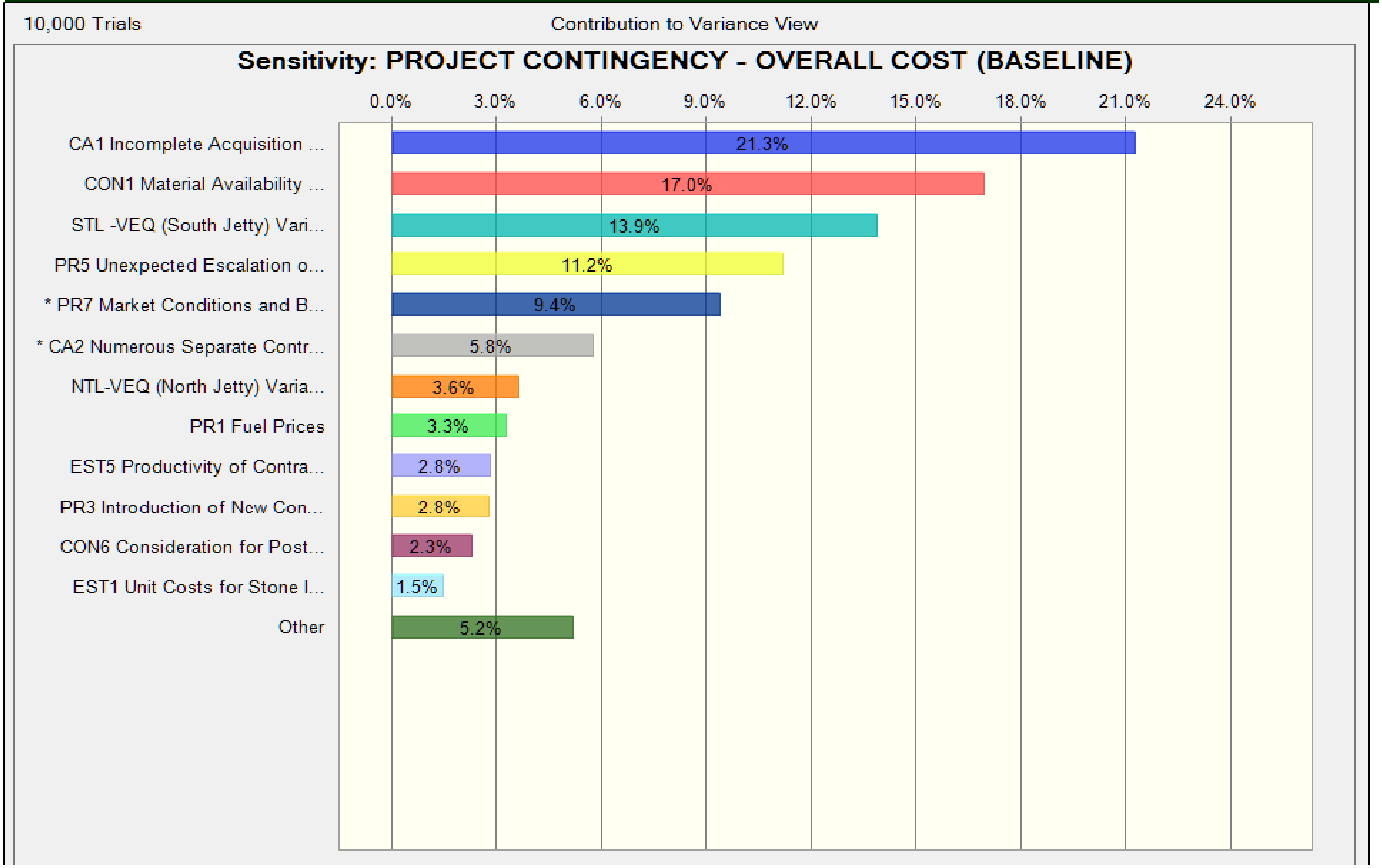
Risk No.	Risk/Opportunity Event	UPDATE 04/24/12	UPDATE 06/08 /12	Project Cost: Likelihood*	Project Cost: Impact*	Project Cost: Risk Level*	Variance Distribution	Correlation to Other(s)	Crystal Ball Simulation Expected Values ($$$): Low	Crystal Ball Simulation Expected Values ($$$): Most Likely	Crystal Ball Simulation Expected Values ($$$): High		Crystal Ball Simulation Expected Values (%s): Low	Crystal Ball Simulation Expected Values (%s): Most Likely	Crystal Ball Simulation Expected Values (%s): High
Internal Risks (Internal Risk Items are those that are generated, caused, or controlled within the PDT's sphere of influence.)															
PROJECT & PROGRAM MGMT															
PPM-1	PPM1 Mitigation Features Have not Been Fully Defined	Updated using new mitigation costs. Correlation to LD-1 of 30% that mitigation change here would involve LD-1 cost change	Correlation tie made that was previously missed	Very Likely	Marginal	MODERATE	Triangular	LD-1	($718,695)	$0	$1,796,738	*0*	-0.47%	0.00%	1.18%
PPM-3	PPM3 Project Schedule in Question	n/c		Very Likely	Marginal	MODERATE						*This risk is captured by the Schedule Risk Analysis*			
PPM-4	PPM4 Issues with Multiple Local Agencies	Updated with new MII costs for Off-Loading Facility, Barge Off-loading & Off Loading Fac Dredging cost		Very Likely	Marginal	MODERATE	Uniform		$0	$0	$2,974,769	*0*	0.00%	0.00%	1.95%
PPM-5	PPM5 Coordination/Communication Difficulties	Updated w/ new Const Cost from TPCS		Likely	Marginal	MODERATE	Triangular		$0	$0	$1,942,400	*0*	0.00%	0.00%	1.27%
PPM-8	PPM8 Unplanned Work that Must Be Accommodated	Updated w/ new Const Cost from TPCS		Very Likely	Marginal	MODERATE	Uniform	PPM-6 but PPM-6 in not in Cost model because of it's low risk level. See schedule risk model	$0	$0	$1,666,600	*0*	0.00%	0.00%	1.09%
CONTRACT ACQUISITION RISKS															
CA-1	CA1 Incomplete Acquisition Strategy	Updated w/ new Const Cost from TPCS		Very Likely	Significant	HIGH	Triangular		($7,625,950)	$0	$15,251,900	*0*	-5.00%	0.00%	10.00%
CA-2	CA2 Numerous Separate Contracts	Updated w/ new Const Cost from TPCS	High range value greater than $3m so Significant Impact Level	Very Likely	Significant	HIGH	Triangular		$0	$0	$7,625,950	*0*	0.00%	0.00%	5.00%
TECHNICAL RISKS															
TL-1	TL1 Variation in Estimated Quantities	**n/c**		Likely	Significant	HIGH						*This risk is captured at the Feature Level revision 120424 moved it back to overall see*			
TL-2	TL2 Changes in the Cross-Section Designs	**n/c**		Likely	Marginal	MODERATE						*This risk is captured at the Feature Level revision 120424 moved it back to overall see*			
TL-3	TL3 Stone Sizing	**n/c**		Likely	Marginal	MODERATE						*This risk is captured at the Feature Level revision 120424 moved it back to overall see*			
TL-4	TL4 Spur Groins	**This Element removed from design/plan**		Likely	Marginal	MODERATE	Triangular		$0	$0	$0	*0*	0.00%	0.00%	0.00%
NTL-VEQ	NTL-VEQ (North Jetty) Variation in Est. Quantities	Revised with cost for north Jetty matl		Likely	Significant	HIGH	Triangular		($4,487,338)	$0	$5,983,117	*0*	-2.94%	0.00%	3.92%
NTL-3	NTL3 Stone Sizing (North Jetty)	Revised with cost for north Jetty matl		Likely	Marginal	MODERATE	Triangular		($1,495,779)	$0	$2,243,669	*0*	-0.98%	0.00%	1.47%
STL-VEQ	STL -VEQ (South Jetty) Variation in Estimated Quantities	Revised with cost for South Jetty matl		Likely	Significant	HIGH	Triangular		($7,948,187)	$0	$10,597,582	*0*	-5.21%	0.00%	6.95%
STL-3	STL3 Stone Sizing (South Jetty)	Revised with cost for South Jetty matl		Likely	Marginal	MODERATE	Triangular		($1,495,779)	$0	$3,189,481	*0*	-0.98%	0.00%	2.09%
ATL-VEQ	ATL-VEQ (A Jetty) Variation in Estimated Quantities	Revised with cost for Jetty A matl		Likely	Marginal	MODERATE	Triangular		($1,780,896)	$0	$2,374,528	*0*	-1.17%	0.00%	1.56%
ATL-3	ATL3 Stone Sizing (A Jetty)	Revised with cost for Jetty A matl	Consideration of actual range of $ impact show this to be low risk therefore removed from Cost Risk Model	Likely	Negligible	LOW	Triangular			$0		*Removed from model due to low risk level 6/8/12*	0.00%	0.00%	0.00%

Risk No.	Risk/Opportunity Event	UPDATE 04/24/12	UPDATE 06/08 /12	Project Cost			Variance Distribution	Correlation to Other(s)	Expected Values ($$$)				Expected Values (%)		
				Likelihood*	Impact*	Risk Level*			Low	Most Likely	High		Low	Most Likely	High
LANDS AND DAMAGES RISKS												0			
LD-1	LD1 Mitigation Needs Undefined	No Changed in HiLow see PPM-1 correlation		Very Likely	Marginal	MODERATE	Triangular	PPM-1	$0	$0	$1,500,000	0	0.00%	0.00%	0.98%
LD-2	LD2 Roadway Repair Requirements	No Changed in HiLow		Very Likely	Marginal	MODERATE	Triangular		$0	$0	$1,500,000	0	0.00%	0.00%	0.98%
LD-3	LD3 Lands and Damages Not Included in Estimate	No Changed in HiLow		Likely	Marginal	MODERATE	Triangular		$0	$0	$1,500,000	0	0.00%	0.00%	0.98%
REGULATORY AND ENVIRONMENTAL RISKS															
RE-2	RE2 Impact to Wetland by Culvert Design	Updated using new mitigation costs		Likely	Marginal	MODERATE	Uniform		($179,674)	$0	$1,078,043	0	-0.12%	0.00%	0.71%
RE-3	RE3 Project in a Coastal Zone	n/c		Likely	Marginal	MODERATE						*This risk is captured by Risk PPM-4*			
RE-5	RE5 Agency Actions Take Longer than Expected	n/c		Likely	Marginal	MODERATE						*This risk is captured by the Schedule Risk Analysis*			
RE-6	RE6 Requirements Added by NMFS	No Changed in HiLow		Likely	Marginal	MODERATE	Uniform	RE-5 See Schedule Risk Model for RE-5	$0	$0	$2,500,000	0	0.00%	0.00%	1.64%
CONSTRUCTION RISKS															
CON-1	CON1 Material Availability and Delivery	No Change in assumption of % of Hi/Low, but updated with new Material cost $s from MII estimate		Likely	Significant	HIGH	Triangular		($4,870,856)	$0	$14,612,567	0	-3.19%	0.00%	9.58%
CON-6	CON6 Consideration for Post Award Cost Modifications	Updated w/ new Const Cost from TPCS		Likely	Significant	HIGH	Triangular		$0	$0	$7,625,950	0	0.00%	0.00%	5.00%
ESTIMATE AND SCHEDULE RISKS															
EST-1	EST1 Unit Costs for Stone In Question	No Change in assumption of % of Hi/Low, but updated with new Material cost $s from MII estimate		Likely	Marginal	MODERATE	Triangular		($2,590,444)	$0	$3,281,878	0	-1.70%	0.00%	2.15%
EST-2	EST2 Special Equipment Assumptions	Updated based on equipment cost in MII 04/24/12		Likely	Marginal	MODERATE	Triangular		($1,494,940)	$0	$2,989,880	0	-0.98%	0.00%	1.96%
EST-4	EST4 Schedule Depicts Logical Construction Sequencing, Phasing, and Parallel Activities	n/c		Likely	Marginal	MODERATE						*This risk is captured by the Schedule Risk Analysis*			
EST-5	EST5 Productivity of Contractor Labor and Equipment	Updated w/ new Const Cost from TPCS		Unlikely	Significant	MODERATE	Triangular		($2,755,157)	$0	$5,510,313	0	-1.81%	0.00%	3.61%
Programmatic Risks (External Risk Items are those that are generated, caused, or controlled exclusively outside the PDT's sphere of influence.)															
PR-1	PR1 Fuel Prices	Update 4/24/12 used total direct equipment costs of new MII estimate x MU 1.248 (see Ref. EST-2) w/ $3.41/gal, 2.87, 3.13 vs. $6.82/gal, 5.74, 6.26 for Road Diesel, offrdDiesel, & Gasoline resp		Likely	Marginal	MODERATE	Triangular		$0	$0	$7,807,497	0	0.00%	0.00%	5.12%
PR-2	PR2 Adequacy of Project Funding	nc	High range value greater than $3m so Significant Impact Level	Likely	Significant	HIGH						*This risk is captured by the Schedule Risk Analysis*			
PR-3	PR3 Introduction of New Constraints/Requirements	Updated w/ new Const Cost from TPCS		Likely	Significant	HIGH	Triangular		$0	$0	$7,625,950	0	0.00%	0.00%	5.00%
PR-4	PR4 Local Communities Pose Objections	No Change		Likely	Marginal	MODERATE	Uniform		$0	$0	$1,500,000	0	0.00%	0.00%	0.98%

Risk No.	Risk/Opportunity Event	UPDATE 04/24/12	UPDATE 06/08 /12	Project Cost: Likelihood*	Project Cost: Impact*	Project Cost: Risk Level*	Variance Distribution	Correlation to Other(s)	Expected Values ($$$): Low	Expected Values ($$$): Most Likely	Expected Values ($$$): High		Expected Values (%s): Low	Expected Values (%s): Most Likely	Expected Values (%s): High
PR-5	PR5 Unexpected Escalation on Stone	Updated based on MII file 120427 Material costs	High range value greater than $3m so Significant Impact Level	Likely	Significant	HIGH	Triangular		$0	$0	$14,370,518	*0*	0.00%	0.00%	9.42%
PR-7	PR7 Market Conditions and Bidding Climate	Updated w/ new Const Cost from TPCS		Likely	Significant	HIGH	Triangular		($7,625,950)	$0	$15,251,900	*0*	-5.00%	0.00%	10.00%
										$152,519,000		*Not Part of Study - Placeholder for Project Summation Purposes Only*			
										$0					

PROJECT CONTINGENCY - OVERALL COST (BASELINE)		PROJECT CONTINGENCY - OVERALL (BASELINE)	Percentile	Baseline TPC	Contingency	Baseline w/ Contingency	Contingency %
			0%	$152,519,000	**($124,312)**	**$152,394,688**	**-0.08%**
			5%	$152,519,000	**$18,406,374**	**$170,925,374**	**12.07%**
			10%	$152,519,000	**$21,722,637**	**$174,241,637**	**14.24%**
			15%	$152,519,000	**$23,989,872**	**$176,508,872**	**15.73%**
			20%	$152,519,000	**$25,936,272**	**$178,455,272**	**17.01%**
			25%	$152,519,000	**$27,513,811**	**$180,032,811**	**18.04%**
			30%	$152,519,000	**$29,058,770**	**$181,577,770**	**19.05%**
			35%	$152,519,000	**$30,508,291**	**$183,027,291**	**20.00%**
			40%	$152,519,000	**$31,832,358**	**$184,351,358**	**20.87%**
			45%	$152,519,000	**$33,071,912**	**$185,590,912**	**21.68%**
			50%	$152,519,000	**$34,311,499**	**$186,830,499**	**22.50%**
			55%	$152,519,000	**$35,547,767**	**$188,066,767**	**23.31%**
			60%	$152,519,000	**$36,715,940**	**$189,234,940**	**24.07%**
			65%	$152,519,000	**$38,099,366**	**$190,618,366**	**24.98%**
			70%	$152,519,000	**$39,472,435**	**$191,991,435**	**25.88%**
			75%	$152,519,000	**$41,029,293**	**$193,548,293**	**26.90%**
			80%	$152,519,000	**$42,784,412**	**$195,303,412**	**28.05%**
			85%	$152,519,000	**$44,764,351**	**$197,283,351**	**29.35%**
			90%	$152,519,000	**$47,208,096**	**$199,727,096**	**30.95%**
			95%	$152,519,000	**$51,037,982**	**$203,556,982**	**33.46%**
			100%	$152,519,000	**$72,235,522**	**$224,754,522**	**47.36%**

MCR Jetties Rehabilitation Feasibility Report - Cost and Schedule Risk Analysis Revised 06/08/12



MCR Jetties Rehabilitation Feasibility Report - Cost and Schedule Risk Analysis Revised 06/08/12

Risk Refer No.	Risk Event	Low	Most Likely	High
PPM-1	Mitigation Features Have not Been Fully Defined	($718,695)	$0	$1,796,738
		$2,874,781	$3,593,476	$5,390,214

Notes: This item captures the risk that the ultimate configuration of the mitigation features will cause a variance from the current baseline estimate.

Likely Likely assumes no change from the baseline estimate.

Low Low assumes less area will be impacted by the construction activities. Assume a 20% reduction from the most likely.

High High assumes more mitigation may be required due to the multiple years of construction which could required intermin mitigation actions. Assume 50% higher costs.

From MII 120608 w/ mitig. Acre matching EA

North Jetty	
DD07 Site Mitigation	$590,541
South Jetty	
EE07 Site Mitigation	$2,121,094
Jetty A	
AA08 Wetlands Mitigation	$881,841
Total (Current)	**$3,593,476**

MCR Jetties Rehabilitation Feasibility Report - Cost and Schedule Risk Analysis Revised 06/08/12

Risk Refer No.	Risk Event	Low	Most Likely	High
PPM-4	Issues with Multiple Local Agencies	$0	$0	$2,974,769

Notes: This item captures the risk that issues with local agencies will cause a variance from the current baseline estimate.

Likely Likely assumes no change from the baseline estimate.

Low Low assumes no change from the baseline estimate.

High High assumes that agencies have requirements that necessitate altering the offloading plans, increasing the costs for offloading facility construction by 25% and offloading facitlity dredging and barge offloading by 15%.

Update with MII file "MCR Preferred Plan 120608.mlp" costs
Note

North Jetty	**Construction**	**Dredging Costs**	**Barge Off-Loading**
2015 Sta 20+00 to 30+00, 30+00 to 45+00	$1,156,962	$247,481	$1,226,575
2016 Sta 45+00 to 54+00, 55+00 to 63+00, 64+00 to 71+00, 72+00 to 76+00		$249,767	$1,188,395
2017 Sta 77+00 to 85+00, 99+00 to 101+00	$141,848	$255,024	$486,047
South Jetty			
2017 - STA 167+00 to 175+00, STA 182+0(	$2,314,091	$162,013	$1,448,035
2018 - STA 197+00 to 215+00, STA 215 to 222		$164,028	$1,445,091
2019 - STA 223 to 246		$164,053	$1,331,939
2020 - STA 258 to 290	$126,972	$162,620	$1,395,980
Jetty A			
2015 - STA 48+00 to 60+00, 69+00 to 73+00, 85+00 to 89+00, 74+00 to 84+00	$1,414,553	$489,631	$603,232
ditto Remove Off-Load Facilities	$132,704		
Total (Current)	**$5,287,129**	**$1,894,617**	**$9,125,292**
Total (Worst Case)	**$6,608,912**	**$2,178,809**	**$10,494,086**
Difference	**$2,974,769**		

MCR Jetties Rehabilitation Feasibility Report - Cost and Schedule Risk Analysis Revised 06/08/12

Risk Refer No.	Risk Event	Low	Most Likely	High
PPM-5	Coordination/Communication Difficulties	$0	$0	$1,942,400

Notes: This item captures the risk that coordination and communication difficulties will cause a variance from the current baseline estimate.

Likely Likely assumes no change from the baseline estimate.

Low Low assumes no change from the baseline estimate.

High High assumes that coordination and communication difficulties increase the cost of PED by up to 10%.

Update with "MCR TPCS 120608.xlsx"

	Current	Worst Case
Total Construction Costs	$152,519,000	
30 Account (PED) from TPCS 4/24/12	$19,424,000	$21,366,400
Difference		**$1,942,400**

MCR Jetties Rehabilitation Feasibility Report - Cost and Schedule Risk Analysis Revised 06/08/12

Risk Refer No.	Risk Event	Low	Most Likely	High
PPM-8	Unplanned Work that Must Be Accommodated	$0	$0	$1,666,600

Notes: This item captures the risk that unplanned work will cause a variance from the current baseline estimate.

Likely Likely assumes no change from the baseline estimate.

Low Low assumes no change from the baseline estimate.

High High assumes that unplanned work that must be accommodated during the review and development phases could increase the costs of PED by up to 10%.

Update with "MCR TPCS 120608.xlsx"

	Current	Worst Case
Total Construction Costs	$152,519,000	
30 Account (PED) from TPCS 6/08/12	$16,666,000	$18,332,600
Difference		**$1,666,600**

MCR Jetties Rehabilitation Feasibility Report - Cost and Schedule Risk Analysis Revised 06/08/12

Risk Refer No.	Risk Event	Low	Most Likely	High
CA-1	Incomplete Acquisition Strategy	($7,625,950)	$0	$15,251,900
		$144,893,050	$152,519,000	$167,770,900

Notes: This item captures the risk that lack of acquisition strategy planning will cause a variance from the current baseline estimate.

Likely Likely assumes no change from the baseline estimate.

Low

Low assumes that the ultimate acquisition strategy could lead to more favorable contract situations, saving up to 5% from the currently contemplated construction costs.

High

High assumes that the ultimate acquisition strategy could lead to less favorable contracting situations, increasing the construction costs by up to 10%.

Update with "MCR TPCS 120608.xlsx"

Risk Refer No.	Risk Event	Low	Most Likely	High
CA-2	Numerous Separate Contracts	$0	$0	$7,625,950
		$152,519,000	$152,519,000	$160,144,950

Notes: This item captures the risk that having numerous separate contracts will cause a variance from the current baseline estimate.

Likely Likely assumes no change from the baseline estimate.

Low

Low assumes no change from the baseline estimate.

High High assumes that having numerous contracts for the project may increase the costs of contracting, and lead to less favorable contract markups, and lack of efficiencies, increasing the construction costs by 5%.

Update with "MCR TPCS 120608.xlsx"

MCR Jetties Rehabilitation Feasibility Report - PDT Risk Register - North Jetty

Risk Refer No.	Risk Event	Low	Most Likely	High
NTL-VEQ	Variation in Estimated Quantities (North Jetty)	($4,487,338)	$0	$5,983,117

	Current	Best Case	Worst Case
North Jetty	**$29,915,584**	$25,428,246	$35,898,701
Difference	**$0**	**($4,487,338)**	**$5,983,117**

Notes: This item captures the risk that variation in estimated quantities will cause a variance from the current baseline estimate.

Likely Likely assumes no change from the baseline estimate.

Low Low assumes that the ultimate quantities could be significantly less than contemplated, leading to a quantity reduction of up to 15% (per FAR clause 52.211-18 IAW Section 11.703c).

High

High assumes that the worst case is up to 20% additional quantity.

update with file "MCR Preferred Plan 120608.mlp" $24,009,297

Direct matl cost of North Jetty * Markup of 1.246

Markup 1.246

MCR Jetties Rehabilitation Feasibility Report - PDT Risk Register - North Jetty

Risk Refer No.	Risk Event	Low	Most Likely	High
NTL-3	Stone Sizing (North Jetty)	($1,495,779)	$0	$2,243,669
		$28,419,805	$29,915,584	$32,159,253

Notes: This item captures the risk that sizing of stone will cause a variance from the current baseline estimate.

Likely Likely assumes no change from the baseline estimate.

Low

Low assumes that up to 25% of the stone costs 5% less due to stone sizing and up to 25% of the stone costs 15% less due to stone sizing.

High

High assumes that up to 25% of the stone costs 10% more due to stone sizing and up to 25% of the stone costs 20% more due to stone sizing.

update with file "MCR Preferred Plan 120608.mlp"
Direct matl cost of North Jetty * Markup of 1.246

Markup	1.246
Current	**$29,915,584**
Best Case	**$28,419,805**
Worst Case	**$32,159,253**

MCR Jetties Rehabilitation Feasibility Report - PDT Risk Register - South Jetty

Risk Refer No.	Risk Event	Low	Most Likely	High
STL-VEQ	Variation in Estimated Quantities (South Jetty)	($7,948,187)	$0	$10,597,582

	Current	Best Case	Worst Case
South Jetty	$52,987,912	$45,039,725	$63,585,494
Difference	**$0**	**($7,948,187)**	**$10,597,582**

Notes: This item captures the risk that variation in estimated quantities will cause a variance from the current baseline estimate.

Likely Likely assumes no change from the baseline estimate.

Low Low assumes that the ultimate quantities could be significantly less than contemplated, leading to a quantity reduction of up to 15% (per FAR clause 52.211-18 IAW Section 11.703c).

High High assumes that the worst case is up to 20% additional quantity.

update with file "MCR Preferred Plan 120608.mlp" $42,526,414

Direct matl cost of South Jetty * Markup of 1.246

Markup 1.246

MCR Jetties Rehabilitation Feasibility Report - PDT Risk Register - South Jetty

Risk Refer No.	Risk Event	Low	Most Likely	High
STL-3	Stone Sizing (South Jetty)	($2,126,321)	$0	$3,189,481
		$40,400,093	$42,526,414	$45,715,895

Notes: This item captures the risk that sizing of stone will cause a variance from the current baseline estimate.

Likely Likely assumes no change from the baseline estimate.

Low

Low assumes that up to 25% of the stone costs 5% less due to stone sizing and up to 25% of the stone costs 15% less due to stone sizing.

High

High assumes that up to 25% of the stone costs 10% more due to stone sizing and up to 25% of the stone costs 20% more due to stone sizing.

update with file "MCR Preferred Plan 120608.mlp"

Direct matl cost of South Jetty * Markup of 1.246

Markup	1.246
Current	**$42,526,414**
Best Case	**$40,400,093**
Worst Case	**$45,715,895**

MCR Jetties Rehabilitation Feasibility Report - PDT Risk Register - Jetty A

Risk Refer No.	Risk Event	Low	Most Likely	High
ATL-VEQ	ATL-VEQ (A Jetty) Variation in Estimated Quantities	($1,780,896)	$0	$2,374,528

	Current	Best Case	Worst Case
Jetty A	$11,872,640	$10,091,744	$14,247,168
Difference	**$0**	**($1,780,896)**	**$2,374,528**

Notes: This item captures the risk that variation in estimated quantities will cause a variance from the current baseline estimate.

Likely Likely assumes no change from the baseline estimate.

Low Low assumes that the ultimate quantities could be significantly less than contemplated, leading to a quantity reduction of up to 15% (per FAR clause 52.211-18 IAW Section 11.703c).

High

High assumes that the worst case is up to 20% additional quantity.

update with file "MCR Preferred Plan 120608.mlp" $9,515,569

Direct matl cost of South Jetty * Markup of 1.246

Markup 1.248

MCR Jetties Rehabilitation Feasibility Report - Cost and Schedule Risk Analysis Revised 06/08/12

Risk Refer No.	Risk Event	Low	Most Likely	High
LD-1	Mitigation Needs Undefined	$0	$0	$1,500,000

Notes: This item captures the risk that lack of information regarding mitigation needs (for real estate footprint) will cause a variance from the current baseline estimate.

Likely Likely assumes no change from the baseline estimate.

Low

Low assumes no change from the baseline estimate.

High

High assumes that mitigation needs reveal the requirement to purchase a significant amount of real estate, costing up to $1.5 Million (based on input from the PDT).

MCR Jetties Rehabilitation Feasibility Report - Cost and Schedule Risk Analysis Revised 06/08/12

Risk Refer No.	Risk Event	Low	Most Likely	High
LD-2	Roadway Repair Requirements	$0	$0	$1,500,000

Notes: This item captures the risk that roadway repair requirements to support the contract will cause a variance from the current baseline estimate.

Likely Likely assumes no change from the baseline estimate.

Low Low assumes no change from the baseline estimate.

High High assumes that significant roadway repairs are necessary over the lifetime of the project, costing up to $1.5 Million (based on input from the PDT).

Risk Refer No.	Risk Event	Low	Most Likely	High
LD-3	Lands and Damages Not Included in Estimate	$0	$0	$1,500,000

Notes: This item captures the risk that not having the lands and damages in the current estimate will cause a variance from the current baseline estimate.

Likely Likely assumes no change from the baseline estimate.

Low Low assumes no change from the baseline estimate.

High High assumes that not having a real estate estimate could increase the overall project cost by up to $1.5 Million (based on input from the PDT).

MCR Jetties Rehabilitation Feasibility Report - Cost and Schedule Risk Analysis Revised 06/08/12

Risk Refer No.	Risk Event	Low	Most Likely	High
RE-2	Impact to Wetland by Culvert Design	($179,674)	$0	$1,078,043
		$3,413,802	$3,593,476	$4,671,519

Notes: This item captures the risk that impacts to wetlands by the culvert design will cause a variance from the current baseline estimate.

Likely Likely assumes no change from the baseline estimate.

Low Low assumes less impact than anticipated, saving up to 5% from the mitigation costs.

High High assumes more impact that anticipated, costing up to 30% more than currently estimated for mitigation.

From MII 120608 w/ mitig. Acre matching EA

North Jetty	
DD07 Site Mitigatio	$590,541
South Jetty	
EE07 Site Mitigatio	$2,121,094
Jetty A	
AA08 Wetlands Mit	$881,841
Total (Current)	**$3,593,476**

MCR Jetties Rehabilitation Feasibility Report - Cost and Schedule Risk Analysis Revised 06/08/12

Risk Refer No.	Risk Event	Low	Most Likely	High
RE-6	Requirements Added by NMFS	$0	$0	$2,500,000

Notes: This item captures the risk that requirements added by NMFS will cause a variance from the current baseline estimate.

Likely Likely assumes no change from the baseline estimate.

Low Low assumes no change from the baseline estimate.

High High assumes that NMFS requires more mitigation than currently estimated, adding up to $2.5 Million in costs (value based on historical experience).

MCR Jetties Rehabilitation Feasibility Report - Cost and Schedule Risk Analysis Revised 06/08/12

Risk Refer No.	Risk Event	Low	Most Likely	High
CON-1	Material Availability and Delivery	($4,870,856)	$0	$14,612,567
		$92,546,258	$97,417,114	$112,029,681

Notes:	This item captures the risk that material availability and delivery will cause a variance from the current baseline estimate.
Likely	Likely assumes no change from the baseline estimate.
Low	Low assumes delivery from one source. Assume possible 5% decrease in transportation costs.
High	High assumes multiple sources with longer delivery routes. Assume a 15% increase due to transportation costs. Update with "MCR TPCS 120608.xlsx" Direct Matl cost of $78,051,280 * Markup of 1.246

Risk Refer No.	Risk Event	Low	Most Likely	High
CON-6	Consideration for Post Award Cost Modifications	$0	$0	$7,625,950
		$152,519,000	$152,519,000	$160,144,950

Notes: This item captures the risk that post-award contract modifications will cause a variance from the current baseline estimate.

Likely Likely assumes no change from the baseline estimate.

Low Low assumed no change from the baseline estimate.

High High assumes up to 5% of the estimated contract cost for post-award contract modifications, based on historical metrics and rules of thumb.

MCR Jetties Rehabilitation Feasibility Report - Cost and Schedule Risk Analysis Revised 06/08/12

Risk Refer No.	Risk Event	Low	Most Likely	High
EST-1	Unit Costs for Stone In Question	($2,590,444)	$0	$3,281,878
		$94,794,664	$97,385,108	$100,666,986

Notes: This item captures the risk that not having accurate unit costs for stone will cause a variance from the current baseline estimate.

Likely Likely assumes no change from the baseline estimate. UPDATE 06/08/12 update with Material cost from MII estimate

Low Low assumes with a avg direct cost of $121/ton. Assume the cost is $5/ton less.

High High assumes a $20 increase per ton due to availability and possible longer delivery routes.
Update with "MCR TPCS 120608.xlsx"
Direct Matl cost of $78,051,280 * Markup of 1.246

MCR Jetties Rehabilitation Feasibility Report - Cost and Schedule Risk Analysis Revised 06/08/12

Risk Refer No.	Risk Event	Low	Most Likely	High
EST-2	Special Equipment Assumptions	($1,494,940)	$0	$2,989,880
		$28,403,863	$29,898,803	$32,888,683

Notes: This item captures the risk that inaccurate assumptions regarding special equipment will cause a variance from the current baseline estimate.

Likely Likely assumes no change from the baseline estimate.

Low

Low assumes estimate has oversized equipment. Assume 5% reduction, due to gaining efficiencies based on decreased equipment costs for operation and mobilization.

High High assumes larger equipement is required for the upper range of stone. This would increase equipement costs as well are mob/demb costs. Assume 10% increase due to efficiency loss and additional mobilization.

Update with "MCR TPCS 120608.xlsx"

10 BREAKWATERS AND SEAWALLS

Equipment Costs Direct	$23,963,005
Equipment cost w/ Gen MU	**$29,898,803**

Update with "MCR TPCS 120608.xlsx"

Total Extended Costs Direct	122,239,462
Total Extended Costs Contract	152,519,000
General Total markup	1.248

MCR Jetties Rehabilitation Feasibility Report - Cost and Schedule Risk Analysis Revised 06/08/12

Risk Refer No.	Risk Event	Low	Most Likely	High
EST-5	Productivity of Contractor Labor and Equipment	($2,755,157)	$0	$5,510,313
		$52,347,977	$55,103,134	$60,613,447

Notes: This item captures the risk that inaccurate assumptions regarding special equipment will cause a variance from the current baseline estimate.

Likely Likely assumes no change from the baseline estimate.

Low

Low assumes that productivity is up to 5% better than estimated in the baseline estimate, due to procuring a highly efficient contractor.

High

High assumes that productivity is up to 10% decreased than currently estimated, due to procuring a less efficient contractor.

	direct	Total w/ 1.246 MU
update with file "MCR Preferred Plan 120608.mlp" Productivity affects Labor & Equip Cost but not matl		
total MII cost		$152,519,000
Matl cost from MII	$78,075,932	$97,415,866
Amount to base Productivity effects		$55,103,134

MCR Jetties Rehabilitation Feasibility Report - Cost and Schedule Risk Analysis Revised 06/08/12

Risk Refer No.	Risk Event	Low	Most Likely	High
PR-1	Fuel Prices	$0	$0	$7,807,497
			$29,898,803	$37,706,300

Notes: This item captures the risk that fuel prices will cause a variance from the current baseline estimate.

Likely Likely assumes no change from the baseline estimate. Estimate used current price of $3.95 road & $3.37 offroad diesel, and $3.67/ gal gasoline.

Low Low assumes no change from the most likely cost of fuel.

High High assumes fuel prices that fuel prices could double to up to $7.90/gallon for on-road diesel and $6.74/gal off road and $7.34/gal.

Update 06/08/12 used total direct equipment costs of new MII estimate x MU 1.246 (see Ref. EST-2) w/ $3.95/gal, $3.37, 3.67 vs. $7.90/gal, 6.74, 7.34

		direct	1.248
Equipment costs	**@ $3.95/gal road diesel**	**23,963,005**	**29,898,803**
Equipment costs	**@ $7.90/gal "**	**30,220,483**	**37,706,300**

MCR Jetties Rehabilitation Feasibility Report - Cost and Schedule Risk Analysis Revised 06/08/12

Risk Refer No.	Risk Event	Low	Most Likely	High
PR-3	Introduction of New Constraints/Requirements	$0	$0	$7,625,950
			$152,519,000	$160,144,950

Notes: This item captures the risk that the introduction of new constraints or requirements will cause a variance from the current baseline estimate.

Likely Likely assumes no change from the baseline estimate.

Low

Low assumes no change from the baseline estimate.

High

High assumes that new constraints or requirements are required, increasing the overall project cost by up to 5% to cover environmental/regulatory considerations not currently contemplated.

Update with "MCR TPCS 120608.xlsx"

MCR Jetties Rehabilitation Feasibility Report - Cost and Schedule Risk Analysis Revised 06/08/12

Risk Refer No.	Risk Event	Low	Most Likely	High
PR-4	Local Communities Pose Objections	$0	$0	$1,500,000

Notes: This item captures the risk that local communities posing objections will cause a variance from the current baseline estimate.

Likely Likely assumes no change from the baseline estimate.

Low Low assumes no change from the baseline estimate.

High High assumes that if local communities pose objections, it could add up to $1.5 Million in costs (based on input from the PDT).

MCR Jetties Rehabilitation Feasibility Report - Cost and Schedule Risk

Risk Refer No.	Risk Event	Low	Most Likely	High
PR-5	Unexpected Escalation on Stone	$0	$0	$14,370,518
		$105,872,920	$105,872,920	$120,243,438

Notes: This item captures the risk that unexpected escalation on the price of stone will cause a variance from the current baseline estimate.

Likely Likely assumes no change from the baseline estimate.

Low

Low assumes the cost of stone will not change from the most likely case.

High

High assumes an escalation on stone of up to 3% per year (over and above national/local market average inflation for materials).

Update 6/08/12 with matl Direct costs from MII file "MCR Preferred Plan 120608.mlp"
added markup see Ref. EST-1

					1.247706735			3.0%
2013	N Jetty	S Jetty	A Jetty	Year Total Direct	Marked up to Contract Cost	CWCCIS	Total	3% per year above CWCCIS
2014	$0		$0	$0	$0	2.63%	$0	$0
2015	$10,380,220		$9,312,853	$19,693,073	$24,571,180	4.43%	$25,659,683	$27,222,358
2016	$8,363,746			$8,363,746	$10,435,502	6.31%	$11,093,982	$12,122,694
2017	$5,811,783	$12,546,831		$18,358,614	$22,906,167	8.23%	$24,791,344	$27,902,877
2018		$10,165,633		$10,165,633	$12,683,728	10.18%	$13,974,932	$16,200,776
2019		$10,684,312		$10,684,312	$13,330,888	12.16%	$14,951,924	$17,853,379
2020		$10,810,553		$10,810,553	$13,488,399	14.18%	$15,401,055	$18,941,354
2021				$0	$0	16.23%	$0	$0
2022				$0	$0	18.32%	$0	$0
2023				$0	$0	20.45%	$0	$0
2024				$0	$0	22.62%	$0	$0
2025				$0	$0	24.83%	$0	$0
2026				$0	$0	27.08%	$0	$0
2027				$0	$0	29.36%	$0	$0
2028				$0	$0	31.68%	$0	$0
2029				$0	$0	34.06%	$0	$0
2030				$0	$0	36.48%	$0	$0
2031				$0	$0	38.93%	$0	$0
2032				$0	$0	41.43%	$0	$0
2033				$0	$0	43.98%	$0	$0
							$105,872,920	$120,243,438

MCR Jetties Rehabilitation Feasibility Report - Cost and Schedule Risk Analysis Revised 06/08/12

Risk Refer No.	Risk Event	Low	Most Likely	High
PR-7	Market Conditions and Bidding Climate	($7,625,950)	$0	$15,251,900
		$144,893,050	$152,519,000	$167,770,900

Notes: This item captures the risk that market conditions and bidding climate will cause a variance from the current baseline estimate.

Likely Likely assumes no change from the baseline estimate.

Low

Low assumes that market prices are better than anticipated, saving up to 5% in construction costs.

High

High assumes that market forces make the overall project cost up to 10% more expensive.

MCR Jetties Rehabilitation Feasibility Report - SCHEDULE Risk Analysis Model UPDATE 120608

Contingency on Base Estimate	80% Confidence Project Cost	
Baseline Estimate Cost (Most Likely) ->	**$152,519,000**	
Baseline Estimate Cost Contingency Amount ->	$42,784,412	28.1%
Baseline Estimate Construction Cost (80% Confidence) ->	**$195,303,412**	

Contingency on Schedule	80% Confidence Project Schedule	
Project Schedule Duration (Most Likely) ->	**99.3 Months**	
Schedule Contingency Duration ->	40.0 Months	40.3%
Project Schedule Duration (80% Confidence) ->	**139.3 Months**	
Project Schedule Contingency Amount (80% Confidence) ->	**$4,107,655**	2.7%

Project Contingency	80% Confidence Project Cost	
Project Contingency Amount (80% Confidence) ->	**$46,892,067**	30.7%
Project Contingency Percentage (80% Confidence) ->	**31%**	

Project Cost (80% Confidence) ->	**$199,411,067**

- PROJECT CONTINGENCY DEVELOPMENT -

Contingency Analysis

Most Likely Cost Estimate	$152,519,000

		Contingency Amounts					%	
Confidence Level	Project Cost	All Jetties	Overall	North Jetty	South Jetty	Jetty A	Contingency	
0%	$151,892,316	($626,684)	($626,684)	$0	$0	$0	-0.41%	152,519,000
5%	$172,394,030	$19,875,030	$19,875,030	$0	$0	$0	13.03%	152,519,000
10%	$176,092,967	$23,573,967	$23,573,967	$0	$0	$0	15.46%	152,519,000
15%	$178,606,976	$26,087,976	$26,087,976	$0	$0	$0	17.10%	152,519,000
20%	$180,758,742	$28,239,742	$28,239,742	$0	$0	$0	18.52%	152,519,000
25%	$182,512,343	$29,993,343	$29,993,343	$0	$0	$0	19.67%	152,519,000
30%	$184,219,191	$31,700,191	$31,700,191	$0	$0	$0	20.78%	152,519,000
35%	$185,813,143	$33,294,143	$33,294,143	$0	$0	$0	21.83%	152,519,000
40%	$187,292,121	$34,773,121	$34,773,121	$0	$0	$0	22.80%	152,519,000
45%	$188,663,633	$36,144,633	$36,144,633	$0	$0	$0	23.70%	152,519,000
50%	$190,033,063	$37,514,063	$37,514,063	$0	$0	$0	24.60%	152,519,000
55%	$191,402,350	$38,883,350	$38,883,350	$0	$0	$0	25.49%	152,519,000
60%	$192,717,581	$40,198,581	$40,198,581	$0	$0	$0	26.36%	152,519,000
65%	$194,240,013	$41,721,013	$41,721,013	$0	$0	$0	27.35%	152,519,000
70%	$195,758,510	$43,239,510	$43,239,510	$0	$0	$0	28.35%	152,519,000
75%	$197,472,777	$44,953,777	$44,953,777	$0	$0	$0	29.47%	152,519,000
80%	$199,411,067	$46,892,067	$46,892,067	$0	$0	$0	30.75%	152,519,000
85%	$201,603,687	$49,084,687	$49,084,687	$0	$0	$0	32.18%	152,519,000
90%	$204,328,305	$51,809,305	$51,809,305	$0	$0	$0	33.97%	152,519,000
95%	$208,549,053	$56,030,053	$56,030,053	$0	$0	$0	36.74%	152,519,000
100%	$231,528,466	$79,009,466	$79,009,466	$0	$0	$0	51.80%	152,519,000

- BASE CONTINGENCY DEVELOPMENT -

Contingency Analysis

Most Likely Cost Estimate	$152,519,000							
		Contingency Amounts					%	
Confidence Level	Project Cost	All Jetties	Overall	North Jetty	South Jetty	Jetty A	Contingency	
0%	$152,394,688	($124,312)	($124,312)	$0	$0	$0	-0.08%	152,519,000
5%	$170,925,374	$18,406,374	$18,406,374	$0	$0	$0	12.07%	152,519,000
10%	$174,241,637	$21,722,637	$21,722,637	$0	$0	$0	14.24%	152,519,000
15%	$176,508,872	$23,989,872	$23,989,872	$0	$0	$0	15.73%	152,519,000
20%	$178,455,272	$25,936,272	$25,936,272	$0	$0	$0	17.01%	152,519,000
25%	$180,032,811	$27,513,811	$27,513,811	$0	$0	$0	18.04%	152,519,000
30%	$181,577,770	$29,058,770	$29,058,770	$0	$0	$0	19.05%	152,519,000
35%	$183,027,291	$30,508,291	$30,508,291	$0	$0	$0	20.00%	152,519,000
40%	$184,351,358	$31,832,358	$31,832,358	$0	$0	$0	20.87%	152,519,000
45%	$185,590,912	$33,071,912	$33,071,912	$0	$0	$0	21.68%	152,519,000
50%	$186,830,499	$34,311,499	$34,311,499	$0	$0	$0	22.50%	152,519,000
55%	$188,066,767	$35,547,767	$35,547,767	$0	$0	$0	23.31%	152,519,000
60%	$189,234,940	$36,715,940	$36,715,940	$0	$0	$0	24.07%	152,519,000
65%	$190,618,366	$38,099,366	$38,099,366	$0	$0	$0	24.98%	152,519,000
70%	$191,991,435	$39,472,435	$39,472,435	$0	$0	$0	25.88%	152,519,000
75%	$193,548,293	$41,029,293	$41,029,293	$0	$0	$0	26.90%	152,519,000
80%	$195,303,412	$42,784,412	$42,784,412	$0	$0	$0	28.05%	152,519,000
85%	$197,283,351	$44,764,351	$44,764,351	$0	$0	$0	29.35%	152,519,000
90%	$199,727,096	$47,208,096	$47,208,096	$0	$0	$0	30.95%	152,519,000
95%	$203,556,982	$51,037,982	$51,037,982	$0	$0	$0	33.46%	152,519,000
100%	$224,754,522	$72,235,522	$72,235,522	$0	$0	$0	47.36%	152,519,000

- SCHEDULE CONTINGENCY (DURATION) DEVELOPMENT -

Contingency Analysis

Most Likely Schedule Duration	99.3 Months							
Confidence Level	Project Duration	All Jetties	Overall	North Jetty	South Jetty	Jetty A	Contingency	
0%	94.4 Months	-4.9 Months	-4.9 Months	0.0 Months	0.0 Months	0.0 Months	-4.92%	99
5%	113.6 Months	14.3 Months	14.3 Months	0.0 Months	0.0 Months	0.0 Months	14.40%	99
10%	117.4 Months	18.0 Months	18.0 Months	0.0 Months	0.0 Months	0.0 Months	18.15%	99
15%	119.8 Months	20.4 Months	20.4 Months	0.0 Months	0.0 Months	0.0 Months	20.57%	99
20%	121.8 Months	22.4 Months	22.4 Months	0.0 Months	0.0 Months	0.0 Months	22.58%	99
25%	123.5 Months	24.1 Months	24.1 Months	0.0 Months	0.0 Months	0.0 Months	24.31%	99
30%	125.1 Months	25.7 Months	25.7 Months	0.0 Months	0.0 Months	0.0 Months	25.89%	99
35%	126.5 Months	27.1 Months	27.1 Months	0.0 Months	0.0 Months	0.0 Months	27.31%	99
40%	128.0 Months	28.6 Months	28.6 Months	0.0 Months	0.0 Months	0.0 Months	28.83%	99
45%	129.3 Months	29.9 Months	29.9 Months	0.0 Months	0.0 Months	0.0 Months	30.12%	99
50%	130.5 Months	31.2 Months	31.2 Months	0.0 Months	0.0 Months	0.0 Months	31.39%	99
55%	131.8 Months	32.5 Months	32.5 Months	0.0 Months	0.0 Months	0.0 Months	32.70%	99
60%	133.2 Months	33.9 Months	33.9 Months	0.0 Months	0.0 Months	0.0 Months	34.14%	99
65%	134.6 Months	35.3 Months	35.3 Months	0.0 Months	0.0 Months	0.0 Months	35.50%	99
70%	136.0 Months	36.7 Months	36.7 Months	0.0 Months	0.0 Months	0.0 Months	36.93%	99
75%	137.5 Months	38.2 Months	38.2 Months	0.0 Months	0.0 Months	0.0 Months	38.47%	99
80%	139.3 Months	40.0 Months	40.0 Months	0.0 Months	0.0 Months	0.0 Months	40.27%	99
85%	141.4 Months	42.1 Months	42.1 Months	0.0 Months	0.0 Months	0.0 Months	42.35%	99
90%	144.1 Months	44.8 Months	44.8 Months	0.0 Months	0.0 Months	0.0 Months	45.10%	99
95%	147.9 Months	48.6 Months	48.6 Months	0.0 Months	0.0 Months	0.0 Months	48.94%	99
100%	165.3 Months	66.0 Months	66.0 Months	0.0 Months	0.0 Months	0.0 Months	66.40%	99

- SCHEDULE CONTINGENCY (AMOUNT) DEVELOPMENT -

Contingency Analysis $ from delays

Most Likely Cost Estimate	$152,519,000							
Confidence Level	Project Cost	All Jetties	Overall	North Jetty	South Jetty	Jetty A	Contingency	
0%	$152,016,628	($502,372)	($502,372)	$0	$0	$0	-0.33%	152,519,000
5%	$153,987,656	$1,468,656	$1,468,656	$0	$0	$0	0.96%	152,519,000
10%	$154,370,329	$1,851,329	$1,851,329	$0	$0	$0	1.21%	152,519,000
15%	$154,617,104	$2,098,104	$2,098,104	$0	$0	$0	1.38%	152,519,000
20%	$154,822,469	$2,303,469	$2,303,469	$0	$0	$0	1.51%	152,519,000
25%	$154,998,531	$2,479,531	$2,479,531	$0	$0	$0	1.63%	152,519,000
30%	$155,160,421	$2,641,421	$2,641,421	$0	$0	$0	1.73%	152,519,000
35%	$155,304,852	$2,785,852	$2,785,852	$0	$0	$0	1.83%	152,519,000
40%	$155,459,763	$2,940,763	$2,940,763	$0	$0	$0	1.93%	152,519,000
45%	$155,591,721	$3,072,721	$3,072,721	$0	$0	$0	2.01%	152,519,000
50%	$155,721,564	$3,202,564	$3,202,564	$0	$0	$0	2.10%	152,519,000
55%	$155,854,583	$3,335,583	$3,335,583	$0	$0	$0	2.19%	152,519,000
60%	$156,001,641	$3,482,641	$3,482,641	$0	$0	$0	2.28%	152,519,000
65%	$156,140,647	$3,621,647	$3,621,647	$0	$0	$0	2.37%	152,519,000
70%	$156,286,075	$3,767,075	$3,767,075	$0	$0	$0	2.47%	152,519,000
75%	$156,443,485	$3,924,485	$3,924,485	$0	$0	$0	2.57%	152,519,000
80%	**$156,626,655**	**$4,107,655**	**$4,107,655**	**$0**	**$0**	**$0**	**2.69%**	152,519,000
85%	$156,839,336	$4,320,336	$4,320,336	$0	$0	$0	2.83%	152,519,000
90%	$157,120,209	$4,601,209	$4,601,209	$0	$0	$0	3.02%	152,519,000
95%	$157,511,070	$4,992,070	$4,992,070	$0	$0	$0	3.27%	152,519,000
100%	$159,292,944	$6,773,944	$6,773,944	$0	$0	$0	4.44%	152,519,000

MCR Jetties Rehabilitation Feasibility Report OVERALL Schedule Risk Analysis Model

			Project Cost					Crystal Ball Simulation Expected Values (mos.)				Crystal Ball Simulation Expected Values (%s)		
Risk No.	Risk/Opportunity Event	UPDATE 120424	Likelihood*	Impact*	Risk Level*	Variance Distribution	Correlation to Other(s)	Low	Most Likely	High		Low	Most Likely	High
Internal Risks (Internal Risk Items are those that are generated, caused, or controlled within the PDT's sphere of influence.)														
PROJECT & PROGRAM MGMT														
PPM-1	PPM-1 Mitigation Features Have not Been Fully Defined	No change	Very Likely	Significant	HIGH	Triangular		-2.0 Months	0.0 Months	4.0 Months	0-Jan-00	-2.04%	0.00%	4.08%
PPM-3	PPM-3 Project Schedule in Question	No change	Very Likely	Significant	HIGH	Triangular	CON-4. Say 0.50 correlation of schedule change due to Quanties (PPM3) vs change due to construction/productio assumptions (CON-4)	-3.0 Months	0.0 Months	6.0 Months	0-Jan-00	-3.06%	0.00%	6.12%
PPM-4	PPM-4 Issues with Multiple Local Agencies	No change	Very Likely	Significant	HIGH	Uniform		0.0 Months	0.0 Months	6.0 Months	0-Jan-00	0.00%	0.00%	6.12%
PPM-5	PPM-5 Coordination/Communication Difficulties	No change	Likely	Significant	HIGH	Triangular		-2.0 Months	0.0 Months	4.0 Months	0-Jan-00	-2.04%	0.00%	4.08%
PPM-6	PPM-5 Internal Red Tape Causing Delays in Obtaining Approvals and Decisions	No change	Likely	Significant	HIGH	Uniform	PPM-8 Internaral red tape is a small portion of possible unplanned work, say 20%. So use 0.2 correlation	0.0 Months	0.0 Months	6.0 Months	0-Jan-00	0.00%	0.00%	6.12%
PPM-8	PPM-8 Unplanned Work that Must Be Accommodated	No change	Very Likely	Significant	HIGH	Uniform	PPM-6	-3.0 Months	0.0 Months	6.0 Months	0-Jan-00	-3.06%	0.00%	6.12%
CONTRACT ACQUISITION RISKS														
CA-1	CA-1 Incomplete Acquisition Strategy	6/8/12 Ugraded Impact level to Significant since High range > 3 mo	Likely	Significant	HIGH	Triangular		-3.0 Months	0.0 Months	6.0 Months	0-Jan-00	-3.06%	0.00%	6.12%
CA-2	CA-2 Numerous Separate Contracts	Update 120424 Plan time frame reduced to 6 years with only 4 contracts. Cumulative delay of 1 months per contract for HIGH.	Very Likely	Significant	HIGH	Triangular		0.0 Months	0.0 Months	4.0 Months	0-Jan-00	0.00%	0.00%	4.08%
TECHNICAL RISKS														
TL-1	TL-1 Variation in Estimated Quantities	UPDATE 120424 Update total schedule length to 99 months (Start 9/3/12 to end of 5/2/20 plus 182 days of work that year) Assume variation of quantities -15% to Plus 20% proportional to duration needed.	Likely	Significant	HIGH	Triangular		-14.9 Months	0.0 Months	19.8 Months	0-Jan-00	-15.15%	0.00%	20.21%
REGULATORY AND ENVIRONMENTAL RISKS														
RE-5	RE-5 Agency Actions Take Longer than Expected	No change	Likely	Significant	HIGH	Uniform		0.0 Months	0.0 Months	12.0 Months	0-Jan-00	0.00%	0.00%	12.25%
RE-7	RE-7 Recurring Permits Required	No change	Likely	Marginal	MODERATE	Yes-No/Uniform		0.0 Months	0.0 Months	6.0 Months	0-Jan-00	0.00%	0.00%	6.12%
CONSTRUCTION RISKS														
CON-1	CON-1 Material Availability and Delivery	No change Assume difficulty in availability and deliery affect start of project but after several year this risk element would be worked out so same High/lows	Unlikely	Significant	MODERATE	Triangular		-2.0 Months	0.0 Months	4.0 Months	0-Jan-00	-2.04%	0.00%	4.08%

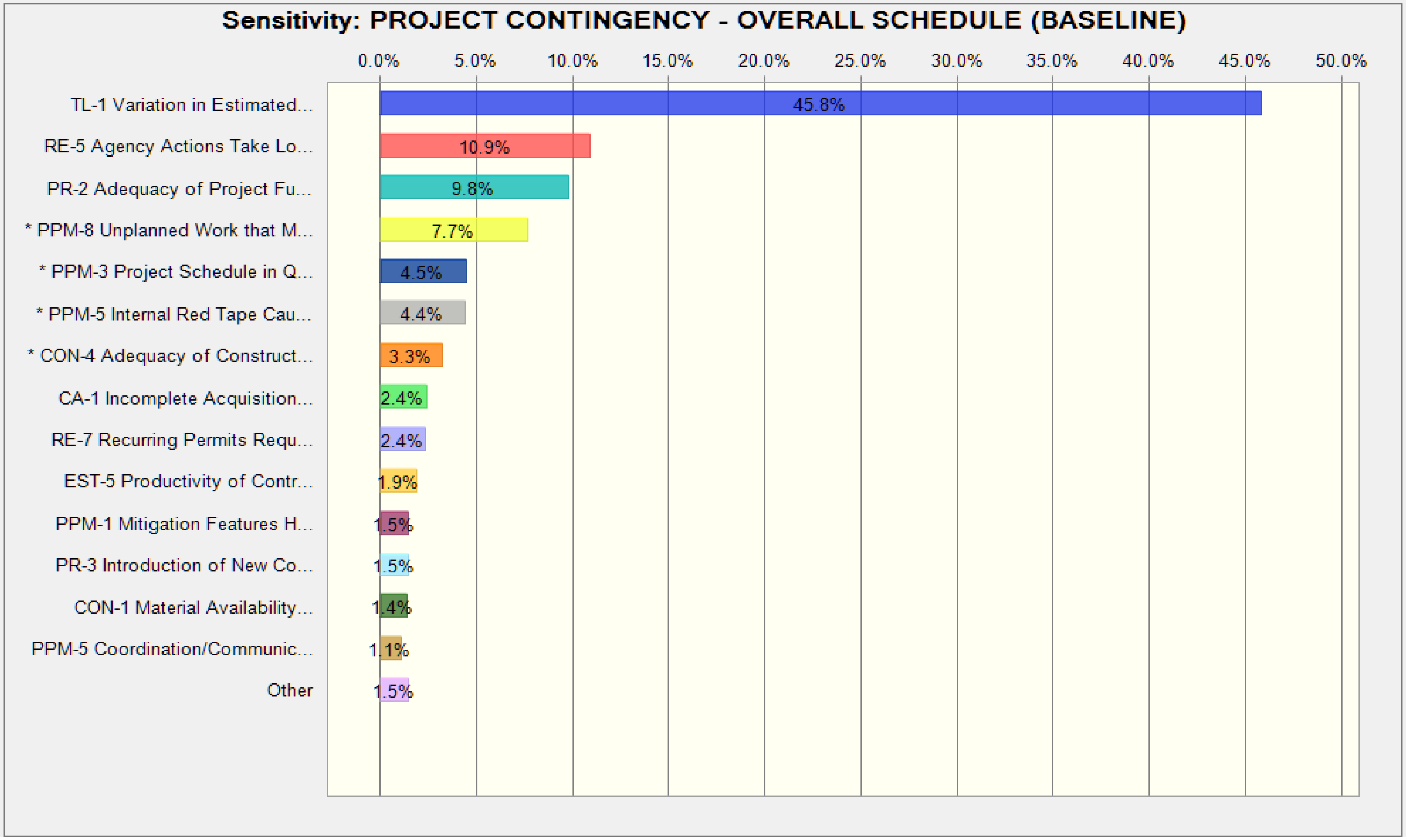
Risk No.	Risk/Opportunity Event	UPDATE 120424	Project Cost: Likelihood*	Project Cost: Impact*	Project Cost: Risk Level*	Variance Distribution	Correlation to Other(s)	Expected Values (mos.): Low	Expected Values (mos.): Most Likely	Expected Values (mos.): High		Expected Values (%s): Low	Expected Values (%s): Most Likely	Expected Values (%s): High
CON-4	CON-4 Adequacy of Construction Schedule	Update 120424. Total plan is about half duration of previous. Reduce Hi/lows from -3 to +6 mo to -1.5 to +3 mo	Likely	Significant	HIGH	Triangular	PPM-3	-1.5 Months	0.0 Months	3.0 Months	*0-Jan-00*	-1.53%	0.00%	3.06%
ESTIMATE AND SCHEDULE RISKS														
EST-4	EST-4 Schedule Depicts Logical Construction Sequencing, Phasing, and	No change	Likely	Significant	HIGH	Triangular					***This risk is captured by Risk CON-4***			
EST-5	EST-5 Productivity of Contractor Labor and Equipment	Update with new durations of construction activities	Unlikely	Significant	MODERATE	Triangular		-2.0 Months	0.0 Months	4.0 Months	*0-Jan-00*	-2.06%	0.00%	4.11%
Programmatic Risks (External Risk Items are those that are generated, caused, or controlled exclusively outside the PDT's sphere of influence.)														
PR-2	PR-2 Adequacy of Project Funding	Update assume overall delay of up to 1 year since updated total duration is about half previous plan	Likely	Significant	HIGH	Uniform		0.0 Months	0.0 Months	12.0 Months	*0-Jan-00*	0.00%	0.00%	12.25%
PR-3	PR-3 Introduction of New Constraints/Requirements	No change in Hi/low assume this would occur in beginning so same	Likely	Significant	HIGH	Triangular		0.0 Months	0.0 Months	6.0 Months	*0-Jan-00*	0.00%	0.00%	6.12%
PR-4	PR-4 Local Communities Pose Objections	Ditto	Likely	Significant	HIGH	Uniform		0.0 Months	0.0 Months	3.0 Months	*0-Jan-00*	0.00%	0.00%	3.06%
									98.0 Months **0.0 Months**		*Not Part of Study - Placeholder for Project Summation Purposes*			

PROJECT CONTINGENCY - OVERALL SCHEDULE (BASELINE)	Percentile	Baseline Schedule Duration	Contingency	Baseline w/ Contingency	Contingency %
	0%	98.0 Months	**-4.9 Months**	**93.1 Months**	**-4.99%**
	5%	98.0 Months	**14.3 Months**	**112.3 Months**	**14.59%**
	10%	98.0 Months	**18.0 Months**	**116.0 Months**	**18.40%**
	15%	98.0 Months	**20.4 Months**	**118.4 Months**	**20.85%**
	20%	98.0 Months	**22.4 Months**	**120.4 Months**	**22.89%**
	25%	98.0 Months	**24.1 Months**	**122.1 Months**	**24.64%**
	30%	98.0 Months	**25.7 Months**	**123.7 Months**	**26.25%**
	35%	98.0 Months	**27.1 Months**	**125.1 Months**	**27.68%**
	40%	98.0 Months	**28.6 Months**	**126.6 Months**	**29.22%**
	45%	98.0 Months	**29.9 Months**	**127.9 Months**	**30.53%**
	50%	98.0 Months	**31.2 Months**	**129.2 Months**	**31.82%**
	55%	98.0 Months	**32.5 Months**	**130.5 Months**	**33.14%**
	60%	98.0 Months	**33.9 Months**	**131.9 Months**	**34.61%**
	65%	98.0 Months	**35.3 Months**	**133.3 Months**	**35.99%**
	70%	98.0 Months	**36.7 Months**	**134.7 Months**	**37.43%**
	75%	98.0 Months	**38.2 Months**	**136.2 Months**	**39.00%**
	80%	98.0 Months	**40.0 Months**	**138.0 Months**	**40.82%**
	85%	98.0 Months	**42.1 Months**	**140.1 Months**	**42.93%**
	90%	98.0 Months	**44.8 Months**	**142.8 Months**	**45.72%**
	95%	98.0 Months	**48.6 Months**	**146.6 Months**	**49.60%**
	100%	98.0 Months	**66.0 Months**	**164.0 Months**	**67.31%**

NWP - MCR Jetties Rehabilitation Feasibility Report - Schedule Risk Analysis

10,000 Trials

Contribution to Variance View



MCR Jetties Rehabilitation Feasibility Report OVERALL Schedule Risk Analysis Model

Enter Estimated Total Project Cost (Price Level)	**$152,519,000**	
Average Anticipated Annual Amount	**$18,687,543**	
Enter Current OMB Escalation Rate	**1.60%**	
Enter Current Project Location Escalation Rate	**1.71%**	1.71%
Enter Assumed Monthly Recurring Costs Rate	**5.70%**	

	Date	Escalation Delta Amount	Monthly Recurring Costs Amount	Total Schedule Contingency
Enter Current Project Start	3-Sep-12			
Enter Baseline Project Completion	1-Nov-20	$0.00		$0.00
Project Completion at 0% Confidence	5-Jun-20	-$68,398.95	($433,972.80)	-$502,371.76
Project Completion at 5% Confidence	10-Jan-22	$199,960.59	$1,268,695.70	$1,468,656.29
Project Completion at 10% Confidence	3-May-22	$252,062.31	$1,599,266.96	$1,851,329.26
Project Completion at 15% Confidence	15-Jul-22	$285,661.22	$1,812,442.95	$2,098,104.17
Project Completion at 20% Confidence	14-Sep-22	$313,622.07	$1,989,846.98	$2,303,469.05
Project Completion at 25% Confidence	5-Nov-22	$337,593.29	$2,141,937.83	$2,479,531.12
Project Completion at 30% Confidence	23-Dec-22	$359,634.96	$2,281,786.27	$2,641,421.24
Project Completion at 35% Confidence	4-Feb-23	$379,299.49	$2,406,552.35	$2,785,851.84
Project Completion at 40% Confidence	22-Mar-23	$400,390.97	$2,540,372.10	$2,940,763.08
Project Completion at 45% Confidence	30-Apr-23	$418,357.27	$2,654,363.42	$3,072,720.69
Project Completion at 50% Confidence	7-Jun-23	$436,035.73	$2,766,528.45	$3,202,564.19
Project Completion at 55% Confidence	17-Jul-23	$454,146.50	$2,881,436.38	$3,335,582.88
Project Completion at 60% Confidence	29-Aug-23	$474,168.78	$3,008,472.30	$3,482,641.09
Project Completion at 65% Confidence	9-Oct-23	$493,094.79	$3,128,552.67	$3,621,647.46
Project Completion at 70% Confidence	21-Nov-23	$512,895.00	$3,254,179.65	$3,767,074.66
Project Completion at 75% Confidence	7-Jan-24	$534,326.71	$3,390,158.03	$3,924,484.74
Project Completion at 80% Confidence	1-Mar-24	$559,265.75	$3,548,389.45	$4,107,655.20
Project Completion at 85% Confidence	3-May-24	$588,222.68	$3,732,113.36	$4,320,336.04
Project Completion at 90% Confidence	25-Jul-24	$626,464.11	$3,974,744.86	$4,601,208.97
Project Completion at 95% Confidence	18-Nov-24	$679,680.70	$4,312,389.69	$4,992,070.39
Project Completion at 100% Confidence	30-Apr-26	$922,286.49	$5,851,657.63	$6,773,944.12

Entry Required

Do Not Overwrite

Summary Data -- Do Not Overwrite

MCR Jetties Rehabilitation Feasibility Report OVERALL Schedule Risk Analysis Model

Risk Refer No.	Risk Event	Low	Most Likely	High
PPM-1	Mitigation Features Have not Been Fully Defined	-2.0 Months	0.0 Months	4.0 Months

Notes: This item captures the risk that the ultimate configuration of the mitigation features will cause a variance from the current baseline schedule.

Likely Likely assumes no change from the baseline schedule.

Low

Low assumes that the ultimate configuration of the mitigation features will be less robust that currently contemplated, improving the schedule by up to 2 months.

High

High assumes that the ultimate configuration of the mitigation features will be more robust that currently contemplated, delaying the schedule by up to 4 months.

MCR Jetties Rehabilitation Feasibility Report OVERALL Schedule Risk Analysis Model

Risk Refer No.	Risk Event	Low	Most Likely	High
PPM-3	Project Schedule in Question	-3.0 Months	0.0 Months	6.0 Months

Notes: This item captures the risk that eventual project schedule will cause a variance from the current baseline schedule.

Likely Likely assumes no change from the baseline schedule.

Low

Low assumes that the ultimate execution of the schedule is more effective than currently contemplated, improving the schedule by up to 3 months.

High

High assumes that the ultimate execution of the schedule is less effective than currently contemplated, delaying the schedule by up to 6 months.

MCR Jetties Rehabilitation Feasibility Report OVERALL Schedule Risk Analysis Model

Risk Refer No.	Risk Event	Low	Most Likely	High
PPM-4	Issues with Multiple Local Agencies	0.0 Months	0.0 Months	6.0 Months

Notes: This item captures the risk that issues with local agencies will cause a variance from the current baseline schedule.

Likely Likely assumes no change from the baseline schedule.

Low Low assumes no change from the baseline schedule.

High High assumes that issues with local agencies delay the project by up to 6 months.

MCR Jetties Rehabilitation Feasibility Report OVERALL Schedule Risk Analysis Model

Risk Refer No.	Risk Event	Low	Most Likely	High
PPM-5	Coordination/Communication Difficulties	-2.0 Months	0.0 Months	4.0 Months

Notes: This item captures the risk that coordination and communication difficulties will cause a variance from the current baseline schedule.

Likely Likely assumes no change from the baseline schedule.

Low

Low assumes that coordination and communication are more effective than currently contemplated, improving the overall schedule by up to 2 months.

High

High assumes that coordination and communication are less effective than currently contemplated, delaying the overall schedule by up to 4 months.

MCR Jetties Rehabilitation Feasibility Report OVERALL Schedule Risk Analysis Model

Risk Refer No.	Risk Event	Low	Most Likely	High
PPM-6	Internal Red Tape Causing Delays in Obtaining Approvals and Decisions	0.0 Months	0.0 Months	6.0 Months

Notes: This item captures the risk that internal red tape in obtaining approvals and decisions will cause a variance from the current baseline schedule.

Likely Likely assumes no change from the baseline schedule.

Low Low assumes no change from the baseline schedule.

High High assumes internal red tape in obtaining approvals and decisions delay the project by up to 6 months.

MCR Jetties Rehabilitation Feasibility Report OVERALL Schedule Risk Analysis Model

Risk Refer No.	Risk Event	Low	Most Likely	High
PPM-8	Unplanned Work that Must Be Accommodated	-3.0 Months	0.0 Months	6.0 Months

Notes: This item captures the risk that unplanned work will cause a variance from the current baseline schedule.

Likely Likely assumes no change from the baseline schedule.

Low

Low assumes that changes to the overall work scope due to unplanned work may actually reduce scope, eliminating up to 3 months from the overall schedule.

High

High assumes that changes to the overall work scope due to unplanned work may increase scope, adding up to 6 months from the overall schedule.

MCR Jetties Rehabilitation Feasibility Report OVERALL Schedule Risk Analysis Model

Risk Refer No.	Risk Event	Low	Most Likely	High
CA-1	Incomplete Acquisition Strategy	-3.0 Months	0.0 Months	6.0 Months

Notes: This item captures the risk that lack of acquisition strategy planning will cause a variance from the current baseline schedule.

Likely Likely assumes no change from the baseline schedule.

Low Low assumes that the lack of acquisition strategy planning may actually produce more favorable contracting and sequencing that currently contemplated, improving the schedule by up to 3 months.

High High assumes that the lack of acquisition strategy planning may produce less favorable contracting and sequencing that currently contemplated, delaying the schedule by up to 6 months.

MCR Jetties Rehabilitation Feasibility Report OVERALL Schedule Risk Analysis Model

Risk Refer No.	Risk Event	Low	Most Likely	High
CA-2	Numerous Separate Contracts	0.0 Months	0.0 Months	4.0 Months

Notes: This item captures the risk that having numerous separate contracts will cause a variance from the current baseline schedule.

Likely Likely assumes no change from the baseline schedule.

Low

Low assumes no change from the baseline schedule.

High

High assumes that more there will be at least 20-25 separate contract, adding up to one year of cumulative delay due to contract actions and sequencing issues.

Update 120424 Plan time frame reduced to 6 years with only 4 contracts
Cumulative delay assumed to be 1 months each contract for 4 mo

MCR Jetties Rehabilitation Feasibility Report OVERALL Schedule Risk Analysis Model

Risk Refer No.	Risk Event	Low	Most Likely	High
TL-1	Variation in Estimated Quantities	-14.9 Months	0.0 Months	19.8 Months
		84.2	99.0	118.8

Notes: This item captures the risk that variation in estimated quantities will cause a variance from the current baseline schedule.

Likely Likely assumes no change from the baseline schedule.

Low Low assumes the ultimate quantities could be significantly less than contemplated, leading to a quantity reduction of up to 15% (per FAR clause 52.211-18 IAW Section 11.703c), decreasing the overall project time by up to 15%.

High

High assumes that the worst case is up to 20% additional quantity, increasing the overall project time up to 20%.

UPDATE 120424 Update total schedule length to 99 months (Start 9/3/12 to end of 5/2/20 plus 182 days of work that year)

MCR Jetties Rehabilitation Feasibility Report OVERALL Schedule Risk Analysis Model

Risk Refer No.	Risk Event	Low	Most Likely	High
RE-5	Agency Actions Take Longer than Expected	0.0 Months	0.0 Months	12.0 Months

Notes: This item captures the risk that agency actions taking longer than expected will cause a variance from the current baseline schedule.

Likely Likely assumes no change from the baseline schedule.

Low Low assumes no change from the baseline schedule.

High High assumes that issues with approval of the BIOP could delay the project by up one year.

MCR Jetties Rehabilitation Feasibility Report OVERALL Schedule Risk Analysis Model

Risk Refer No.	Risk Event	Low	Most Likely	High
RE-7	Recurring Permits Required	0.0 Months	0.0 Months	6.0 Months

Notes: This item captures the risk that requirements to obtain permits repeatedly throughout the project will cause a variance from the current baseline schedule.

Likely Likely assumes no change from the baseline schedule.

Low Low assumes no change from the baseline schedule.

High High assumes that issues with obtaining recurring permits could delay the overall project by up to 6 months.

MCR Jetties Rehabilitation Feasibility Report OVERALL Schedule Risk Analysis Model

Risk Refer No.	Risk Event	Low	Most Likely	High
CON-1	Material Availability and Delivery	-2.0 Months	0.0 Months	4.0 Months

Notes: This item captures the risk that material availability and delivery will cause a variance from the current baseline schedule.

Likely Likely assumes no change from the baseline schedule.

Low

Low assumes that material is readily available for timely delivery, improving the overall schedule by up to 2 months.

High

High assumes that there are challenges with the availability and delivery of material, delaying the overall project by up to 4 months.

MCR Jetties Rehabilitation Feasibility Report OVERALL Schedule Risk Analysis Model

Risk Refer No.	Risk Event	Low	Most Likely	High
CON-4	Adequacy of Construction Schedule	-1.5 Months	0.0 Months	3.0 Months

Notes: This item captures the risk that uncertainty regarding the accuracy of the construction schedule will cause a variance from the current baseline schedule.

Likely Likely assumes no change from the baseline schedule.

Low Low assumes that the ultimate contractors will perform more efficiently than anticipated on the current construction schedule, improving the overall project schedule by up to 3 months.

High High assumes that the current construction schedule does not adequately capture how ultimate contractors will perform, resulting in delay in the overall project schedule by up to 6 months.

Update 120424. Total plan is about half duration of previous. Reduce Hi/lows from -3 to +6 mo to -1.5 to +3 mo

MCR Jetties Rehabilitation Feasibility Report - Cost and Schedule Risk Analysis Revised 06/08/12

Risk Refer No.	Risk Event	Low	Most Likely	High
EST-5	Productivity of Contractor Labor and Equipment	-2.0 Months	0.0 Months	4.0 Months
		38.3	40.3	44.3

Notes: This item captures the risk that inaccurate assumptions regarding special equipment will cause a variance from the current baseline estimate.

Likely Likely assumes no change from the baseline estimate.

Low

Low assumes that productivity is up to 5% better than estimated, saving up to 2 months (calculated as duration deltas).

High

High assumes that productivity is up to 10% decreased than currently estimated, adding up to 4 months (calculated as duration deltas).

Update 120424 used different work task with more detailed equipment so total equipment hour not easily tell project duration. Base on new schedule for duration of Contruction activities

	Days Construct Activities
2014 N Jetty	95
2015 Jetty A	181
2015 N Jetty	128
2016 N Jetty	123
2017 N Jetty	146
2017 S Jetty	129
2018 S Jetty	127
2019 S Jetty	115
2020 S Jetty	182
total work days	1,226
Total work Months	40.31

MCR Jetties Rehabilitation Feasibility Report OVERALL Schedule Risk Analysis Model

Risk Refer No.	Risk Event	Low	Most Likely	High
PR-2	Adequacy of Project Funding	0.0 Months	0.0 Months	12.0 Months

Notes: This item captures the risk that the adequacy of project funding will cause a variance from the current baseline schedule.

Likely Likely assumes no change from the baseline schedule.

Low

Low assumes no change from the baseline schedule.

High High assumes that challenges in receiving adequate funding in the increments anticipated could lead to an overall project delay of up to 2 years (due to the narrow construction windows each season).

Update assume overall delay of up to 1 year since updated total duration is about half previous plan

MCR Jetties Rehabilitation Feasibility Report OVERALL Schedule Risk Analysis Model

Risk Refer No.	Risk Event	Low	Most Likely	High
PR-3	Introduction of New Constraints/Requirements	0.0 Months	0.0 Months	6.0 Months

Notes: This item captures the risk that the introduction of new constraints or requirements will cause a variance from the current baseline schedule.

Likely Likely assumes no change from the baseline schedule.

Low Low assumes no change from the baseline schedule.

High High assumes the introduction of new constraints or requirements could dleay the overall project schedule by up to 6 months.

MCR Jetties Rehabilitation Feasibility Report OVERALL Schedule Risk Analysis Model

Risk Refer No.	Risk Event	Low	Most Likely	High
PR-4	Local Communities Pose Objections	0.0 Months	0.0 Months	3.0 Months

Notes: This item captures the risk that local communities posing objections will cause a variance from the current baseline schedule.

Likely Likely assumes no change from the baseline schedule.

Low Low assumes no change from the baseline schedule.

High High assumes that local communities posing objections could delay the overall project by up to 3 months.

MCR Jetties Rehabilitation Feasibility Report - SCHEDULE Risk Analysis Model UPDATE 120608
Schedule Roll-up
6/8/2012
Taken from file: "MCR Construction Schedule 120418.pdf"

Task Name	Duration (Days)	Start date		
MCR Long Term Planning Rpt	586	5/24/2010		
2014 Construction Contract 1	535	9/3/2012	99.3	total months to
DDR	210	9/3/2012		
P&S	167	6/24/2013		
Base Condition Contract 1	61	1/10/2014		
NTP		3/24/2014		
North Jetty	95	5/12/2014		
Contract 1 done		9/19/2014		
2015 Jetty A	656	7/1/2013		
DDR	196	7/1/2013		
P&S	157	4/1/2014		
Construct	181	4/27/2015		
done		12/22/2015		
FY15 North Jetty	128	5/11/2015		
2016 North Jetty	123	5/2/2016		
2017 North Jetty	146	5/1/2017		
2017 South Jetty	129	5/1/2017		
2018 South Jetty	127	5/2/2018		
2019 South Jetty	115	5/2/2019		
2020 South Jetty	182	5/2/2020	31-Oct-20	
Contingency	1216.8		29-Feb-24	

Documents

ESTIMATE PRODUCTS **Review for decision document estimates, Feasibility estimates thru IGE**

Project Title & Location:					MCR Major Rehab	**REVIEW COMMENTS**
Project Review Phase:					Feasibility Report	
Product Date:					24-Apr-12	
Reviewer Name & Phone:					Rick Russell, (503)808-4791	
Review Date:					RUSSELL.RICKY.L.1231401349 E-Signed by RUSSELL.RICKY.L.1231401349 VERIFY authenticity with ApproveIt	
					KEY DOCUMENTS SUPPORTING ATR AND COMMENTS	
					ER 1105-2-100, Planning Guidance Notebook.	
					ER 1110-2-1150, Engineering and Design for Civil Works Projects.	
					ER 1110-1-1300, Cost Engineering Policy and General Requirements.	
					ER 1110-2-1302, Civil Works Cost Engineering.	
					EM 1110-2-1304, Civil Works Construction Cost Index System (CWCCIS).	
					ETL 1110-2-573, Construction Cost Estimating Guide for Civil Works.	
					Cost Dx Website: http://www.nww.usace.army.mil/html/OFFICES/Ed/C/default.asp	
Y	**N**	**N/P**	**N/A**		**REVIEW CATEGORIES**	
				DOC	**DOCUMENTS PROVIDED FOR ATR**	
X				**DOC 1**	Report: As a minimum, the Main Report, the Engineering Appendix, Cost Appendix.	
X				**DOC 2**	Scoping documents such as drawings, presentations, photos.	
X				**DOC 3**	Supporting Detailed Estimates in MCACES MII and CEDEP dredge estimates in electronic format.	Dredge unit cost based on historical unit cost and previously ATR certified.
X				**DOC 4**	Construction Schedule.	
X				**DOC 5**	Total Project Schedule, all Features (PED, Acquisiton, and Construction).	
X				**DOC 6**	Cost and Schedule Risk Analysis (>$40M) or basis for contingency when <$40M.	
X				**DOC 7**	CSRA Report documenting the process.	
X				**DOC 8**	Total Project Cost Summary (TPCS).	
X				**DOC 9**	Record of DQC - District Quality Control.	
X				**DOC 10**	Quantity Take-offs (details and summary).	
				SC	**SCOPING DOCUMENTS**	
X				**SC 1**	Scoping documents are adequately developed to the design phase in accordance with ER 1110-2-1150, presenting the Main Report, plan formulation and recommended plan, related scope and cost appendixes, risk analyses, etc.	
X				**SC 2**	Adequate scoping documents have been provided to convey a thorugh and confident understanding of the project scope.	
X				**SC 2**	The scoping documents are accurately portrayed within the estimates.	

X				**SC 3**	Reviewer is confident of scope captured within the estimate, schedule and risk review.	

Estimate

Project Title & Location:					MCR Major Rehab	**REVIEW COMMENTS**
Project Review Phase:					Feasibility Report	
Product Date:					24-Apr-12	
Reviewer Name & Phone:					Rick Russell, (503)808-4791	
Review Date:					RUSSELL.RICKY.L.1231401349 E-Signed by RUSSELL.RICKY.L.1231401349 VERIFY authenticity with ApproveIt	
Y	**N**	**N/P**	**N/A**			
					PROJECT NOTES - (General Construction Details and Narrative)	
				NOTE	**Basis of Cost Estimate Notes**	**REVIEW COMMENTS**
X				**NOTE 1**	Project and Top Folder notes notes present a clear understanding and scope definition.	
X				**NOTE 2**	Scope presented in the project notes is consistent with the scope of the documents for the corresponding plan.	
X				**NOTE 3**	Major project construction features clearly identified in the estimate subfolders.	
X				**NOTE 4**	Top Folder notes clarify major assumptions such as acquisition strategy, expected bid competition, prime and subcontractor assignments, major cost quotes, major construction processes, construction phasing and/or sequencing.	
X				**NOTE 5**	Top Folder notes address significant or high-risk cost items in the project scope.	
X				**NOTE 6**	Notes are adequate to convey project scope and estimate assumptions.	
					Construction Estimate Notes on Critical Costs	**REVIEW COMMENTS**
X				**NOTE 8**	General assumptions noted in the project notes and whether they seem reasonable.	
X				**NOTE 9**	Folder notes provide basis of estimate related to assumptions, quotes, and historical data?	
X				**NOTE 10**	Site and project access considered and presented in the notes.	
X				**NOTE 11**	Critical material sources identified and supported by research.	
X				**NOTE 12**	Unusual construction conditions considered and documented (e.g., studies, geotechnical data, borrow sources, water and water diversion, and weather).	
X				**NOTE 13**	Unique construction techniques considered, documented and reasonable.	
X				**NOTE 14**	Environmental concerns addressed impacting construction activities.	
X				**NOTE 15**	Acquisition Plan identified and matches the estimate structure.	
X				**NOTE 16**	Subcontracting plan and subcontract crafts identified.	Limited subcontractors due to rock delivery cost included in material price of rock.
X				**NOTE 17**	Effective dates for pricing labor, equipment, and material are current.	
				EST	**GENERAL ESTIMATE LAYOUT - Title Structure (Work Breakdown Structure)**	
X				**EST 1**	Estimate developed in proper Work Breakdown Structure (WBS) format in accordance with all guidelines (ETL 1110-2-573).	
X				**EST 2**	Folder title structure and the descriptions adequate to determine what is being estimated.	
X				**EST 3**	WBS adequately reflects all project scope	
X				**EST 4**	Prime and subcontractor assignments appear reasonable.	

X				EST 5	Major Folder quantity units and unit proces appear reasonable.	
X				EST 6	Major folders developed to support a coherent construction schedule development.	
X				EST 7	Major construction features supported by quantity take-offs and appear reasonable.	
					CONSTRUCTION ESTIMATE DETAILS	
				MISC	**Miscellaneous Estimate Details**	**REVIEW COMMENTS**
X				MISC 1	Estimate covers the many minor cost items, that together, can add significantly to the project.	
			X	MISC 2	Costs include any potential Hazardous, Toxic, and Radioactive Waste (HTRW) concerns.	
X				MISC 3	Limited use of generic Cost Book unit prices for critical cost items that could undermine the total cost accuracy.	
X				MISC 4	Limted use of Lump Sum, Each or Allowance items that do not accurately convey scope or pricing.	
X				MISC 5	Limited use of over-ridden unit or detailed costs that results in lost confidence and greater risks.	
				LAB	**Labor**	**REVIEW COMMENTS**
X				LAB 1	Current labor rates used that match the estimate date and location where the work is occurring.	
X				LAB 2	Actual labor rates determined to be reasonable, considering the type of work and other site factors.	
X				LAB 3	Overtime application appears justified, reasonable and logical for major work items.	
X				LAB 4	If overtime is used, the direct cost markup factors correctly entered and applied.	
X				LAB 5	Application of Payroll Tax and Insurance (PT&I) for the selected Contractors: State Unemployment Insurance (SUI) based on the state in which the work is occurring vs. using the AVG default.	
X				LAB 6	Under PT&I for Workmen's Compensation Insurance (WCI), was the selected Contractor Class based on the actual work to be performed vs. using the default for Concrete Work?	
X				LAB 7	Labor rates take into consideration potential labor shortages and includes any necessary subsistence or per diem for critical labor elements.	
X				LAB 8	Labor consideration made in mobilization and demobilization efforts.	
X				LAB 9	Correct labor rates used for Building, Heavy, Highway, Residential.	
			X	LAB 10	Marine Work – Work performed on or over navigable waterways addresses Longshoreman and Harbor Workers Act insurance, if required by the state.	No additional LS&H factor added. Estimate assumes large landbased rock/earth contractor.
			X	LAB 11	Dredging – Labor rate database updated to reflect the latest wage rates available for dredging work at the location.	Historical unit cost for dredging utilized in estimate.
			X	LAB 12	Dredging – Labor rates appear reasonable, based on the location and type of plant performing the work.	Historical unit cost for dredging utilized in estimate.

Estimate

				EQ	Equipment	REVIEW COMMENTS
X				EQ 1	Correct regional equipment rates used for the location where the work is occurring.	
X				EQ 2	Database updated to reflect the latest fuel prices for the work site.	
X				EQ 3	Critical equipment choices, size and rates appear reasonable, considering work type and site conditions.	
X				EQ 4	Rates for Average, Difficult, Severe or Standby are correctly applied and justified within the notes.	
X				EQ 5	Standby rates used, in order to ensure that Ownership Costs for equipment were covered for the normal 40 hour work week.	
X				EQ 6	Standby rates included for equipment mobilization and demobilization.	
X				EQ 7	Rental rates used for equipment not normally owned by the selected contractor. Were operating costs for rented equipment included?	
X				EQ 8	If warranted, were other factors (such as the Cost of Money) updated to reflect current conditions?	
			X	EQ 9	Dredging – Based on the actual site conditions, quantities, disposal areas, and schedule: was the selected dredge plant determined to be appropriate for the contract at hand?	
			X	EQ 10	Dredging - Appropriate dredge, dredge size and number of dredges reasonable for the work.	
			X	EQ 11	Dredging – Dredge plant costs based on the current CEDEP database.	
			X	EQ 12	Dredging - Was the dredge plant database, contained in CEDEP, reviewed and were plant costs determined to be reasonable based on the proposed work?	
			X	EQ 13	Dredging – Include costs for dredge plant during periods of standby or non-working hours and weather impacts.	
				CP	**Crews & Productivity**	**REVIEW COMMENTS**
X				CP 1	Critical crew composition and productivity appear reasonable for the major work items.	
X				CP 2	Productivity efficiencies or inefficiencies considered and explained.	
X				CP 3	Critical project productivity rates appear reasonable. Notes describe logic.	
X				CP 4	Heavy equipment crews include the supporting labor and equipment necessary to perform the task at the selected productivity.	
X				CP 5	For large earthwork projects, crew assemblies and productivities for excavation, load, haul, placement, compaction and disposal correlate.	
			X	CP 6	Dredging – crew productivity and any applied efficiency factors adequately justified in the estimate.	
				MAT	**Materials**	**REVIEW COMMENTS**
X				MAT 1	Major quantities supported by a quantity take-off document.	Rock quantities provided by EC-HY
X				MAT 2	Major, critical or volatile materials and quantities identified at the detail level.	
X				MAT 3	Estimate correctly includes State Sales Tax or Gross Receipts Tax to materials and supplies purchased for the contract.	

X				**MAT 4**	Estimate notes identify the source of major material quotes, with source, name and date of quote (escalation concern).	
X				**MAT 5**	Estimate makes adjustments for loss due to handling, placement, cutting, transportation, contamination, etc. Notes document adjustments.	10% Added to rock quantities.
X				**MAT 6**	Earthwork quantities indentified based on BCY for excavated material, LCY for hauled material, ECY for placed material.	
X				**MAT 7**	Earthwork quantities make reasonable adjustments between BCY, LCY and ECY.	
X				**MAT 8**	Line item note description for material purchase indicates if shipping is included for major items.	
				MOB	**Mobilization - Preparatory Work, Demobilization – Cleanup**	**REVIEW COMMENTS**
X				**MOB 1**	Mobilization and demobilization costs are detailed or appropriate.	
X				**MOB 2**	Total mobilization and demobilization cost appear reasonable.	
X				**MOB 3**	Multiple mobilizations considered for longer projects impacted by weather or environmental restrictions.	
			X	**MOB 4**	Dredge work: Estimate includes preparation of dredge attendant plant for transfer, the cost to move all plant and equipment return of tug or towing vessel, and preparation of the plant to start work.	
			X	**MOB 5**	Dredge Work: Project and estimate clearly include a construction support site.	
			X	**MOB 6**	Dredge Work: Estimate includes all costs to secure machinery and equipment for storage.	
			X	**MOB 7**	Dredging - Pipeline mobilization, assembly and relocation for surface and underwater appropriately considered.	
				SUB	**Subcontracting**	**REVIEW COMMENTS**
			X	**SUB 1**	Subcontractor assignments and markups reasonable for the tasks assigned.	Estimate assumes single prime contractor with no subs. Rock delivery sub included with material purchase price of rock.
			X	**SUB 2**	Estimate identifies subcontract quotes and addresses markup applications with the quotes.	
			X	**SUB 3**	Appropriate consideration has been made in addressing multi-tier subcontracting for specialty items.	
				PR	**Prime Contractor**	**REVIEW COMMENTS**
x				**PR 1**	Prime contractor(s) has been aptly assigned with reasonable markups.	
X				**PR 2**	Are appropriate taxes included or excluded as may be required?	
X				**PR 3**	Field office overhead reasonable for this project?	
X				**PR 4**	Field Office Overhead includes mobilization if not identified elsewhere.	
X				**PR 5**	Home office overhead appears reasonable for the type of prime contractor specialty.	
X				**PR 6**	Profit appears reasonable and based on the weighted guideline method or justified by other means.	
X				**PR 7**	Bond appears reasonable.	

Schedule

Project Title & Location:					MCR Major Rehab	REVIEW COMMENTS
Project Review Phase:					Feasibility Report	
Product Date:					24-Apr-12	
Reviewer Name & Phone:					Rick Russell, (503)808-4791	
Review Date:					RUSSELL.RICKY.L.1231401349 E-Signed by RUSSELL.RICKY.L.1231401349 VERIFY authenticity with ApproveIt	
Y	**N**	**N/P**	**N/A**			
				SCH	**SCHEDULES**	
				CS	**Construction Schedule**	**REVIEW COMMENTS**
X				**CS 1**	Reflects the estimate and identifies critical aspects of the project scope and construction activities.	
X				**CS 2**	Key milestones are depicted.	
X				**CS 3**	Reflects reasonable logic of activities performed.	
X				**CS 4**	Indicates a likely critical path.	
X				**CS 5**	Reflects the estimate productivities for critical path items.	
X				**CS 6**	Presents sequential and parallel activities where reasonable.	
X				**CS 7**	Makes distinction between single shift, and double shift.	
X				**CS 8**	Takes into consideration overtime where applicable.	
X				**CS 9**	Depicts critical or time-sensitive orders or procurements.	
X				**CS 10**	Considers weather issues, environmental restrictions, winter construction.	
X				**CS 11**	Considers project ramp up, mobilization and demobilization.	
				PS	**Project Schedule**	**REVIEW COMMENTS**
X				**PS 1**	The Project Schedule in the decision document report includes all FEATURE activities; i.e. review and approval, planning, engineering and design, procurement, construction, close-out and turn-over.	
X				**PS 2**	The project schedule clearly presents reasonable dates to determine inflation based on escalation indexes, i.e., the activity beginning date or the activity midpoint?	

CSRA-Contingency

Project Title & Location:					MCR Major Rehab	REVIEW COMMENTS
Project Review Phase:					Feasibility Report	
Product Date:					24-Apr-12	
Reviewer Name & Phone:					Rick Russell, (503)808-4791	
Review Date:					RUSSELL.RICKY.L.1231401349 E-Signed by RUSSELL.RICKY.L.1231401349 VERIFY authenticity with ApproveIt	
Y	**N**	**N/P**	**N/A**			
					RISK-BASED CONTINGENCY	
				CSRA	**Formal Cost and Schedule Risk Analysis (CSRA for >$40M)**	**REVIEW COMMENTS**
X				**CSRA 1**	CSRA structure and process follows the Cost Dx guidance.	
X				**CSRA 2**	CSRA model provided in electronic format using Excel and Crystal Ball softwares.	
X				**CSRA 3**	CSRA Report follows Cost Dx template.	
X				**CSRA 4**	CSRA considers total cost and total schedule, all features.	
X				**CSRA 5**	Risk Register developed by major PDT members for all project Features.	
X				**CSRA 6**	Organizational and PM risks considered.	
X				**CSRA 7**	Contract Acquisition risks considered.	
X				**CSRA 8**	Technical risks considered.	
X				**CSRA 9**	Scope quality and detail addressed.	CSRA Update to 4/24/2012 data
X				**CSRA 10**	Lands and Damages and Relocations considered.	
X				**CSRA 11**	Regualtory and Environmental risks considered.	
X				**CSRA 12**	Construction risks considered.	
X				**CSRA 13**	Estimate and schedule accuracy risks considered.	
X				**CSRA 14**	Volatile pricing and extreme escalation considered.	
X				**CSRA 15**	Material availability and transport considered.	
X				**CSRA 16**	External risks: funding, stakeholders, labor, weather, opposition, bidding competition considered.	
X				**CSRA 17**	Does the CSRA consider opportunities such as VE and alternatives?	
X				**CSRA 18**	Risk register tracks logically from Concerns, PDT Discussions, Likelihood and Impacts to a reflective Risk Level.	

X				**CSRA 19**	Risk model considers any risk duplications and correlations between cost and schedule risk events?	
X				**CSRA 20**	Risk event correlations have been minimized.	
X				**CSRA 21**	CSRA model includes the moderate and high risks.	
X				**CSRA 22**	CSRA considers both internal and external risks.	
X				**CSRA 23**	CSRA supported by market research and documented assumptions.	
X				**CSRA 24**	CSRA results traceable back to the PDT Risk Events.	
X				**CSRA 25**	CSRA model variance distributions appear reasonable w/ backup assumptions.	
X				**CSRA 26**	Contingency value based upon an 80% confidence level.	
X				**CSRA 27**	Contingencies appear reasonable based on project complexity and ATR findings.	
				CV	**Contingency Value**	**REVIEW COMMENTS**
X				**CV 1**	Rates appear reasonable for each major Feature item?	
X				**CV 2**	Overall rate appears reasonable based on reviewers knowledge of project scope and estimates.	

TPCS

Project Title & Location:					MCR Major Rehab	REVIEW COMMENTS
Project Review Phase:					Feasibility Report	
Product Date:					24-Apr-12	
Reviewer Name & Phone:					Rick Russell, (503)808-4791	
Review Date:					RUSSELL.RICKY.L.1231401349	
Y	**N**	**N/P**	**N/A**			
				TPCS	**TOTAL PROJECT COST SUMMARY in Current Dollars (first**	
X				**TPCS 1**	Proper TPCS format (ETL 1110-2-573).	
X				**TPCS 2**	Price level date shown is consistent with the estimate preparation date.	
X				**TPCS 3**	All project-related Civil Works WBS Features depicted.	
X				**TPCS 4**	Base costs reflects the esitmate development in current dollars.	
X				**TPCS 5**	Summary page roll up supported by sub-project calculations.	
X				**TPCS 6**	Costs reasonable for PED (30 Feature). Note: percentages are sometimes used to develop these costs.	
X				**TPCS 7**	30 Feature clearly includes costs for PM, P&E, E&D, Reviews & VE, Contracting, reprographics, EDC, Planning during construction.	
X				**TPCS 8**	Costs reasonable for Construction Management (31 Feature Code). Note: percentages are sometimes used to develop these costs.	
X				**TPCS 9**	Contingencies shown separately for each Feature.	
X				**TPCS 10**	Contingency rates match the risk based contingency results (commonly the 80 percent confidence level).	
					TOTAL PROJECT COST SUMMARY in Current Dollars (second column set)	
X				**TPCS 11**	Depicts budget year for decision document funding request.	
X				**TPCS 12**	Includes escalation from estimate date to budget year: EM 1110-2-1304, Civil Works Construction Cost Index System (CWCCIS).	
X				**TPCS 13**	Captures total project cost for all Featrures to budget year.	
					TOTAL PROJECT COST Inflated to Fully Funded Estimate (third column set)	
X				**TPCS 14**	Escalation dates and rates shown for each inflated Feature.	
X				**TPCS 15**	Escalation dates consistent with the project schedule.	
X				**TPCS 16**	Escalation based on price indexes from the current CWCCIS, EM 1110-2-1304 and correctly applied.	

			X	**TPCS 17**	Section 902 Limit ONLY; If lands and damages are inflated, is the escalation for inflation based on the Consumer Price Index? (ref. ER 1105-2-100, Determining Section 902 Limit)	
					TOTAL PROJECT COST SUMMARY - Federal and Non-Federal Costs	
X				**TPCS 18**	Federal and non-Federal cost share percentages shown.	
			X	**TPCS 19**	Project cost share percent consistent with the Cost Sharing Agreement?	
			X	**TPCS 20**	If applicable, is the cost/value of non-Federal in-kind services shown?	
			X	**TPCS 21**	Cost shares calculated correctly.	
X				**TPCS 22**	Signature blocks for PM, Cost Chief, Real Estate Chief (ER 1110-2-1302)	

Reports

Y	N	N/P	N/A			REVIEW COMMENTS
Project Title & Location:					MCR Major Rehab	
Project Review Phase:					Feasibility Report	
Product Date:					24-Apr-12	
Reviewer Name & Phone:					Rick Russell, (503)808-4791	
Review Date:					RUSSELL.RICKY.L.1231401349 E-Signed by RUSSELL.RICKY.L.1231401349 VERIFY authenticity with ApproveIt	
Y	**N**	**N/P**	**N/A**			
					REPORTS - Basic Information for Reviewer – Scope and Form	
				MR	**Draft Main Report, General**	**REVIEW COMMENTS**
X				**MR 1**	Complete report document provided. As a minimum: Main Report, Engineering Appendix, Cost Appendix, cost tables and project schedule.	
X				**MR 2**	Package meets the requirements within ER 1105-2-100, Exhibit G of the Planning Guidance Notebook?	
X				**MR 3**	Executive Summary clearly presents the "Total Project Cost" (TPC) inflated through the project schedule. The TPC at the time the project is authorized by Congress becomes the Baseline Cost Estimate (BCE). The BCE is subject to cost limits of Section 902 Water Resources Development Act of	
X				**MR 4**	Reported costs for all project Features included in the TPC and reflect the estimating products.	
X				**MR 5**	Report indicates the Total Project Schedule or duration (ER 1110-2-1150).	
	X			**MR 6**	Both required costs (budget constant dollars and fully funded) presented in the Executive Summary.	
	X			**MR 7**	Report makes distinction between the Federal and Non-Federal dollars.	
					Comparative Construction Cost Estimates	**REVIEW COMMENTS**
X				**MR 8**	Presents the various estimate scopes, technical/design data, method of construction, and assumptions used for developing the comparative estimates included and described (ER 1110-2-1302).	
X				**MR 9**	Comparative cost estimates developed at the same price level.	
X				**MR 10**	TPC of each comparative estimate accurately used in the economic analysis comparisons, such as costs and benefits at the same price level (ER 1105-2-100).	
X				**MR 11**	Contingencies adequate for each alternative in consideration for the alternative risks/complexity.	
					Cost Engineering Appendix	**REVIEW COMMENTS**

Reports

X				**CA 1**	Summarizes the scope of the supporting documents and describes the basis of the estimate, such as method of construction, major assumptions and cost data resources used to cost the major cost elements (ER 1110-2-1302).	
X				**CA 2**	Summarizes the uncertainties associated with major cost items (ER 1105-2-100, appendix E).	
X				**CA 3**	Summarizes the cost risk and resulting contingency development for the recommended plan construction cost estimate. A risk analysis report is required for any project estimated to greater than $40M.	
X				**CA 4**	Describes the development of the Plan construction schedule.	
X				**CA 5**	Summarizes and describes the basis and development of TPC. For example, the source and basis of engineering and design (E&D) (Feature 30), construction management (Feature 31), other pertinent feature costs, the price level of the constant dollar estimates (preparation date and program year date), and basis of cost indexes for inflating the project costs (inflated dollar basis) through the project schedule.	

MCR Jetties Major Rehab Report

Project Management Plan

Prepared by: Project Delivery Team
Portland District
US Army Corps of Engineers
P2 Project Number: 123160
Original Date: May 2006 Revision Number: 02 Revision Date: June 2012

TABLE OF CONTENTS

APPENDICES

1. PURPOSE OF PLAN

The purpose of this Project Management Plan is to establish scope, schedule, budgets, and technical performance requirements for the management and control of the project from planning, engineering, and design through construction. This plan has been developed in accordance with Portland District Project Management Business Process Policy and Procedure Manual and Engineering Regulation 5-1-11.

2. PROJECT AUTHORIZATION

Congress authorized improvement of the Mouth of the Columbia River (MCR) for navigation through the following legislation:

- Senate Executive Document 13, 47th Congress 2nd Session (5 July 1884) authorized the Corps to construct the south jetty (first 4.5 miles) for the purpose of attaining a 30-foot channel across the bar at the MCR.
- House Document 94, 56th Congress 1st Session (3 March 1905) authorized the Corps to extend the south jetty (to 6.62 miles) and construct a north jetty (2.35 miles long) for the purpose of attaining a 40-foot channel (0.5 mile wide) across the bar at the MCR.
- House Document 249, 83rd Congress 2nd Session (3 September 1954) authorized a bar channel of 48 ft depth and a spur jetty ("B") on the north shore of the inlet. Funds for Jetty "B" construction were not appropriated.
- Public Law 98-63 (30 July 1983) authorized the deepening of the northern most 2,000 ft of the MCR channel to a depth of 55 ft below MLLW.

3. PROJECT BACKGROUND AND HISTORY

The South Jetty and North Jetty at the mouth of the Columbia River (MCR) were constructed to secure the Federal navigation channel. The South Jetty is about 6.6 miles long. Its first 4.3 miles were constructed between 1885 and 1895 and was raised and extended to its authorized length in 1913-1914. In addition to the primary South Jetty, four groins perpendicular to the jetty (lengths 500 to 1000 ft.) were also authorized and constructed in order to stabilize the jetty foundation. The length of South Jetty being addressed in this study extends from approximately station 145+00 to station 375+50, a length of approximately 4.4 miles.

The North Jetty is about 2.3 miles long and was constructed between 1915 and 1917. Jetty A was constructed to a length of 1.1 miles and is located upstream of the North Jetty in order to train the navigation channel away from the North Jetty foundation. A second training jetty of a similar length as Jetty A, Jetty B, was also authorized but never constructed. Its location was proposed to be between Jetty A and the North Jetty. These existing project features were authorized by the River and Harbor Acts of 5 July 1884, 3 March 1905, and 3 September 1954.

4. PROJECT PURPOSE

All three primary jetties at the MCR, the North Jetty, South Jetty, and Jetty A are in need of repair including major rehabilitation of seriously deteriorated sections which have been exposed to increased wave heights and deteriorated foundation conditions. The last major repairs on the three structures were, 1965, 1982, and 1962 for the North, South, and Jetty A, respectively. Interim repairs (design based on a 10% annual wave exceedence) were conducted on a portion of the North Jetty during 2005. Interim repairs are scheduled for portions of the South Jetty for 2006 and 2007.

Structural degradation has accelerated in recent years because of increased storm activity and loss of sand shoal material, upon which the jetties were constructed, resulting in increased jetty maintenance costs and emergency repairs. Damages to Jetty A may result in a reduced ability to train the navigation channel flow away from the North Jetty foundation. Breaching of either the North or South Jetties would allow sand to migrate into the Columbia River navigation channel, thereby potentially disrupting deep draft navigation and increasing dredging requirements. Scour of the seabed along the channel-side of the North Jetty has resulted in increased depths of 10 to 40 ft, impacting not only the stability of jetty foundation but also wave impact on the already vulnerable jetty cross section. Increased depths along both the ocean-side and channel-side of the South Jetty have also resulted in increased wave impact. The North, South, and Jetty A heads have been damaged for a length of 2040 ft., 6210 ft., and 890 ft., respectively.

5. PROJECT SCOPE

The Major Rehabilitation Project Evaluation Report (Major Rehab Report) will address all three primary jetties, north, south, and Jetty A. The main purpose of the rehabilitation is to provide a reliable and cost-effective repair for the north and south jetties which control the navigation channel and to Jetty A, which protects the north jetty from foundation scour. Jetty roots and trunks will be the focus of the first part of the Major Rehab Report, scheduled for completion in March 2007. Since foundation stability is essential to obtaining a reliable long-term repair, jetty-perpendicular spur groins will also be evaluated. The first report will evaluate methods to stop further recession of the jetty heads by stabilizing the existing head position. The next part of the Major Rehab Report will address the necessity and extent of repairing the deteriorated heads of the 3 jetties.

The intent of the proposed design concepts will be three-fold: (1) Improve the stability of the foundation (toe) of each jetty as affected by scour; (2) Improve the side slope (above and below water) stability of each jetty as affected by classical static slope stability criteria; and (3) Improve the dynamic stability of each jetty as affected by wave forces impinging on the jetties.

The proposed rehabilitation work would occur along a 23,100 ft reach of the south jetty (stations 145 to 375+50) and a 12,200 ft reach of the north jetty (stations 0 to 122). Jetty A stations addressed would be from station 40 to 97, a length of 5,700 ft. The first phase of the rehabilitation work would require placement of approximately 200,000 to 800,000 tons along the north jetty and 500,000 to 1,200,000 tons along the south jetty. Stone placement along Jetty A would be expected to range from 80,000 to 200,000 tons. The total stone placed on the south and north jetty to date is 8.7 and 3.3 million tons, respectively. Armor stone sizes for the proposed rehabilitation is expected to range from 15 to 50 tons for the north and south jetties and from 10 to 30 tons for the Jetty A.

5.1 General

- The Major Rehab Report will center around the structural integrity of the jetties including the North Jetty, South Jetty and Jetty A

- The Project phases will include: A Major Rehab Report concentrating on the roots, trunks of the North and South Jetties and restoring the jetties in a general sense within the authorized limits. Rehabilitation of Jetty A will also be studied during this phase. After the Major Rehab Report, a Design Documentation Report (DDR) and plans and specifications (P&S) will be prepared, followed by construction for each of the two major rehab reports.
- The objective of the Major Rehab Report is to determine the proper level of Federal investment to extend jetty structure life to secure the Federal navigation channel.
- Identification of and stakeholders to date include: Users of the river system as well as the park system. We will be focusing our public outreach to the Columbia Solutions Group, a group supported and endorsed under a signed MOU by CEQ and both Governors for Oregon and Washington. In addition, the Lower Columbia Ports and the Columbia River Channel Coalition will be actively involved. The study will also involve a public process and at least one set of public meetings.
- Services to be Provided: Engineering , environmental, and economic input and analysis to produce the key products listed below.
- Key Products will consist of the Major Rehab Report, DDR, and P&S.
- Location: The Project is located at the Mouth of the Columbia River, Oregon and Washington.
- This work is intra-related to the O&M of the MCR project, Regional Sediment Management work at the MCR, and the MCR jetty interim repairs to both the North and South Jetties.

5.2 Critical Assumptions and Constraints

This study focuses on the structural stability of the jetty structures and assumes that the ebb tidal shoal will continue to erode at the current rate and trend.

5.3 Product Plans

The Major Rehab Report will consist of the following details:

5.3.1 Environmental Compliance

Development of the Environmental Assessment (EA) shall be consistent with protecting the Nation’s environment, pursuant to national environmental statues, applicable executive orders, and other Federal requirements. The EA shall address all requirements of all applicable environmental statutes for all alternatives considered, including the requirements of the National Environmental Policy Act, Section 404 of the Clean Water Act, Section 103 of the Marine Protection, Research, and Sanctuaries Act, the Coastal Zone Management Act, and the Endangered Species Act.

5.3.1.1 NEPA Compliance

The National Environmental Policy Act (NEPA) of 1969, as amended (NEPA) (42 U.S.C. 4321 et seq.) and the Council on Environmental Quality (CEQ) NEPA regulations (40 CFR Parts 1500-1508) contain provisions that require Federal agencies to consider and evaluate the environmental impacts and prepare Federal rationale that documents proposed Federal actions in accordance with the letter and spirit of the Act. The NEPA process will be used to ensure that all project activities and products are in full compliance with applicable environmental laws and regulations. In addition, the EA and integrated NEPA document will be subjected to public review, and will incorporate comments from State, Federal, and local agencies, Native American Tribes and non-governmental agencies.

Corps guidance for implementing the NEPA process can be found in ER 200-2-2, *Procedures for Implementing NEPA*. The various components of the project will be analyzed for impact on the environment. In addition, NEPA compliance will be fully integrated with the six step planning process.

5.3.1.2 Clean Water Act Compliance

Section 404 of the Clean Water Act of 1977 requires that all projects involving the discharge of dredged or fill material into waters of the United States be evaluated for water quality and other effects prior to making discharge. In-water discharges included in the base plan will be evaluated in accordance with guidelines established by the EPA under the authority of Section 404(b)(1) of the Act. A Section 404(b)(1) evaluation of the impacts on water quality will be included in the application for the 401 certification.

5.3.1.3 Endangered Species Act Compliance

The Endangered Species Act is intended to protect and promote the recovery of animals and plants that are in danger of becoming extinct due to the activities of people. A list of threatened or endangered species likely to occur in the vicinity of the project will be obtained from the U.S. Fish and Wildlife Service and NOAA Fisheries Service. Biological assessments will be prepared that examine the impacts associated with implementing the project. This work will require close coordination and cooperation with various oversight agencies, in particular, the ODEQ, NOAA Fisheries Service, ODFW, and USFWS. The USFWS and NOAA Fisheries Service will review the Biological Assessments and prepare Biological Opinions that assess the project's compliance with the ESA. The Biolgical Opinions may also contain terms and conditions required to implement the project. USACE will prepare an implementation plan to comply with any terms and conditions contained in the Biological Opinions.

An Essential Fish Habitat (EFH) assessment will also be prepared as required under the Magnuson Fishery Conservation and Management Act. The EFH assessment will be prepared concurrently with the Biological Assessments. The U.S. Fish and Wildlife Service and NOAA Fisheries will review the EFH assessment concurrent with the Biological Assessments. A response to the EFH will be prepared and it may contain also terms and conditions required to implement the project. USACE will then prepare an implementation plan to comply with the terms and conditions.

5.3.1.4 Cultural Resources

Cultural resource studies are required by Federal and state law to determine potential impacts on historic and prehistoric archaeological resources as a result of project related activities. All proposed project areas will be examined for cultural resources potential. This will include file searches of existing site information, field surveys as needed, and coordination with the Oregon State Historic Preservation Office, Advisory Council, and Native American Groups. A report of findings and recommendations will be prepared and submitted to the state SHPO.

5.3.2 Plan Formulation/Economics/Main Report

Development of the Major Rehab Report will follow the USACE planning process. The USACE planning process consists of six steps as defined in Section 2-3 of ER 1105-2-100. The six steps consist of 1) identify problems and opportunities, 2) inventory and forecast conditions, 3) formulate alternative plans, 4) evaluate alternative plans, 5) compare alternative plans, and 6) select a plan. This process provides a systematic approach to making determinations at each step so that the interested public and decision-makers are fully aware of the basic assumptions employed, the data and information analyzed, the areas of risk and uncertainty, the reasons and rationales used, and the significant implications of each alternative plan. All steps in the planning process shall be thoroughly documented. The final planning products shall consist of a draft and final Major Rehab Report with NEPA documentation.

5.3.3 Engineering Appendix

The engineering appendix will conform with Major Rehabilitation technical guidance. Reliability indices will be calculated for existing conditions as well as for the full range of alternatives for each structure. Alternatives developed will address potential alterations in jetty cross section as well as different material types and characteristics. The various designs as well as interpretation of potential impacts of design options will be supported by both physical and numerical hydraulic modeling. Physical consequences of alternative paths will be tied to economic consequences through the development of an event tree which utilizes a Monte Carlo simulation of risk throughout the project life.

5.3.4 Design Documentation Report

The purpose of the DDR is to document the final design concept for the construction of the MCR North and South Jetties. The DDR provides the technical basis for the plans and specifications. All technical, construction, environmental, and operating issues regarding the MCR North and South Jetties will be resolved during the DDR phase prior to the beginning of plans and specifications. The DDR will also serve to document basic design criteria, design decisions, design assumptions, methods of analysis, and summarize important calculation results. Each technical specialty will include a chapter in the DDR. Construction cost estimates and schedules for the construction of the MCR North and South Jetties will be developed. The work will be done using in-house technical staff. Purchased professional services will be used as necessary to support the in-house effort.

This project requires extensive modification of an English units based structure. Therefore metric units will not be used on this project.

Major tasks to be accomplished are listed below:

- 3-Dimensional Hydraulic Model
- Quarry Investigations
- VE Study
- Following construction design decisions made during EDC and construction will be documented and included as a final section, ER 110-2-1150.

5.3.5 Plans and Specifications

Contract drawings and specifications will be prepared for the construction of the MCR North and South Jetties. A formal, approved construction cost estimate will be prepared that will serve as the Independent Government Estimate. The PDT will also prepare an Engineering Considerations and Instructions (ECI) report outlining the engineering considerations, design concepts, design assumptions, special instructions, and any unique design details that went into the development of the construction contract. The purpose of this report is to aid field personnel in the supervision and inspection of the construction contract. The work will be done using in-house technical staff. Purchased professional services will be used as necessary to support the in-house effort.

This project requires extensive modification of an English units based structure. Therefore metric units will not be used on this project.

6. PROJECT DELIVERY TEAM

The Project Delivery Team (PDT) includes: the Project Manager, District technical staff, stakeholders, and division staff members necessary to effectively develop and deliver the project. The Project Manager is responsible for overall project execution and is the team leader of the project delivery team. In addition, the Project Manager is the District point of contact and operates as the District Commander's representative for this project. Technical lead is responsible for the day-to-day management of their assigned product; compiling product budgets; development and updating of detailed product schedules; quality control of assigned products, assisting in the preparation of the PMP; and delivery of assigned products on schedule and within budget. There is one TL assigned for the MRR, as we move into the DDR and P&S Phase additional TL will be assigned for the those products and this PMP will be updated to reflect those decisions. PDT members contribute their particular expertise necessary for project execution. Team members for each WBS product, service, or deliverable are listed in Appendix A.

7. WORK BREAKDOWN STRUCTURE

The Work Breakdown Structure is a deliverable-oriented grouping of project elements that organizes and defines the total scope of the project. The Work Breakdown Structure identifies the products and sub-products that will be required to implement the total project. It presents these products and sub-products in a hierarchical arrangement. The Responsibility Assignment Matrix (RAM) lists the Work Breakdown Structure; identifies the organization responsible for accomplishing that work, and the technical lead for managing each product, deliverable, or service. The RAM is listed in Appendix B.

8. CONTRACTING AND ACQUISITION

Contract specific acquisition strategies will be developed for each individual contract to be advertised and awarded. Factors to be considered in determining the specific acquisition strategies include but are not limited to technical complexity of the work, whether a construction or a supply/install format will be used, environmental considerations/constraints, construction schedules and magnitude of construction. In addition, maximum consideration will be given to placing contracts with qualified small, small disadvantaged, and women-owned business concerns in support of the District's Small and Disadvantaged Business Utilization program. Acquisition strategies will be fully staffed through the Project Delivery Team and Office of Counsel.

9. COMMUNICATIONS PLAN

9.1 Project Delivery Team

Project delivery team members will generally meet bi-weekly (more or less often as necessary) to discuss technical issues, program strategy, critical milestones, budget, and team progress. Meeting minutes will be provided to the entire team and meeting minutes will be kept in the project directory.

9.2 Internal Briefings

The Project Manager will brief the District Corporate Board as required. The project's Technical Lead will brief the Engineer Review Board as required.

9.3 Regulatory and Resource Agencies

Meetings with the resource agencies will be done as necessary and will consist of brainstorming, criteria development and clarification, product review, and alternative evaluations and development. Agency input is critical during these meetings in regards to environmental clearances necessary for the project.

9.4 Public Involvement

The PDT is responsible for assisting the PM in determining all stakeholder project communications requirements, to include both external and internal communications. Mike McAleer has been selected for Public Affairs Office support, as a member of the PDT, for the development of the communications and public involvement plan based on the complexity and sensitivity of the project. A plan for public involvement is provided in Appendix E.

9.5 Project Directory

Electronic copies of all documents related to this project are stored in the project directory located at: contact project manager.

10. CHANGE CONTROL

10.1 Project Management Plan (PMP)

The Project Management Plan is a living document that will be updated or revised, as necessary, throughout the life of the project. Updates are defined as changes to the Project Management Plan that do not substantially modify the scope, schedule, or cost of the project. Updates to the PMP do not require formal review. Revisions to the PMP reflect changes in scope, schedule, or cost of the project and require formal review. Review with possible revisions to the Project Management Plan for this project are scheduled for:

- Prior to the Initiation of DDR
- Prior to the Initiation of P&S
- Prior to the Initiation of Major Rehab Report
-

10.2 Construction Change Orders

For construction contracts, NWP will utilize the Basic Change Order Document (BCD) used by the Resident Field Office (EC-R) for proposed construction contract modifications. Basic Change Order Documents from the Contracting Officer's Representative will be submitted ahead of time for approval and will be used by EC-R to alert the Project Manager of required revisions to the project estimate prior to the start of negotiations. The Project Manager will approve all discretionary changes, non-discretionary changes that exceed ACO authority, and confirm funding for all changes prior to finalization.

11. QUALITY MANAGEMENT

Quality control is the process employed to ensure the performance of a task meets the agreed upon requirements and appropriate laws, policies, and technical criteria, on schedule and within budget.

11.1 Project Management Plan

Quality control procedures, as applied to the Project Management Plan, will follow the Portland District Project Management Business Process Policy and Procedure Manual and Engineering Regulation 5-1-11.

11.2 WBS Products and Deliverables

The WBS products and deliverables will be produced for the following stakeholders: the public, NOAA Fisheries, Washington Department of Ecology, Oregon DEQ, and Oregon Department of Land Conservation and Development.

11.2.1 Quality Control

Product quality is the responsibility of everyone on the PDT. Technical quality of WBS products and deliverables shall be achieved through a process that includes development of realistic comprehensive work plans, well defined functional and technical criteria, close coordination among PDT members, and conformance to accepted USACE and industry standards, including ISO 9001 for engineering and construction products. In addition, WBS products and deliverables shall be reviewed by highly qualified staff from their respective section prior to submittal of the final product. For Engineering products and deliverables, computations will be checked and initialed prior to submittal of the final product.

11.2.2 Agency Technical Review

The purpose of an independent technical review is to assure the integrity and accuracy of the technical products produced. In particular, the ATRATR team will ensure that WBS products and deliverables are safe, functional, constructible, economical, and reasonable; engineering assumptions, concepts and analyses are valid and comply with accepted USACE and industry standards; economic analyses and cost estimates are reasonable and accurate; and that WBS products and deliverables comply with U.S. laws, regulations, and existing public policy. ATRATR certification is required for the following WBS products and deliverables:

- Major Rehab Report
- DDRs
- P&S

11.2.3 BCOE Certification

The purpose of Biddability, Constructibility, Operability, and Environmental Reviews (BCOE) is to ensure efficient construction that is environmentally sound, to minimize cost and time growth, to avoid unnecessary changes and claims, as well as to ensure safe efficient operations by the user. BCOE Certification is required for the following WBS products and deliverables:

- P&S
- DDRs

11.2.4 Reviews

WBS products and deliverables shall be reviewed as they are developed to ensure they meet project objectives, comply with regulatory and engineering guidance, and meet expectations of quality. Informal reviews, consisting of PDT presentations and discussions, shall be documented with meeting minutes. Formal reviews, consisting of review comments, review conferences, and backchecking, shall be documented using Dr. Checks. Product reviews will occur at the times shown in the schedule.

11.3 Construction Products

Obtaining quality construction is a combined responsibility of the construction contractor and the government. Construction products include those that are acquired using either Construction Contracts or Supply and Install Contracts. Quality control specifications will be incorporated into the contract specifications for each construction product. In general, the Contractor will implement a quality control system that ensures the final product is constructed in accordance with the contract plans and specifications and the project objectives. In addition, the Resident Office will develop a Quality Assurance plan for each construction product. Government Quality Assurance Representatives (GQAR) will monitor the construction progress and perform periodic on-site inspections as necessary.

11.4 Lessons Learned

As the project progresses, design lessons learned will be documented using the Design Quality Lessons Learned module in Dr. Checks and construction lessons learned will be documented in RMS. Lessons learned should focus on the positive aspects of a project as well as the negative ones.

12. SAFETY AND OCCUPATIONAL HEALTH PLAN

All aspects of this project shall comply with the Portland District Safety Plan. For construction or service contracts, contractors will submit an Accident Prevention and Site-Specific Safety Plan as identified in the contract specifications; in accordance with EM 385-1-1 (USACE Safety and Health Requirements Manual); and meeting Federal, state and local codes, regulations, and standards.

13. RISK MANAGEMENT PLAN

Risk management is the systematic process of identifying, assessing, making risk decisions, implementing controls, and analyzing risk decisions during the entire project life cycle. Monthly reviews by the project delivery team of progress and deliverables will assess potential problems and develop appropriate actions.

Risk will be minimized through the use of schedules, metrics, and assignment of specific responsibilities. Contingencies to manage financial risk have been incorporated in the cost estimates for each WBS product, deliverable, or service.

14. VALUE MANAGEMENT PLAN

Value Management (VM) is a process to facilitate and encourage the understanding, consideration, and integration of the needs of all stakeholders and PDT members. Value Management seeks the highest value for a project by balancing resources and quality. The VM process emphasizes the use of multi-disciplinary teams and their resulting synergy, using a functional analysis approach for decision making. The VM process will be applied continuously throughout the life cycle of the project.

Engineer Regulation 1110-2-1150 requires a value engineering study for all projects with an estimated construction cost of $2.0 million or more. The estimated construction costs exceeds $2.0 million, so a formal value engineering team study shall be performed on the earliest document available that establishes the functional requirements of the project and includes a Microcomputer Aided Cost Engineering System (MCACES) cost estimate. In addition, during the preparation of each design document, additional value engineering team studies will be conducted if the PDT identifies areas for potential cost savings and/or design improvements. It is envisioned that one VE study will be conducted after completion of the MRR and during the DDR.

To capture the benefits of potential cost reducing construction methods and technologies employed by a contractor, Value Engineering Change Proposal clauses, in accordance with FAR 52.248-3, will be included in all project construction specifications.

15. FISCAL MANAGEMENT

The Project Manager will allocate funds to the Technical Lead for completion of products as outlined in the PMP. The PM is responsible for management of all contingency. The Technical Lead is responsible for sub-allocations and detailed budgeting for their assigned products. The Technical Lead can change the distribution amoung team members without the approval of the Project Manager as long as the scope or overall cost of the product is not changed. It is anticipated that this will be done with concurrence from the affected offices. With the incorporation of the CEFMS financial system, the budget will be tracked and monitored at all times. Technical Lead will assist the Project Manager in the preparation of 2101's (i.e. monthly schedules of obligations and expenditures).

16. PROJECT CLOSEOUT PROCEDURES

Project Closeout will occur for construction efforts. After final inspection and acceptance of the project, property transfer documents will be prepared to transfer to plant in service. These documents include any as-built drawings, O&M manuals, warranties, or other documents pertaining to the project. This will occur as soon as practical following completion of construction of the project. Computations will be scanned and placed in the project directory. The Resident Engineer will process documents such as the final pay estimate and contractor evaluation required for closing the applicable construction contract. In addition, all construction documents and photos will be scanned and placed in the project directory after final close out of the construction contracts.

17. APPROVAL

FOR THE PROJECT DELIVERY TEAM:

____

Eric Bluhm
Project Manager

Appendix A – List Of Project Delivery Team Members

The team members listed below will be involved in all the WBS products, services, or deliverables mentioned in the PMP.

PDT MEMBERS		OFFICE	OFFICE SYMBOL	PHONE
Eric	Bluhm	Project Manager	CENWP-PM-FP	x4759
Mark	Brodesser	Technical Lead	EC-DC	x4914
Rod	Moritz	Coastal Engineer	CENWP-EC-HY	x4864
Barbara	Cisneros	Environmental	CENWP-PM-E	x4784
Karen	Bahus	Technical Writer	Contractor	503-642-4971
Richard	Gunsolus	Geologist	CENWP-EC-HG	x4854
Dave	Scofield	Geotechnical Engineer	CENWP-EC-HG	x4867
Phil	Ohnstad	Cost Engineer, Ch	CENWP-EC-CC	x4424
Karen	Garmire	Construction	CENWP-EC-R	503-492-3570 X222
Jacob	Macdonald	GIS	CENWP-EC-CM	x4844
Brian	Shenk	HAC	CENWP-HAC	x4221
Michelle	Helms	Public Affairs	CENWP-PA	x4517
Ralph	Banse-Fay	Contracting, Chief	CENWP-CT-C	x4612

2. WBS Product, Deliverable, or Service (add as required)

NAME	DISCIPLINE	ORGANIZATION
Bob Patev	ATR Lead	CENAE-EP-E
Alan Jeffries	ATR - Coastal Engineering	CEPOA-EN-CW-HH
Kevin Knight	ATR – Economics/Planning	CESPN-ET-PC
George Hart	ATR – Environmental	CENWS-PM-PL-ER
Kim Callan	ATR – Cost Engineering	CENWW-ED-C

APPENDIX B – RESPONSIBILITY ASSIGNMENT MATRIX

Work Breakdown Structure for Major Rehab Reports (Products, Deliverables, and Services).	**Action Office**	**POC**
Project Management	CENWP-PM-FP	Eric Bluhm
ESA/Environmental Compliances	CENWP-PM-E	Barbara Cisneros
Plan Formulation/Economics/Main Report	CENWP-HAC	Brian Shenk
Engineering Appendix	CENWP-EC-HY	Rod Moritz

Work Breakdown Structure for Future Phases (Products, Deliverables, and Services).	**Action Office**	**POC**
DDR	TBD	TBD
P&S	TBD	TBD

Appendix C – Project Schedule

The project schedule was developed using input from PDT members. Activities listed are those necessary to provide products, deliverables, and services listed in the Work Breakdown Structure (WBS). P2 Project Manager was used to link prerequisite tasks and the critical path method was used to determine major milestones in the overall project schedule. The P2 Project Number is 123160. Scheduled critical milestones and links among the tasks will be tracked and monitored. If milestones are missed, corrective actions will be discussed by the team and elevated to management as necessary if issues exist. The baseline schedule will be fixed after approval of the PMP.

Major project milestones are listed below. (S) or (F) indicates start or finish of an activity.

MAJOR PROJECT MILESTONES

Major Rehab Reports (Products, Deliverables, and Services)	**Baseline (F)**	**Actual**
PMP	July 2006	Revised
ESA/Environmental Compliances	Feb 2011	June 2012
Plan Formulation/Economics/Main Report	March 2011	June 2012
Engineering Appendix	March 2011	June 2012

Future Phases (Products, Deliverables, and Services)	**Baseline (F)**	**Actual**
DDR	Mar 2014	
P&S	Sep 2014	

Appendix D – Budgets and Cost Estimates

Project budgeting involves allocating the overall cost estimate to individual activities over time so that project cost performance can be measured. The funding source for this project is O&M.

Detailed cost estimates will be an appendix of the Major Rehab report and finalized during P&S.

Appendix E – Communications and Public Involvement

E.1 Purpose Statement: This plan provides direction and guidance for Portland District as it strives to provide its own employees, as well as special interest groups, local businesses, organizations and citizens with complete, accurate and timely information about the Mouth of the Columbia River North and South Jetties Major Rehabilitation Project Evaluation

E.2 Goals and E.3 Objectives:

- Ensure the Commander, project manager and technical leads are an active and integral part of the overall Mouth of the Columbia River North and South Jetties Major Rehabilitation Project Evaluation Communication Plan.
- Improve Corps communications to and with the media, special interest groups, businesses and citizens of the surrounding communities.
- Improve two-way communication within the Corps' own organization, especially within the Mouth of the Columbia River North and South Jetties Major Rehabilitation Project Evaluation PDT and the vertical team.
- Proactively provide information to all those impacted to give the Corps the opportunity to tell its story rather than rely on others to interpret the Corps' actions, issues and decisions during construction.
- Generate inclusiveness. Including everyone in the process builds teamwork and a feeling of belonging, breaking down feelings of us vs. them, which are common in relationships between the Corps and local citizens, especially when controversial issues arise.

E.4 Communications Team:

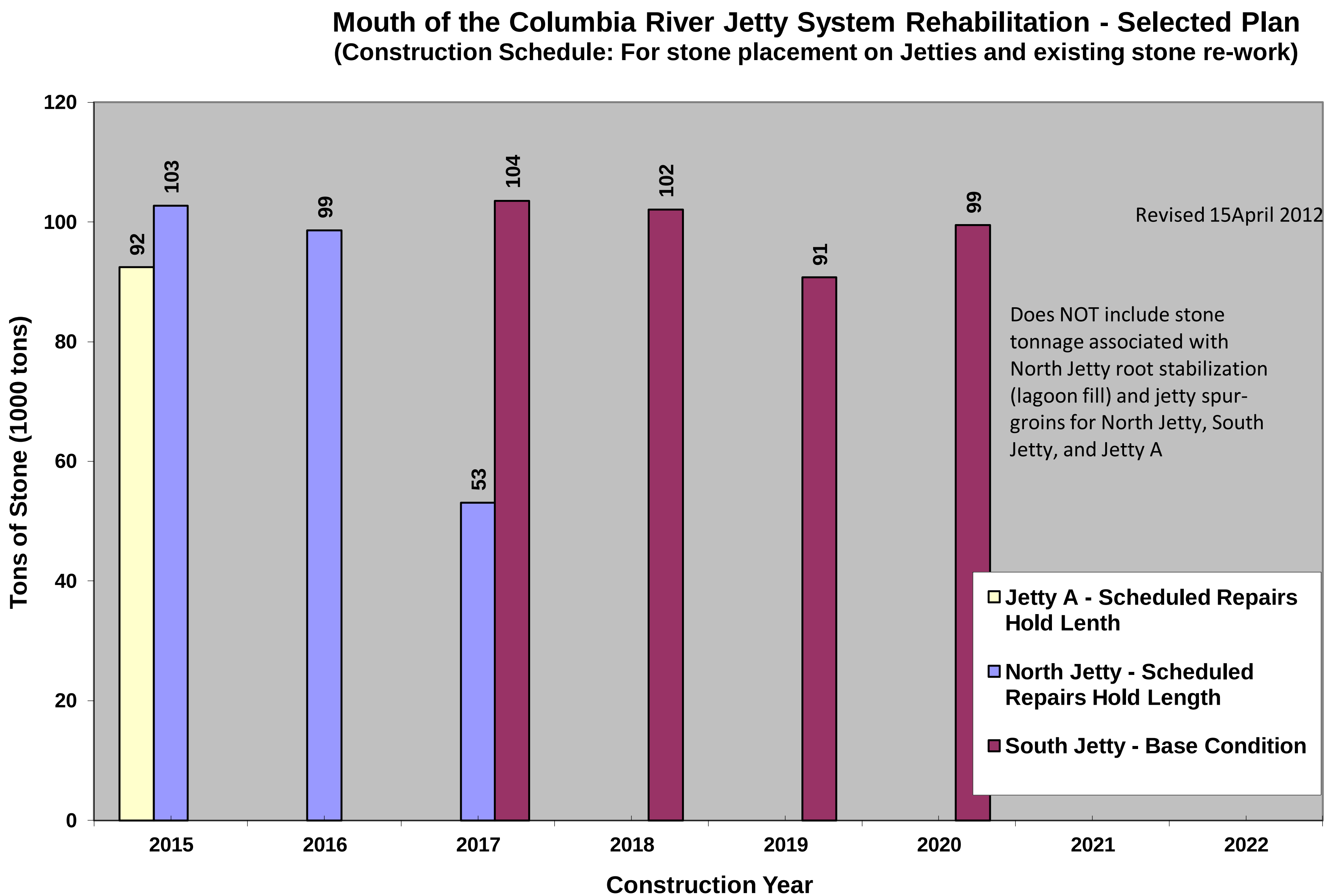
Portland District:			Office	Phone
Eric	Bluhm	Project Manager	CENWP-PM-FP	x4759
Mark	Brodesser	Technical Lead	EC-DC	x4914
Heidi	Moritz	Coastal Engineer	CENWP-EC-HY	x4893
Rod	Moritz	Coastal Engineer	CENWP-EC-HY	x4864
Kim	Larson	Environmental	CENWP-PM-E	x4776
Karen	Bahus	Technical Writer	Contractor	503-642-4971
Richard	Gunsolus	Geologist	CENWP-EC-HG	x4854
Dave	Scofield	Geotechnical Engineer	CENWP-EC-HG	x4867
Phil	Ohnstad	Cost Engineer, Ch	CENWP-EC-CC	x4424
Reed	McDowell	Construction	CENWP-EC-R	503-492-3570 x222
Louis	Landre	Real Estate	CENWP-RE	x4677
Jacob	Macdonald	GIS	CENWP-EC-CM	x4844
Brian	Shenk	HAC	CENWP-HAC	x4221
Diana	Fredlund	Public Affairs	CENWP-PA	x4514
Ralph	Banse-Fay	Contracting, Chief	CENWP-CT-C	x4612

US Army Corps of Engineers®

Portland District

Appendix G – Summary Construction Schedule for Stone Placement

Mouth of the Columbia River North and South Jetties Major Rehabilitation Project Evaluation Report



Mouth of the Columbia River Jetty System Rehabilitation - Selected Plan
(Construction Schedule: For stone placement on Jetties and existing stone re-work)
Tons of Stone (1000 tons)
0
20
40
60
80
100
120
92
103
99
53
104
102
91
99
Revised 15April 2012
Does NOT include stone tonnage associated with North Jetty root stabilization (lagoon fill) and jetty spur-groins for North Jetty, South Jetty, and Jetty A
Jetty A - Scheduled Repairs Hold Lenth
North Jetty - Scheduled Repairs Hold Length
South Jetty - Base Condition
2015
2016
2017
2018
2019
2020
2021
2022
Construction Year

** = rework % varies from 10% - 20%, based on estimated tonnage placed per 100 ft jetty.
0.15

JETTY "A" Schedule Repairs Hold Length - REVISED 12 APR 2012

Year	From Sta	To Sta	Re-Work** (5 to 15 tons) (tons)	Small Armor (3 to 15 tons) (tons)	Large Armor (4 to 18 tons) (tons)	Total New Armor + Existing Stone Re-work for Each Repair Campaign based on template neat-line tolerances (tons)
	48+00	60+00	4,823	32,150		36,973
2015	69+00	73+00	1,608		10,717	12,324
	85+00	89+00	1,608		10,717	12,324
	74+00	84+00	4,019		26,792	30,810
		TOTAL	12,056	32,150	48,225	
				TOTAL NEW REPAIR ARMOR on jetty	80,375	92,431

** = rework % varies from 10% - 20%, based on estimated tonnage placed per 100 ft jetty.
0.15

NORTH JETTY Schedule Repairs Hold Length - REVISED 15 APR 2012

Year	From Sta	To Sta	Re-Work** (5 to 15 tons) (tons)	Small Armor (6 to 18 tons) (tons)	Large Armor (8 to 24 tons) (tons)	Total New Armor + Existing Stone Re-work for Each Repair Campaign based on template neat-line tolerances (tons)
2015	20+00	30+00	5,360	35,733		41,093
	30+00	45+00	8,040	53,599		61,639
2016	45+00	54+00	4,824	32,160		36,983
	55+00	63+00	2,144	14,293		16,437
	64+00	71+00	3,752	25,013		28,765
	72+00	76+00	2,144	14,293		16,437
2017	77+00	85+00	4,288	11,435	17,152	32,874
	99+00	101+00	3,000		17,200	20,200
		TOTAL	33,552	186,525	34,352	
				TOTAL NEW REPAIR ARMOR on jetty	220,877	254,429

** = rework % varies from 10% - 20%, based on estimated tonnage placed per 100 ft jetty.
0.15

SOUTH JETTY Base Condition - REVISED 12 APR 2012

Year	From Sta	To Sta	Re-Work** (5 to 15 tons) (tons)	Small Armor (6 to 15 tons) (tons)	Medium Armor (10 to 20 tons) (tons)	Large Armor (13 to 26 tons) (tons)	Super Armor (16 to 33 tons) (tons)	Total New Armor + Existing Stone Re-work for Each Repair Campaign based on template neat-line tolerances (tons)
2017	167+00	175+00	5,146	17,152	17,152			39,449
	182+00	195+00	8,361	27,872	27,872			64,105
2018	197+00	215+00	9,262	30,873	30,873			71,008
	215+00	222+00	4,052		15,008	12,006		31,066
2019	223+00	246+00	11,835		39,449	39,449		90,733
2020	258+00	290+00	12,973			36,224	50,261	99,459
		TOTAL	51,629	75,896	130,353	87,680	50,261	
					TOTAL NEW REPAIR ARMOR on jetty		344,191	395,820

MCR Jetty System Major Rehabilitation Evaluation Report

Appendix H

Summary of Events and Review Documentation

APPENDIX H - MCR Jetties Major Rehabilitation Report – Summary of Events

Table of Contents

ATTACHMENTS

1. ATR Certification Letter
2. Model Certification Letter
3. IEPR Comments and Responses
4. Disapproval Memo
5. Path Forward Memo
6. Model Approval Plan
7. Revised MRR Review Plan
8. Final NWP Responses
9. ATR Certification

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1. Background

Over the past six years the Portland District has been developing the MCR Jetties Major Rehabilitation Report (MRR). In June 2011, the foundation of the report—a planning tool called the "Stochastic Risk-Based Model"—was disapproved by HQUSACE. Consequently, the Portland District has spent the past year revising the model and MRR. Appendix H summarizes the key events—particularly over the past two years—and describes the differences between 2011 draft report and the final 2012 MRR.

2. History

The Corps began looking at applying a system approach to the MCR entrance in 1999, had an interruption from study to conduct interim repairs on the North Jetty in 2005, and the South Jetty in 2006 and 2007. The Portland District reinitiated the MRR effort in FY 2006 after facilitating emergency interim repairs on 3,000 feet the North Jetty in 2005; and later the placement of over 130,000 tons of stone to repair the South Jetty in 2006 and 2007. In early 2006 the district began discussion with Northwester Division (NWD) regarding the long-term maintenance of the jetties. Specifically, in February 2006, the district began scoping an accelerated study to address the extensive deterioration of the all three jetties of the MCR system: North, South and Jetty A, which protects the North Jetty root. It was determined that the study will need to clearly lay out what is authorized, what is rehabilitation, and what is new work. It was clarified that "jetty extensions" are not new work, rather rehabilitation of the current jetty arms. Lastly, it was agreed that modeling studies to support the recommended plan would be necessary.

In March of 2007 the district received delegated authority approval. This cleared the way for the MRR to be approved by NWD if the district met all policy requirements per EC 1165-2-206 (and today ER-1165-2-502). It was also determined that the MRR studies should be at a feasibility level of detail; however, some alternatives may be screened out a much lower level. For example, rebuilding the jetties to their authorized lengths were analyzed and determined infeasible, within and outside the existing jetty footprints.

From FY 07 through 10 the MRR planning model, the Stochastic Risk Based (SRB) model, was developed to assess and rank repair and rehabilitation alternatives. Concurrently, the Project Delivery Team (PDT) reached agreement on the base condition, the "fix-as-fails" approach, which assumed that the jetty would be maintained just in time to prevent a breach.

In addition, through FY10, NWP considered where the end of each of three jetties should be and developed three jetty length options:

- rebuild the jetties to their authorized lengths
- rebuild the jetties to the midpoint between the authorized length and the existing jetty end station
- rehabilitating the jetty to the current end station

NWP has considered major alternatives to the authorized cross-section that included designs that stayed on the existing footprint and those that went off the existing footprint, including realigning the entire system. Alternatives that extended the jetty lengths significantly beyond the existing end station or reconstructed the jetties off the existing footprint were deemed infeasible.

In FY 2010, a 90% draft of the MRR underwent District Quality Control (DQC) and Agency Technical Review (ATR). The underlying tenets of that report included a base condition involving a fix-as-fails approach where each jetty was allowed to degrade as low as 20% of the originally authorized cross-section remaining above

MLLW -5, resulting in forecasted breaches. The hypothetical breaches would release material into the navigation channel, leading to emergency dredging. Breaches were forecasted to primarily occur in the winter, thus emergency dredging was very expensive, and reliability of the navigational channel became questionable. Moreover, breach volumes entering the navigation channel were difficult to quantify. In an attempt to model these effects, the SRB model code became more complex as the analysis was developed and the timing of the runs became very long and the economics was embedded within the model code. NWP also developed a qualitative numeric scoring of alternatives that included several factors beyond average annual cost.

The IEPR was conducted from December 2010 through April 2011. Concurrently, the SRB model underwent substantial review, including ATR approval and DDN-PCX model certification in January 2011. This documentation was then forwarded to HQUSACE for final approval where it was disapproved in June 2011 because the IEPR panel raised concerns about the frequency and severity of breaching and sediment transport in the base condition.

After consultation with NWD, it was decided that an MMR should be produced for the most critical portions of the North Jetty for inclusion in the FY 2014 budget submission. Therefore,
the lagoon fill between STA 20 to 60 and critical repairs between STA 86 to 99 were removed from the MRR alternatives and included in the revised base condition.

NWP then decided to revise the SRB model, MRR and appendices per IEPR comments and hired Moffatt & Nichol, a coastal engineering consultant. Furthermore, the A/E task order emphasized improving the model code; showing compliance with current technology and Corps policy; providing additional documentation; improving practicality with data inputs and outputs; and user manual; clearly identifying the use and limitations of the model consistent with EC 1105-2-412.

Due to the level of construction and high mobilization costs, the revised FY 12 base condition—identified as an interim-repair approach—was developed to replace the FY 11 “fix-as-fails” approach. The new base condition allows the upper portion of the jetty is allowed to be degraded until approximately 40% of the cross-section is remaining prior to repair action being initiated. This change in the base condition allows for repair actions to take place prior to a breach event, and thereby eliminates breaching and sediment transport through the jetty, affecting the navigational channel and significantly reduces winter emergency dredging.

The economics analysis is now outside the model in a post-process spreadsheet. The code has been modularized and simplified so that there is one code for all three jetties. The user’s manual provides enough detail for a knowledgeable coastal engineer to run the model. These changes improved the transparency of the model’s sub-routines, dependant and independent variables, and damage functions leading to the ultimate approval of the model on 27 April 2012.

The preceding series of events resulted in a change in the selected plans for the three jetties. Subsequent to the model review and IEPR, the MRR underwent DQC, NWD, and ATR reviews, including DDN-PCX review and approval of the report review plan and model review plan.

Sections 3, 4, 5, and 6 of this appendix outline key dates, multiple reviews, differences between the 2011 and 2012 MRRs, and document the study’s funding history. Eight attachments are included to document reviews.

3. Key Dates

a. FY 2006: Major Rehabilitation Report study initiated.
b. March 2006: NWD provides initial guidance
c. FY 07-10: SRB model developed and MRR study conducted.

d. 24 August 2010: ATR Certification Letter recommending model certification and approval for use to the Deep-Draft Navigation Center of Expertise (DDN-PCX), (see Attachment 1).
e. 21 October 2010: ATR of Major Rehab Report completed (all comments closed out, no certification memo on record)
f. 21 January 2011: DDN-PCX provides model certification and forwards documentation to HQUSACE for review (see Attachment 2).
g. 07 April 2011: Final IEPR comments, responses and backchecks provided by Battelle. Three of 25 comments remain open (see Attachment 3).
h. 09 June 2011: Draft SRB model disapproval memo provided by HQUSACE.
i. 15 August 2011: Disapproval memo signed (see Attachment 4).
j. 17 August 2011: Path forward memo requesting vertical team concurrence issued (see Attachment 5).
k. 26 August 2011: Task Order issued to Moffatt & Nichol to assist with SRB model revisions, validation and verification, and revisions to MRR and its appendices per the IEPR comments.
l. 01 December 2011: Model Approval Plan submitted to DDN-PCX (see Attachment 6).
m. 23 December 2011: Draft SRB Model User's Manual completed.
n. 06 January 2012: Draft Model User's Interface completed.
o. 13 January 2012: SRB Model Matlab code finalized.
p. 23 December 2011: Draft SRB Model User's Manual completed.
q. 06 January 2012: Draft Model User's Interface completed.
r. 13 January 2012: SRB Model Matlab code finalized.
s. 20 January 2012: IPR: NWP briefed HQUSACE, NWD model and MRR path forward.
t. 27 April 2012: HQUSACE approves the SRB model for one-time use.
u. 09 May 2012: Draft MRR provided to NWD for review and approval.
v. 29 May 2012: Revised MRR Review Plan resubmitted to the DDN-PCX.
w. 31 May 2012: NWD comments on MRR provided.
x. 04 June 2012: Revised MRR Review Plan approved by the DDN-PCX (see Attachment 7).
y. 07 June 2012: NWP responses to NWD comments provided.
z. 15 June 2012: Final NWP responses to NWD comments (see Attachment 8).
aa. 15 June 2012: Received Cost Certification from PCX at NWW
bb. 22 June 2012: Received ATR Certification on MRR (see Attachment 9).
cc. 29 June 2012:

4. Selected Plans Comparison

Key Component	2011 Report	2012 Report
North Jetty	Schedule Repair w/features (cap & spur groins) 11 alternatives evaluated Not NED Plan	Scheduled Repairs, hold head >11 alternatives evaluated NED Plan
South Jetty	Schedule Repair w/features (cap & spur groins) 14 alternatives evaluated Not NED Plan	Base Condition plan selected >14 alternatives evaluated NED Plan
Jetty A	Immediate Rehab w/features (cap & spur groins) 3 alternatives evaluated NED Plan	Scheduled Repairs, hold head >3 alternatives evaluated NED Plan
Model	NWP Lead	NWP/Moffatt & Nichol Lead
Cost	~$500M; 2012-2032 Contingency: 36% Mitigation (offloading, stockpile, wetland, 404)	$239M; 2015-2020 Contingency: 29% Mitigation (offloading, stockpile)
NEPA	2nd time for public review Signed FONSI (NJ lagoon fill, NJ critical repairs, SJ dune augmentation/stabilization)	2nd time for public review FONSI (MMR, MRR & SJ dune)

5. Differences between 2011 & 2012 Reports

Key Component	"Delta"	Comments
North Jetty	Base Condition (MMR actions: Lagoon Fill and critical repairs STA 86-99)	Base Condition not longer "fix-as-fails"; now interim repair
South Jetty	Less aggressive maintenance and repair	Change addresses IEPR comments
Jetty A	No head capping or spur groins	Hold head alternative evaluation will be reassessed during DDR
Model	User manual w/input interface; extensive external review by Moffatt & Nichol; modularity (3 sets of code down to 1 set); economics external to model; changed model parameters drove changes in alternatives and selected plans	HQUSACE approved model for one-time use on 27 April 2012
Cost	Construction Sequencing; shortened schedule	Used same assumptions, cost engineering tools and processes; NWW certification on both
NEPA	Included near-shore placement by Corps	

6. Funding History

Fiscal Year	Budget Amount	Appropriated Amount
2006	875,000.00	873,707.00
2007	475,000.00	467,009.00
2008	868,500.00	705,114.00
2009	387,000.00	560,260.00
2010	635,000.00	1,195,490.00
2011	750,000.00	762,000.00
2012	----	671,222.00
	$3,990,500.00	$5,234,802.00

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Attachment 1

(Appendix H)

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CENAE-EP-HG 24 August 2010

MEMORANDUM FOR: Mr. Bernard E. Moseby, CESAM-PD-FE, Chief, Economic Analysis and Deputy Director, Deep Draft Navigation Planning Center of Expertise

SUBJECT: Review and Certification Letter for the Mouth of the Columbia River (MCR) Stochastic Reliability Based (SRB) Lifecycle Model for the MCR Major Rehabilitation Report

The following is the background information on the review process for the certification of the MCR SRB Lifecycle Model:

1. In October 2009, a request was made by the NWP PM to the ATR team leader to assist in obtaining model certification of the Mouth of the Columbia (MCR) Stochastic Reliability Based (SRB) model. This process was conducted using current USACE planning guidance and coordinated through the Deep Draft Navigation PCX to request from USACE Headquarters an "approved for use" status of the MCR SRB model.

2. A technical review of the MCR SRB model was initiated in November 2009 and has continued to date utilizing both part of the ATR team (Mr. Robert C. Patev, Team Leader and Mr. Wally Brassfield, ATR cost team member) and Mr. John Winkelman, a Coastal Regional Technical Specialist (RTS), from North Atlantic Division (NAD). Since the MCR SRB model was developed using the MATLAB language/software, Mr. Winkelman was an important part of this team due to his knowledge of the software, his technical position as a coastal engineer/planner Regional Technical Specialist with the HSDR PCX, and his past work experience in SPD on West Coast coastal navigation projects.

3. The review was begun in November 2009 by Mr. Patev and Mr. Winkelman and included a visit to CENAE by Mr. Hans Moritz, who is the developer of the MCR SRB model. The meeting lasted approximately two days and included a detailed presentation of the model code, model development assumptions, variable and model input descriptions, a discussion of the model output, and a lengthy discussion of model philosophy. Questions or comments generated prior to and during the meeting were documented and addressed as part of the Dr. Checks review process. Twenty three comments were generated and submitted into Dr. Checks in January 2010. Questions and comments were related to model coding, model variables and model constant value selection, model assumptions, and limited coastal engineering issues. Each issue and question was answered and/or addressed satisfactorily.

4. Following this meeting and installation of the MCR SRB MATLAB code at NAE, a number of variables and their ranges were defined to investigate model performance, sensitivity, and stability of the code. This was performed in terms of engineering reliability aspects of the program only. During this phase of the review, Mr. Moritz provided the review team with a list of key variables and constants within the code for validation. Many of these variables were discussed further during a number of

email/phone exchanges during this phase. After these communications and detailed examination of the code, the values selected in the model for engineering parameters were determined to be reasonable and based upon a sound engineering decision process. When these values were changed in the model, noticeable changes to the model output were recognized, but the model did not produce any unreasonable results in terms of engineering reliability.

5. The values for costs included in the MCR SRB model were reviewed and modified by Mr. Brassfield in July 2010. However, the validation of the methods and mathematical calculation for the estimation of the economic consequences produced by the model has not been reviewed by any team member since this was outside of their areas of expertise.

The following limitations, review assumptions and technical recommendations were drawn by the review team during their review:

1. With a model of this size and complexity it is difficult to determine if all of the code is error proof or if the model is providing the exact correct answer. However, based on the review, as described, the model, from a coastal analysis/performance stand point does appear to be reasonable and is a reasonable tool for determining the future, relative performance of various maintenance schemes for the MCR jetties discussed in the MRR. As with any model of this complexity, and for a system of this complexity, the precise numbers and resulting values are likely not absolutely correct but instead are reasonable and relatively correct between alternatives.

2. This model and code has only been reviewed as to what was included in the code installed at NAE in 2009. This review was limited only to the aspects of the engineering reliability and not the actual consequence determination in the program. The cost inputs have been reviewed by the ATR cost team member but the application of the economics to the outputs has not been validated as part of this review. In addition, any additional changes or modifications of the code should be reviewed by the ATR team to determine the validation of those modifications to the code and the replication of the results with previous versions of the code.

3. The MCR SRB model was developed to perform an integrated analysis of both engineering reliability and consequence assessment. Typically, major rehabilitation models are developed separately into stand alone models for engineering reliability and economic consequences. If the schedule permits, I would strongly recommend that the SRB process and results be validated with a simpler model using hazard functions from the SRB reliability curves and the development of consequences using a traditional economic simulation model.

4. During the Independent External Peer Review (IEPR), it is important to provide the additional documentation and explanations discussed in my previous comments. Also, the face to face meeting for explaining the model is essential due to the complexity of the model. This is a model that is trying to meet a difficult USACE planning objective that covers an immensely complicated coastal engineering project and forecasts an uncertain

future. It should also be made clear what the purpose of the model is, and that this is a project specific model that has been developed, honed, and calibrated for this specific project area. The numerous factors and variables, etc. within this model, to a great extent, are project specific and are not to be used in a generalized model for other USACE projects.

5. Based on the information presented above, I recommend that the MCR SRB lifecycle model be certified as is and a request be sent to USACE Headquarters as “approved for use” for the MCR Major Rehabilitation Report only.

If there are any questions regarding this memorandum, please do not hesitate to contact me at your earliest convenience.

Robert C. Patev
ATR Team Leader
NAD Navigation RTS

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Attachment 2

(Appendix H)

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DEPARTMENT OF THE ARMY
SOUTH ATLANTIC DIVISION, CORPS OF ENGINEERS
ROOM 10M15, 60 FORSYTH ST., S.W.
ATLANTA GA 30303-8801

REPLY TO
ATTENTION OF

CESAD-PDS-P 21 January 2011

MEMORANDUM FOR Commander, HQ USACE (CECW-NWD-RIT/Lisa Fleming)

SUBJECT: Model Certification – Approval for Use, Columbia River at the Mouth, Oregon and Washington, Major Rehabilitation of the Jetty System at the Mouth of the Columbia River, Stochastic Reliability-Based (SRB) Model

1. References:

a. EC 1165-2-209, "Civil Works Review Policy", 31 January 2010.

b. EC 1105-2-412, "Assuring Quality of Planning Models", 20 July 2009.

c. EC 1105-2-407, "Planning Models Improvement Program: Model Certification", 31 May 2005.

d. Memorandum, CECW-CP, 30 March 2007, Subject: Peer Review Process.

e. Supplemental information for the "Peer Review Process" Memo, dated March 2007.

2. In accordance with EC 1165-2-209, "Civil Works Review Policy" Model Certification – Approval for Use, the Major Rehabilitation of the Jetty System at the Mouth of the Columbia River, Stochastic Reliability-Based (SRB) Model, has been coordinated with and executed through the Deep Draft Navigation Planning Center of Expertise (DNN-PCX).

3. The review was performed by Robert C. Patev, CENAE-EP-W (Team Leader) and John Winkelman, CENAE-EP-WM, New England District, Corps of Engineers. The Model Assessment Criteria documentation that supports a recommendation of 'Approval for Use' for the SRB is enclosed. The Deep Draft Center is requesting coordination of the enclosed documentation package through the Planning CoP Leader for processing, review and recommendation.

4. The Deep Draft Navigation Planning Center of Expertise (DDN-PCX) point of contact is Bernard Moseby, Technical PCX Deputy, CESAM-PD-FE, (251) 694-3884.

Encls

WILBERT V. PAYNES
Director, Deep Draft Navigation
Planning Center of Expertise

CF:
CENWD-PDD (Valerie Ringold)

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Attachment 3

(Appendix H)

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Compiled Comments and Responses

on the

IEPR of the Columbia River at the Mouth, Oregon and Washington Major Rehabilitation Evaluation Report

Comment (#1):

The economic analysis used to select the National Economic Development (NED) plan cannot be validated, nor can it be determined if assumptions were applied correctly in the economic spreadsheet models.

Basis for Comment:

Economics is the key consideration in evaluating the NED plan, which was selected as the recommended plan. Several issues were identified in the review documents and the economic spreadsheet models that could significantly change the outcome of the economic analysis and the selection of the recommended plan. These issues primarily pertain to the calculation of net present values (NPVs) and Average Annual Costs (AACs), and the presentation of the economic analysis results.

Calculation of NPVs and AACs

- The AACs, based on the NPVs presented in Table 2-1 and Table 2-2, appear to be based on a Federal discount rate of 4.125%, not 4.375%, as stated in the report.
- The calculation of the NPVs and AACs in the economic spreadsheet model for the North Jetty are based on a discount rate of 4.125%, not 4.375%, as stated in the report.
- The period (actual calendar years) of the annual stream of costs used to calculate the NPVs for each alternative differ between alternatives in the economic spreadsheet models; also, the actual calendar years included in these periods were not stated in the report.
- The unit costs for jetty repair and dredging, as presented in the SRB model, are increased over time such that after 50 years, costs will be 15% greater than at present. In accordance with ER 1105-2-100, p. 2-11 (USACE, 2000), when conducting economic analysis, prices should be held constant over the period of analysis.

Presentation of Results

- The NPVs and AACs in the spreadsheets for the North Jetty and South Jetty differ from the results presented in the report.
- The term NED, the process of calculating NED benefits, and the method of selecting the NED plan are not explained in Section 2 or Appendix C of the report.
- The SRB model uses Monte Carlo simulation to increase the confidence of life cycle estimates and allow for evaluation of variance by producing project cost output, including mean and standard deviation values (Appendix A2, p. A2-49). The risk and uncertainty associated with estimating the stream of annual costs and the resulting NPVs, AACs, and benefit-to-cost (B/C) ratios are not addressed in the economic analysis.
- The costs of the NED plan of $250 million in the Executive Summary are presented on a fully funded basis, whereas the costs in the main report are presented as NPVs, resulting in confusion.

Significance – High:

The inability to validate the economic analysis and the assumptions used in the economic spreadsheet model could impact the selection of the NED, or recommended plan.

Recommendations for Resolution:
1. Calculate the NPVs and AACs using the FY10 Federal discount rate of 4.375% for all alternatives; basing the NPVs on the stream of project costs for the 50-year period of analysis. 2. In accordance with ER 1105-2-100, Chapter 2 (USACE, 2000), revise the formulas in the economic spreadsheet models to reflect the same period of analysis for all alternatives. 3. State the years (annual stream of costs) used in calculating the NPV for each alternative and ensure consistency in alternative evaluation. 4. In accordance with ER 1105-2-100, Chapter 2, p. 2-11 (USACE, 2000), revise the repair and dredging costs to reflect the general level of prices prevailing during or immediately preceding the period of planning for the entire period of analysis. 5. Revise Section 2 and Appendix C of the report to include a definition of the term NED, an explanation of the process of calculating NED benefits, and the method of selecting the NED the plan. 6. In accordance with EP 1130-2-500, Appendix B, p. B-9 (USACE, 1996), report the results of all alternatives in a table displaying the mean net benefits and standard errors of each; providing the 90% confidence interval for the mean net benefits (mean+ 1.64x standard error). 7. Present the costs of the NED plan in the Executive Summary and the main report in both a fully funded basis and in NPV.
USACE Final Evaluator Response (#1)
CONCUR 1. **ADOPT NOW**. NPVs and AACs will be calculated using the current discount rate. Text in the report will be edited to match the discount rate used in the spreadsheets. NPVs will be based on the stream of costs for the 50-year period of analysis. 2. **ADOPT NOW**. The output from the SRB model used labels for the starting year of the analysis that were established years ago in the early stages of model development. While the labels appear to indicate that the initial years of the analysis are either 2008 or 2009, the actual first year of the analysis is generally considered to be in the future, rather than two or three years ago, and specifically would be the first year in which maintenance decisions could be impacted by the knowledge of a decision to perform major rehabilitation in the future. The output from the SRB model can be altered to show that the first year of model output is 2012, but the actual data for Year 1 of the analysis will not change. Labels in the Year column of each spreadsheet will be altered to show that the period of analysis always begins in 2012. In the event that the study continues on into 2012, the labels will be altered again to indicate that the period of analysis begins in 2013. **3.** **ADOPT NOW**. Each alternative will be evaluated using the fifty years from 2012 to 2061. **4.** **ADOPT in FUTURE .** The 15 % increasing trend of costs will be deleted from the base condition re-run. In addition one of the significant frequent repair alternatives will be re-run with the 15% increase taken out to assess with and without final NPV calculation impact. This should not affect the overall plan selection process. **5.** **ADOPT NOW.** Section 2 and Appendix C of the report will be revised to include a definition of the term NED, an explanation of the process of calculating NED benefits, and the method of selecting the NED the plan.

6. **ADOPT NOW.** The results of all alternatives will be displayed in a table showing the mean net benefits and standard errors of each; providing the 90% confidence interval for the mean net benefits (mean+ 1.64x standard error).
7. **ADOPT NOW.** The costs of the NED plan will be presented in the executive summary and elsewhere in the main report in both a fully funded basis and in Net Present Value.

Panel Final BackCheck Response (#1)

Concur.
In reference to Evaluator Response to Recommendation 4, if the impact to the final NPV calculation from re-running one of the frequent repair alternatives with and without the 15 percent cost increase is deemed significant, then all other alternatives should be re-run without the 15 percent cost increase. If the impact is not significant, state in the report that the costs were increased by 15 percent, but the cost increase did not impact overall plan selection.

Literature Cited:

USACE (2000). Planning – Planning Guidance Notebook. Department of the Army, U.S. Army Corps of Engineers, Washington, D.C. Engineer Regulation 1105-2-100. *22* April.

USACE (1996). Project Operations – Partners and Support. Department of the Army, U.S. Army Corps of Engineers, Washington, D.C. Engineer Pamphlet 1130-2-500. 27 December.

Comment (#2):
The analysis of the sediment transport process is not comprehensive, and the data and analysis do not support the conclusions concerning large movement of sediment during a breach event.
Basis for Comment:
The report describes large volumes of sediment that will move into the navigation channel after a breach event. However, the Coastal Modeling System (CMS) numerical model results (CHL, 2007; p. 15, Figure 3.2) indicate minimal sediment movement through a jetty breach, even with the model strongly distorted to encourage movement. Similarly, historic breach events at the MCR inlet and region do not support the sediment movement volumes and rates assumed, nor the assumed sudden jetty failure, and the consequent requirement for emergency repairs and dredging. The assumed jetty breach sediment movement is also inconsistent with recent experience with dredged material disposal at the North Jetty. Approximately 400,000 cubic yards were placed at the site each year during 1999-2008, on average, comparable to some jetty breach scenarios. However, the sediment placed at the North Jetty does not appear to have affected navigation. Similarly, the reported "rapid deterioration" of the North Jetty from 1999 to 2004, when 100,000 cubic yards of sediment leaked through the jetty leading to the repairs in 2005, is not consistent with the assumed scenario of a sudden breach event and large sediment movement. Figures A1-252 to A1-254 of jetty breach sediment movement appear to be artist renderings, not products of analysis. The figures are misleading if they are interpreted as model output. Table 3-10 in the main report is presented but not explained, so there is no clear basis for the "Range of Volume Left in Channel" resulting from a breach of the North Jetty. There is no discussion of any hydrodynamic analysis or evaluation of morphologic changes and corresponding sedimentation of the navigation channel. Significant inconsistencies are present in the sediment transport discussion. For example, the documents discuss sediment disposal practices at the shallow water site (SWS), immediately offshore from the tip of the North Jetty. The EA notes, "Active monitoring and evaluation determined that 80% to 95% of the dredged sand annually placed at the SWS moves northward onto Peacock Spit" (dispersed to the north). However, the main report describes how rip currents along the north side of the North Jetty transport sediment towards the tip and then south into the navigation channel. This implies an unrealistic discontinuity in the sediment budget and sediment paths immediately offshore of the jetty tip. The sediment budgets and analysis are not consistent in different parts of the review documents, and seem to vary depending on whether the analysis is centered on dredged material disposal (emphasizing sediment movement onto nearby shores) or jetty stability (emphasizing sediment movement towards the channel). The jetties are described as functioning like "wingdams" preventing sediment movement into the channel. However, it seems more the case that the North Jetty shields the sands of Benson Beach from the dominant southwesterly waves preventing/slowing longshore sediment transport to the north, rather than south into the channel. Also, the process of sediment movement through a jetty breach is not at all like water through a dam break. The jetties are essentially a pyramid with only a small tip extending above water. What happens below water, with the sediments and foundations, is more central to the long term function and stability of the MCR jetties, navigation channel, and adjacent beaches. A better analysis of sediment transport is needed because the repair alternatives at present are an ever expanding pile of rock on an ever shrinking foundation of sand. The geological history includes more than 225 million cubic yards of dredging since 1956 from the MCR navigation channel, with most disposed offshore (EPA, 2009). The Southwest Washington Coastal Erosion

Study (Gelfenbaum, et al, 2006) concluded, “The carrying capacity of beach sands of Columbia River to the estuary has been reduced by approximately two-thirds over the last century.” The missing sediment from the system and ongoing erosion of the shoals that help protect the jetties all point toward a need for a more rigorous investigation of sediment transport and alternatives that could reduce the loss of sediment and subsequent project O&M costs.

Significance – High:

The rehabilitation project will not be successful if ongoing sediment loss continues and the shoals and jetty foundation wash away.

Recommendations for Resolution*:*

1. Eliminate or justify the unrealistic assumption of sudden jetty failure and large volumes of sediment rapidly moving into the navigation channel. Instead, compare alternatives based on life-cycle costs including ordinary jetty repairs and maintenance dredging costs.
2. Provide a real analysis of sediment transport. Include review and reference to data and findings from maintenance dredging records and the studies of the MCR prepared for the multi-agency Southwest Washington Coastal Erosion Study.
3. Describe how implementation of this project will reduce ongoing erosion of the shoals.

USACE Final Evaluator Response (#2)

CONCUR

The current “fix-as-fails” base condition will be revised to reflect current Corps O&M practices at the mouth of the Columbia River. As a result, a comprehensive sediment transport study will be unnecessary. Also, the report will be revised to clearly describe how scheduled jetty repairs will reduce ongoing erosion of the shoals.

The report describes an uppermost bound as the estimated worst case of what could happen with no intervention with a breach event occurring in winter and over a 3 month time period, resulting in a worst case shoaling consequence. This estimate is constrained to an approximate mid-length breach of the North Jetty only and rarely happens in the actual life cycle simulation. At a navigation project of this magnitude and importance, it is prudent to provide an assessment of the potential risk of a no action pathway for decision-makers to factor into their final decision at the project. The questions, “What could go wrong?” and “What might the consequences be of a failure?” are two questions essential to anticipatory engineering. Graduated levels of breaching potential and consequence were developed and incorporated within the event tree model and discussed within the report. Tables have been provided that summarize the potential number of significant breaches projected over the life cycle as well as the average expected shoaling expected from those breaches for the Base Condition and all of the alternatives.

This worst case estimate is based on experience from other locations where similar breaches have occurred, previous similar occurrences at the MCR, as well as the potential volume and gradient of sediment abutting the north side of the North Jetty. Previous occurrences at MCR where intervention was not undertaken (South Jetty, late 1920’s and Jetty A, 1950’s) indicated significant shoaling within the inlet, and constituted the impetus for rehabilitation of the structures in the 1930’s and 1960’s.

Within the limits of its application, the CMS model did show qualitatively that a significant flow field would be established through the jetty breach while prior to the breach, flow was aligned along the jetty. The CMS model was applied by ERDC to estimate the changes in circulation and associated sediment transport resulting from a breach of the north jetty. The hydrodynamic conditions used to drive the CMS model were observed during September 2005. The CMS model was run for a 6.5 day period. The results of the CMS model indicated that 0.2 meters of deposition may occur within the MCR channel 6.5 days after a breach within the mid-span of the north jetty. Projecting this breach-motivated deposition rate from 6.5 days to 3 months would result in 2.5 meters of deposition within the MCR channel, based on a summer forcing environment. During the elevated wave and water level conditions of winter, flow conditions through a simulated jetty breach would be of a much greater magnitude than that simulated by the CMS model. A significant jetty breach would increase in size and impact over a time frame of 3 weeks to 3 months and is expected to occur only during winter time in response to extreme storm conditions.

Modeling sediment transport (above and below water) coupled with morphological change within complex coastal inlets is still evolving in its application. While hydrodynamic models are fairly mature in their ability to simulate 2-dimensional flow patterns, they are still evolving in their ability to simulate 3-dimensional flow patterns.

Some extreme processes are too complex to be parameterized and cannot be accurately modeled; they have to reasonably estimated to arrive at an uppermost bound. The uppermost bound serves as the extreme potential estimate for the process (or response). The upper bound estimate is not expected to be encountered, but it is used to formulate a strategy for dealing with a given process-response-consequence scenario. The process of establishing an upper bound estimate is often undertaken in water resource engineering, and was done so for this project to evaluate the potential effect of a jetty breach. Due to the intervention measures built into the event tree (emergency repair and emergency dredging, if needed), the uppermost bound is not achieved in the MCR model for a breach event.

Portland District experience at Coos Bay has shown that once a deteriorated jetty cross section experiences increased overtopping as well as scour and wave loading, the transition time to a full jetty breach can be fairly rapid. In the case of Coos Bay, the breach developed over a number of days. At some point in jetty cross section degradation, the resilience of the cross section above water reaches a threshold value where it can transition quickly from a partial jetty cross section to a breached jetty. The onset of material passing into the inlet through the jetty through a damaged and eventually breached cross section occurs over a period of weeks to months.

The hydrodynamic flow path developed after a breach would be significantly different than current conditions during which North Jetty site disposal occurs. The CMS modeling effort (and the Coos Bay example) indicates a jetty perpendicular flow path in contrast to the jetty parallel flow path that occurs now. That jetty-perpendicular flowpath would not only take advantage of the large sediment sink of Peacock Spit but would also tend to transport the sediment directly toward the navigation channel which is in closer proximity to the North Jetty than the South Jetty.

All of the referenced sediment transport paths in the "Basis for Comment" are true and occur under a range of environmental conditions, due to the spatially variable nature of the morphology and the effect of circulation at this inlet. A small but distinct change in the morphology at this inlet (such as a jetty breach) can generate large changes in circulation and morphological response. Evidence can be provided (photos, model results, sediment transport study results, ODMDS performance, beach monitoring) that supports the sediment transport discussion in the report.

What would motivate the transport of sediment through a breach in the North Jetty is the gradient of sediment elevation on either side of the jetty and the gradient in circulation during much of the tidal stage. In addition, wave surge and other storm related effects cause localized and enhanced setup along the North Jetty and along Benson Beach. If a hydraulic connection is made from one side of jetty to another, circulation can occur through that breach during most if not all of the tidal cycle. The maximum level of channel deposition for the worst-case no.rth jetty breach scenario was estimated to be 6 meters, and assumed that such a breach would occur in November and continue un-abated for a 3 month period. Emphasis will be added within the report (and on graphics associated graphics) to clarify that the worst case-scenario is an extreme event and is not expected to occur. The morphology configuration resulting from the worst case jetty breach at north and south jetty is based on the expected volume release of the sediment (morphology) presently being held by the jetties and partial transfer through the breach. The resultant post-breach morphology shown in figures 1-33 and 1-34 account for the expected tidal flow and wave action acting on the gradient of sediment from one side of the jetty to the other and are intended to balance the transfer of sediment volume from onse side of each jetty to the other. The MCR breach event estiamtes are based on similar events occurring at Coos Bay, OR, Grays Harbor, WA, and barrier island breaches.

In the evaluation of alternatives we have considered to our best ability the continued evolution (reduction) of morphology at the MCR, based on previous observations as well as other reference documents. We have estimated those effects by estimating continued toe scour along the jetties and continued increase in depth-limited wave heights along the jetties due to morphology evolution. We are not proposing to extend the jetties to their fully authorized length because the morphology associated with that full length is gone. We are proposing, however, to hold the jetty heads in their present condition to provide the full jetty function and maintain the present morphology as much as possible.

With respect to the Washington Coastal Erosion Study (Gelfenbaum, et al, 2006) and the following statement: “The missing sediment from the system and ongoing erosion of the shoals that help protect the jetties all point toward a need for a more rigorous investigation of sediment transport and alternatives that could reduce the loss of sediment and subsequent project O&M costs.” We are undertaking that effort on a parallel path under the Regional Sediment Management program and will reference those studies by collaborative efforts of USACE and all stake-holders. However, deferred jetty maintenance can have a negative effect on morphology and proactive jetty maintenance can have a positive effect on maintaining the present morphology. Future conditions that have been evaluated institute adaptive management for jetty maintenance. Regardless of conclusions on sediment budget, structural actions are required to maintain the degraded 100 year old jetty system to prevent failure and loss of function. Proactive measures that encourage nearshore placement are a good idea and are being pursued under other authorities. Stabilization of the jetty head locations as well as application of spur groins along the jetty foundation are instituted with the express purpose of reducing the potential for morphology loss along the jetties.

1. **ADOPT NOW.** The base condition will be revised to reflect current Corps O&M practices at the mouth of the Columbia River. The jetty breach discussion in the report will be expanded to explain the difference between a small breach with no significant impacts and a larger breach which is not expected to occur. We will add a description for the logic that incrementally

assesses the response to a breach event along the north jetty, if winter dredging is needed to intercept sediment entering the navigation channel. The current study approach presently includes the life-cycle costs exhibited by ordinary jetty repairs and maintenance dredging costs. Although breaching can represent a significant consequence, its overall effect on the future life cycle performance of the MCR jetties is modest.

2. **NOT ADOPT.** Sediment transport and circulation models have been developed for the MCR and were utilized during the Major Rehabilitation study in a manner appropriate to a feasibility level of study. A catastrophic breach of any of the jetties is not considered to be a statistically significant possibility; therefore, a sedimentation analysis of a breach event is unnecessary. In addition, this type of catastrophic process cannot be accurately simulated in a model. Except for the Base Condition, which allows the jetty heads to continue to recede, the alternatives evaluated are not expected to have large impacts on sediment movement in the inlet. Stabilizing the jetty head positions will assist in anchoring the adjacent morphology in its present configuration. Construction of the spur groins should locally improve jetty foundation conditions and deposition along the jetty toe. Additional sediment transport analyses at this stage will not alter the alternative comparison.

3. **ADOPT NOW.** Language will be added to the report describing how scheduled jetty repairs with engineering features will reduce ongoing erosion to the shoals.

Panel Final BackCheck Response (#2)

Non-concur.

Notwithstanding the additional USACE work described in the Evaluator Response, concerns about the inadequacy of the sediment transport analysis remain.

The USACE response does not really add new information, or justify not doing a better sediment study. Specific points made in the basis of comment are not addressed in the Evaluator's Response.

A sedimentation analysis associated with the breach of any of the jetties needs to be conducted to ensure that all alternatives have been investigated.

Literature Cited:

CHL (2007). Analysis of Jetty Rehabilitation at the Mouth of the Columbia River, Washington/Oregon, USA, Part 2: Regional Circulation, Sediment Transport, and Morphology Change. Draft Report (K. J. Connell and J. D. Rosati). USACE Coastal and Hydraulics Laboratory and Portland District joint product, June.

EPA (2009). 2009 Annual Use Plan: Management of Open Water Dredged Material Disposal Sites, Mouth of Columbia River, OR and WA.
http://www.delawareestuary.org/pdf/RSM%20Workshop/MCR_Site_Usage_Plan_2009.pdf

Gelfenbaum, G. R., Kaminsky, G. M., et al. (2006). Southwest Washington Coastal Erosion Study. U.S. Geological Survey Coastal and Marine Geology Program and Washington Department of Ecology – Coastal Monitoring & Analysis Program.
http://www.ecy.wa.gov/programs/sea/swces/overview/findings.htm.

Comment (#3):
The underlying assumption that navigational impacts will not occur is not substantiated.
Basis for Comment:
The report clearly explains why navigation benefits were not analyzed. The method used to calculate NED benefits is based on the assumption that navigation will not be affected; the economic analysis is therefore based on a least cost analysis. This assumption, however, is not supported by the analysis presented in the report. A North Jetty breach in the winter is assumed to result in immediate mobilization of sediment that may impact navigation. If this assumption is true, it does not necessarily follow that emergency dredging will successfully occur to enable deep draft vessel access. As stated on p. 3-14 of the main report, under base conditions, during winter months, emergency jetty repairs and emergency dredging may not be possible, potentially resulting in impacts to navigation until the emergency activities are completed. The main report also states (p. 1-48) that operating a hopper dredge at the MCR during winter months has not yet been attempted. The report does not address the impact of project construction and dredging activities on navigation. For example, the operation of a dredge in the MCR, especially under extreme winter conditions, could have an adverse impact on navigation in the MCR. The Panel was unable to fully understand the potential impacts on navigation of shoaling resulting from a jetty breach. Since navigation benefits were not evaluated, impacts to the MCR or Lower Columbia River (LCR) channels as a result of shoaling after a jetty breach, in the absence of emergency dredging, is only presented in qualitative terms such as "navigation would be significantly impaired" (p. A2-34). The extent of the impacts are not described (i.e., bar closure, vessels delayed due to having to use tides to access the channel, reduced under-keel clearances, vessel lightloading, etc.). Due to the dismissal of potential navigation impacts, no mitigation is defined.
Significance – High:
Conflicting assumptions concerning impacts to navigation invalidate the logic behind calculating NED benefits using a least cost analysis and impacts the selection of the NED, or recommended, plan.
Recommendations for Resolution:
1. Conduct a transportation cost savings analysis to calculate NED benefits. 2. Include a description of the expected channel depths available after a breach event, and in the absence of emergency dredging, include a description of the portion of the fleet using the channel that will be impacted by the resulting shoaling.
USACE Final Evaluator Response (#3)
CONCUR The base condition will be revised to reflect current Corps O&M practices at the mouth of the Columbia River. Hypothetical breach scenarios discussed in the report will be revised as described in the response to COMMENT 2. The Major Rehab report will be revised to remove all conflicting assumptions concerning navigation impacts.

1. **NOT ADOPT.** Revision of the base condition will eliminate the need for such an analysis. See response to COMMENT 5.
2. **NOT ADOPT.** Since a breach of any of the jetties is not considered to be a statistically significant, descriptions of potential fleet impacts is unnecessary.

Panel Final BackCheck Response (#3)

Concur.

The current base condition maintenance strategy conforms most closely with the fix-as-fails strategy described on p. A2-58 of the report. The revised base condition should reflect current Corps O&M practices, which are best described under the "Interim Repair Jetty Maintenance" strategy on p. A2-58 and by use of the interim repair thresholds presented in Table A2-12.

The Evaluator Response to Recommendation 2 indicates that "Since a breach of any of the jetties is not considered to be statistically significant, descriptions of potential fleet impacts is unnecessary." The Panel assumes this statement reflects the probability of a breach under the proposed revised base condition.

Comment (#4):
The SRB model by itself has very limited value for analyzing alternatives and is not a substitute for conventional economic and engineering analysis.
Basis for Comment:
The SRB model results cannot be verified, as it is a custom-made engineering and economics model applicable only to this project and there is no means for the Panel to examine the inner workings of the SRB model and its internal calculations to assess its "adequacy and acceptability". It is not possible to verify model results, or to repeat the application of the SRB model because there is no User's Manual or detailed description of model inputs and how the model was applied for the Mouth of Columbia River project. Furthermore, the model has not been peer reviewed or tested. Without documentation of successful application, the Panel cannot validate the model or have confidence in the results. The SRB model internal calculations and logic are not a commonly applied method for calculating rubble mound structure reliability and damage. The model analyzes more than 600 variables, stacking process upon process, each with wide error bars, resulting in the accumulation of errors. Significant processes do not appear to be included in the model, such as armor rock breakage and deterioration and deep seated slip-circle failures. Figure A2-18a shows model output for jetty cross-section progressive damage. This figure provides one of the few insights into the inner workings of the SRB model. The figure indicates the physics and process of jetty decay are not modeled correctly because the output is not consistent with cross-sections of observed damage. The engineering evaluation does not include much about the physical modeling (i.e., wave tank results). It seems the wave tank model was used to develop the input and equations within the numerical SRB model. It is more conventional to proceed in the opposite sequence, to use a wave tank model to verify a final design concept and verify numerical model predictions. The wave tank model effort was substantial and likely yielded good insights. However, it does not appear that results were used to their fullest potential because the model output and findings were only applied through the SRB model process. The wave tank model results could have been used as part of an independent evaluation, providing an additional line of evidence along with other investigations, data, and findings. The SRB analysis should only be used as one of many tools in the alternatives evaluation rather than a substitute for the preliminary engineering design. Additional engineering analysis and design documentation needs to be provided as part of the preliminary engineering design report. Documentation through the preliminary engineering design process will lead to improved confidence and reliability of SRB analysis.
Significance – High:
The SRB model functions as a "black box" and does not allow an alternatives analysis that is clearly based on sound technical evidence of engineering design performance.

Recommendations for Resolution:
1. Move the SRB model to an appendix, as supplemental information, and assign it a weight of 10% in the evaluation of alternatives. No further work on the SRB model is recommended as part this project. 2. Include a detailed description of the SRB model application allowing verification of model calculations and how the model was applied to the Mouth of Columbia River project. 3. Demonstrate that the model has been peer reviewed and tested. 4. Move the calculations and elements of the study currently within the SRB model (such as rubble-mound damage, slope stability failure, design wave heights and water levels, economic calculations, and much more) out of the SRB model and provide as separate calculations that can be checked and verified. 5. Provide documentation of preliminary engineering analysis and design which would constitute the basis for the SRB analysis. The preliminary engineering analysis should be provided in the report, with details in appendices. Elements that appear missing or inadequate at this level of design include the following: o Design criteria and basis of design o Structure condition assessment and existing condition survey o Subsurface geotechnical investigation o Development of jetty repair/rehabilitation alternatives o Hydrodynamic analysis (waves, currents, sediment transport) specifically related to the alternatives o Determination of stone sizing for alternatives o Alternative evaluation • Development of evaluation criteria • SRB analysis o Detailed volume and cost estimate for the alternatives.
USACE Final Evaluator Response (#4)
NON CONCUR A custom-made engineering model is standard practice and a requirement for execution of a Major Rehabilitation study which requires the development of a life cycle performance event tree. The model simulates the project event tree and was intended to be applicable specifically to the MCR project and to provide input relevant to the comparison of various jetty structure maintenance options. (See attachment 1_EP_1130_2_500_exerpts for Major Rehabilitation guidance relevant to study execution.) Model documentation has been provided to illustrate how the model operates and how it was applied to the MCR project. Attachment 2_summarizes key locations in the Major Rehab report which addresses primary areas of interest. Attachment 3 simply summarizes the key elements of the life cycle simulation. Attachments 4 and 5 illustrate the project event tree and the model execution flowchart as well as the range of input data which was utilized in the model execution. Major Rehabilitation guidance directs us to probabilistically analyze structure performance modes (methods of failure), translate that to the expected physical degradation of the structure and the project, and summarize what the cost and consequences of that process might be to the functioning of the project. The apparent complexity of the model is directly related to the

intricacies of the project being analyzed as well as the fact that we are attempting to support a critical infrastructure decision relevant to a $200 to $400 million dollar federal investment as well as a $16 billion per year project function. We are analyzing 3 separate primary navigation structures (total length of approximately 7 miles) that have variable existing conditions, variable loading, and variable consequences of failure along each of their lengths. In the end the basic question should be "Does the analysis compare in a reasonable manner the various maintenance alternatives for the MCR structures and are the key performance categories adequately captured?"

The SRB model simulates the project event tree for the MCR jetties. The model tests the sensitivity of parameters used to define various jetty maintenance scenarios, rehab alternatives, and engineering feature. There are no off-the-shelf models that would perform a life cycle analysis of a complex project such as the MCR in any useful way. A great deal of effort went into capturing how this project has performed, performs now, and is expected to perform into the future; using variable loading and changing site conditions, both structurally and functionally. Simply stated, the basic elements of the MCR SRB model are jetty degradation and life-cycle consequences of jetty degradation. The model does not perform design calculations or syntheses of alternative attributes; these aspects of project development were performed external from the SRB model.

The successful application of the model is supported by calibration to 100 years of history as well as projecting reasonable project performance results into the future for a range of alternatives. The model results do not suggest either catastrophic future conditions or unreasonable maintenance requirements for a large infrastructure project subjected to heavy environmental loading and changing future conditions. (Attachment 6 provides the hindcast results for the 100 years of jetty and project evolution.) (Attachment 8 shows the future base condition for the North Jetty as estimated using the project event tree simulation (SRB model) as compared to the observed past maintenance history and other projected O&M rates based on the previous life cycle. Collectively, this figure shows the reasonableness of the SRB model projection for the Base Condition. Additional figures will be added to the main report to show results for the other jetties.)

Standard and approved rubble mound design engineering equations were utilized to assess reliability and performance. The design parameters and attributes were developed external to the model using standard Corps of Engineers practices, i.e. the model itself does not calculate design attributes for various alternatives.

All of the observed historically significant damage processes on the MCR structures include damages either due to slope failure or wave damage processes. A slope stability analysis (refer to Appendix B) determined that deep-seated slip circle failures were not a factor that affects jetty performance at this location. Armor stone breakage has also not be shown to be a significant damage process that needs to be included. (reference Appendix B) The cross section evolution figure noted is a generic representation of primary damage modes and their interactive effects. Damage processes shown are the same as documented and illustrated in the technical literature (reference CEM). (See Attachment 7 for standard representations of rubblemound damage processes as well as cross section examples of those observed processes on the MCR structures.)

Engineering calculations performed in the SRB model are:

- jetty cross section evolution under an annual wave loading scenario
- cumulative cross section damages leading up to either routine or emergency jetty repair
- quantity calculation of rock needed to repair the jetty
- time-varying reliability of the jetty at each 100 ft station
- quantity calculation of dredging needed due to jetty-damage related processes (breach or loss of jetty length)
- engineering calculations of costs to repair or dredging by year.

The products of the model are jetty repair and dredging volumes and costs given in 2010 dollars. That information is provided to the economist on an annual basis over the period of analysis for their economic calculation. External to the model, our economist calculates the BCR by taking the ratio of (Base condition cost- alternative plan costs)/Base condition costs. That economic information in conjunction with the estimate of reliability and other decision metrics is used in the final selection process of the alternatives. A recommended alternative is not selected in the model. The SRB model is a stochastic process model that attempts to account for the potential uncertainty in all of the parameters evaluated related to project performance. Through the Monte Carlo process the interaction of uncertainties contributes (interacts) to the final prediction to arrive at an informed and non-deterministic estimate for metrics of project stability and performance. (See attachment 1_EP_1130_2_500_exerpts for Major Rehabilitation guidance relevant to study execution.)

The physical modeling for the MCR project was used at two separate levels. The first was to evaluate and inform on initial design parameters/elements for cross section alternatives and stone sizes. The physical modeling was also used to provide input to the damage functions utilized to translate initial jetty cross section damage to continued degradation. The physical modelers and designers, and jetty construction experts/representatives worked together to refine and test design alternatives during the physical modeling phase of the study. The extent to which physical modeling was utilized in this study is considered adequate to a feasibility level of design and comparison of alternatives.

1. NOT ADOPT. The SRB model follows the project event tree simulation which is a requirement of the Major Rehabilitation Program Guidance. (See attachment 1.) The model is used to perform a life cycle performance evaluation which is required as part of the alternative analysis. The model is currently under review by USACE HQ; the results of the model will not be used in the Major Rehab Report if the model is not approved for use.
2. ADOPT NOW. Additional description of the model application was provided separately to the panel entitled “Model Operation Guide”. The calibration and verification of the model was demonstrated through the life-cycle hind cast process. The reasonableness of the model results for the MCR project to make future projections based on comparison with other calculation methods will be incorporated into Section 3.7.3. Attachment 8 illustrates the SRB model result projection for the Base Condition for the North Jetty in contrast to past O&M history at the project.
3. ADOPT NOW. The model review/testing has been conducted according to USACE requirements for this type of an application and study. Project specific models developed under the Major Rehabilitation program are not intended for multiple projects and Corps wide use. The SRB model was reviewed/tested at the District level and reviewed/tested through an Agency Technical Review.
4. ADOPT NOW. The model will remain as it currently is, and Section 3.7.3 will provide a description of the calculations that are conducted within the model and those that are calculated

external to the model. Section 3.7.3 will also provide information to demonstrate that individual processes emulated within the SRB model can be verified (Jetty damage, head recession, sediment volume into channel associated with head recession, shoreline recession related to head recession, channel shoaling related to shoreline recession, scour calculations, breach volume estimates). **5. ADOPT NOW**. These elements will be addressed as follows. Design Criteria and Basis of Design will be more fully summarized in Section 3.5, S tructure condition assessment and existing condition survey will be added to Section 1.4 a nd A1, Subsurface geotechnical investigation is addressed in Appendix B. Attachment 9 pr ovides additional information relevant to the request for subsurface investigations. Development of jetty repair/rehabilitation alternatives is currently addressed in Section 3.9, Hydrodynamic analysis summary will be added to Section 3.5, More details on the determination of stone sizing will be added to Section 3.5,The Alternative evaluation occurs outside of the model using model output as well as previously identified decision criteria.
Panel Final BackCheck Response (#4)
Non-concur. While many elements of the SRB model are appropriate and required per USACE guidance and standard engineering practice, it is not reasonable to fold it all together like this into one big model. Event-tree analysis, progressive damage calculations, and life-cycle costs are all good things to analyze. The SRB model effort seems to go off on a tangent from these elements, adding in engineering and other modules. The SRB model seems inappropriate based on USACE published guidance and does not support the project goals. The SRB model effort seems a Research and Development effort grafted onto an applied project. It has not been verified and validated and should not be relied upon.

Comment (#5):
The base condition, as formulated, does not represent the current O&M practice.
Basis for Comment:
The present and future base condition maintenance strategy for the MCR jetties, as currently described in the report, conforms most closely with the fix-as-fails strategy. Under this scenario, jetties will be allowed to deteriorate to the point that just-in-time repairs may not prevent a breach in the jetty, which would result in expensive, winter dredging activities. As the project is currently formulated, the base condition life-cycle costs are the basis for estimating project benefits for all action alternatives. Historical maintenance efforts for MCR jetties are best described by an interim repair strategy. As a result of monitoring and advance repair activities, historically there have been no jetty breaches that have impacted navigation, nor has winter dredging been needed to maintain navigation. EP 1130-2-500, Appendix C, p. C-1 (USACE, 2006) states that for Major Rehabilitation Projects, under the base condition, "maintenance is increased as needed (but within limits) and components or sub-features are repaired on an emergency basis. This essentially represents the current O&M practice." Based on the report, this condition would resemble an interim repair strategy, rather than the fix-as-fails strategy currently described as the base condition.
Significance – High:
Inaccurate formulation of the base condition may increase life cycle costs, and may erroneously escalate project benefits for all action alternatives thus impacting the benefit to cost ratios.
Recommendations for Resolution:
1. Refine the base condition to more closely resemble the current O&M practice, in accordance with EP 1130-2-500, Appendix C (USACE, 1996).
USACE Final Evaluator Response (#5)
CONCUR The base condition utilized in the model will emulate past, current and future with/out project condition levels of maintenance. It is recognized by the PDT that the Jetties currently have a significant amount of deferred maintenance, and that condition was emphasized in the report. It is not the District's policy or intent to allow them to fail to perform their required function. The district will mobilize the resources required to prevent impacts to the channel under all but the most extreme series of events. **1. ADOPT NOW** The base condition will be re-run with the results incorporated into the main report. This will reduce the frequency of the SRB model predicting catastrophic jetty failure, which will also have an impact on both comment 2 and 3.
Panel Final BackCheck Response (#5)
Concur. The current base condition maintenance strategy conforms most closely with the fix-as-fails strategy described on p. A2-58 of the report. The revised base condition should reflect current Corps O&M practices, which are best described under the "Interim Repair Jetty Maintenance" strategy on p. A2-58 and by use of the interim repair thresholds presented in Table A2-12.

Literature Cited:

USACE (1996). Project Operations – Partners and Support. Department of the Army, U.S. Army Corps of Engineers, Washington, D.C. Engineer Pamphlet 1130-2-500. 27 December.

Comment (#6):
The reported analysis and design to mitigate a potential breach of the foreshore dune at the South Jetty root is not adequate.
Basis for Comment:
Potential breaching of the foreshore dune at the South Jetty root, to form a new connection to Trestle Bay, is discussed briefly in a few places, including a proposed cobble berm to mitigate this risk in the main report (Section 3.5.3.3, pp. 3-40 - 3-41, p. 7-1 and elsewhere). Additional analysis is appropriate given the consequences of breaching at this location. It is not clear what analysis has been conducted to evaluate the performance of the proposed dune augmentation. It is not known if the volume of material per linear foot is sufficient to provide the required width of cobble beach for stable conditions upon adjustment after initial placement. Maintenance requirements are not known for this design. Studies by DOGAMI (Allen, 2005) have been conducted on dynamic revetments for shoreline stabilization on the Oregon Coast but do not appear to have been applied. The breaching potential will likely increase with increasing shoreline erosion and loss of sediment from the system. However, potential beneficial use of dredged sediment is not analyzed as part of a design solution for a breach. Long-term erosion trends are assumed and are not adequately addressed in the report. The information provided is inconsistent in this area, with some sections saying the South Jetty dune erosion/augmentation issue will be addressed as part of a separate project, whereas other report sections include South Jetty dune augmentation as part of this project. Foreshore dune breaching has occurred at other coastal inlet navigation jetty structures along the Pacific Coast such as the South Jetty at Grays Harbor, Washington. Beach renourishment with dredged material and jetty structure modification improvements to prevent dune breaching were made with varying levels of success. It is not clear whether these similar project conditions and performance have been evaluated as part of the development and analysis of alternatives at the Columbia River South Jetty location.
Significance – High:
Breaching the dune at the South Jetty root appears to be a substantial risk, with more immediate consequences than breaching of a jetty because of the potential for forming a new tidal inlet with relatively rapid widening and deepening.
Recommendations for Resolution:
1. Either include the South Jetty dune augmentation/stabilization as part of the alternatives, and include costs and preliminary engineering, or state that it is not an element of the proposed work and is part of a separate project. Either way, potential breaching scenarios should be evaluated/modeled and included in the sediment transport and hydraulic analysis. This major investigation is the logical place to add studies of the MCR system (including jetties, navigation channel, estuary, and beaches). 2. Account for long-term shoreline erosion/recession trends in the design. 3. Review other jetty rehabilitation project solutions and performance at coastal inlet navigation facilities such as those conducted at the Grays Harbor South Jetty (Wamsley, 2006).

USACE Final Evaluator Response (#6)

CONCUR

The South Jetty Dune augmentation project while discussed in the MCR Major Rehab Report is a project that will move forward with or with/out the MCR project. The Dune Augmentation project will undergo a design phase where additional alternatives are reviewed and analyzed.

Figure A1-IPR6 shows the specific area of chronic erosion which has been affecting the MCR South Jetty root since the late 1970s. The intertidal zone has receded landward ~40 ft during 2003-2007, reducing the protective foredune along the south jetty root. The 35-ft high foredune protects the backshore (elevation 15-18 ft NAVD) from wave surge action during storms. If the foredune is breached, the backshore will be rapidly eroded; at a rate much higher than the present foredune recession. Without abatement of the present foredune erosion, it is estimated that the Pacific Ocean will establish hydraulic connectivity with Trestle Bay in 6-113 years from 2011, and threaten inlet stability. Two alternatives were investigated at an appropriate screening level, as described below. The Cobble Berm Foredune augmentation was selected based on the attributes described. Figure A1-IPR6 shows a range in proposed options for augmenting the foredune within the erosion embayment, in terms of cross-section template and estimated aerial configuration. The two (2) options for south jetty foredune augmentation were developed based on potential variation of the implementation strategy to achieve the objective which is to stabilize the foredune within the erosion embayment adjacent to the south jetty. To adequately protect the foredune during storm conditions, the template for both template options requires that the top of fill (crest) extend vertically to 25 ft NAVD and have an alongshore application length of ~1,100 ft extending southward from the south jetty root. The constructed template crest would be 10-15 ft above present beach grade and have a 1V:10H slope aspect, from crest to existing grade.

<u>SAND Berm Foredune Augmentation</u>: Augmenting the south jetty foredune using a SAND fill template will require placement of ~225,000 cy of sand. Maximum crest width of the SAND fill template is estimated to extend 400 ft seaward from the seaward base of the present foredune. Construction of the SAND berm augmentation would require 4-8 weeks. Two options may be available for placing the SAND fill material. The gradation of the sand fill material will vary from fine sand to course sand depending upon the source of the material Sand procured from upland sources would be placed using haul trucks and dozers; in this case the sand is more likely to be medium to course sand. Upland sourced sand would be transported on surface roads, through Ft. Stevens Park to the project site to a beach access point at the project site. There is a potential for the sand fill material to be procured from MCR or LCR navigation channel during O&M dredging. The dredged material (clean sand of variable gradation, 0.1 – 0.3 mm) would be pumped ashore, to the south jetty root, using a hopper dredge "pump-ashore" method. The hopper dredge would likely pump-off sand from the interior area of Clatsop Spit near Trestle Bay (CRM 6). The south jetty hopper dredge pump-off area would be located near the jetty stone marine delivery area proposed for South Jetty Rehabilitation. The sand would be pumped through pipeline (18-24 in diameter, for a distance of 1.5 miles during the summer season. A booster pump may be needed at mid-span. The dredged sand would be hydraulically placed at the project site; with dozers used to re-grade the material to the construction template. The pump-ashore method has been used to place MCR dredged sand along the north jetty foredune to stabilize the north jetty root and protect it from wave surge action. A SAND

berm template will be reformed by wave-surge action. The coarser the material, the more stable the berm will be over time. Over time the slope of the sand berm would be flattened to perhaps 1V:70H. If the south jetty is rehabilitated with spur groins, the resilience of the south jetty root and the sand berm will be increased. If the south jetty is not rehabilitated, the sand berm may require maintenance on a periodic basis of 3-6 years; assume 70% replacement volume.

COBBLE Berm Foredune Augmentation: Augmenting the south jetty foredune using a COBBLE fill template will require placement of ~60,000 cy of cobble material. The Gradation of the cobble fill would span 10-200 mm. Maximum crest width of the COBBLE fill template is estimated to extend 70 ft seaward from the seaward base of the present foredune. Construction of the COBBLE berm augmentation would require 2-6 weeks. Cobble fill material would be procured from upland sources and placed using haul trucks and dozers. The cobble material would be transported on surface roads, through Ft. Stevens Park to the project site to a beach access point at the project site. The cobble berm would be more resistant to wave action than a berm constructed using sand. Over time the slope of the cobble berm would be flattened to perhaps 1V:20H. The areal configuration of the cobble berm should preclude significant alongshore displacement. Although offshore transport of the cobble material is expected to be much less than for sand, over a significant period of time, the cobble berm will lose material. The cobble berm would emulate the foreshore conditions similar to those at Seaside, OR 18 miles south of the south jetty. If the south jetty is rehabilitated with spur groins, the resilience of the south jetty root and the sand berm will be increased. If the south jetty is not rehabilitated, the cobble berm may require maintenance on a periodic basis of 4-10 years; assume 40% replacement volume. The advantages of the cobble berm are that it would require less material than a sand berm, exhibit more resiliency, and have a smaller construction foot print. A disadvantage is that the unit cost for cobble material may be higher than for sand.

The timing of this action is expected to be within first 8 years of the proposed jetty rehab project (after 2011). It must be noted that nearshore placement of MCR dredged material within the proposed South Jetty Site (SJS) nearshore disposal site would mitigate the erosion of the south jetty root area. This SJS would complement the proposed foredune augmentation and help ensure balance of the sediment budget south of the south jetty. The SJS should not viewed as a replacement for foredune augmentation.

1. **ADOPT NOW** We will clarify that this is part of the Base Condition which will be implemented regardless of the outcome of the MCR Jetties Major Rehabilitation project. Within a broad assessment we have determined that the consequences of a breach in this area would be high enough to warrant preventive measures as proposed now. Preventative action has been determined to be merited in this location. Potential breaching scenarios and consequences will be evaluated in the design phase of that action.
2. **ADOPT in FUTURE**. L ong-term shoreline erosion/recession trends will be more closely evaluated in the design phase. S hort-term observations since 2003 indicate a rapid recession rate of the foredune is now occurring within the local embayment / erosion zone which extends several hundred meters south of the South Jetty.
3. **ADOPT in FUTURE**. Related studies and reports will be reviewed for inclusion into the DDR.

Panel Final BackCheck Response (#6)
Concur. The shoreline erosion/recession trends should be accounted for now, at an early, high level planning stage and implemented as part of this project.

Literature Cited:
Allen, J. (2005). Cape Lookout shoreline stabilization study: Don't take the cobbles. Cascadia, News from the Oregon Department of Geology and Mineral Industries (DOGAMI). Winter. http://www.oregongeology.com/sub/quarpub/CascadiaWinter2005.pdf

Wamsley, T.V., M.A. Cialone, K. J. Connell, and N.C. Kraus (2006). Breach History and Susceptibility Study, South Jetty, Grays Harbor, Washington. USACE, Coastal and Hydraulics Laboratory. Report ERDC/CHL TR-06-22. September. http://www.dtic.mil/cgi-bin/GetTRDoc?AD=ADA456060&Location=U2&doc=GetTRDoc.pdf

Comment (#7):

The basis of design and design environmental criteria are vague, not consistent within the report, and not consistent with conventional coastal engineering design practice.

Basis for Comment:

The document "design_criteria_info.doc" is vague. It discusses "50 year alternatives," but the term is not defined. It could mean many things, including the following:

1. The project life is 50 years, with complete replacement assumed after 50 years.
2. Design jetty repairs that have the least life-cycle costs over a 50 year period.
3. The economic planning horizon, benefits and costs, are calculated for 50 years.
4. Design to withstand a series of storms over a 50 year period.
5. Design to withstand a single 50 year return period storm event.

Section 3.5.2.1 (Cross Section Intent and Design Philosophy) states, "The repair template must … allow the maximum repair within funding limitations." This indicates the main design criterion is to provide the most repair possible within a budget limit, rather than design to withstand environmental loads and forces. The "funding limitations" are not stated, yet appear to be behind many of the design and planning decisions. Using funding limitations as a design criterion is not the same as an engineered design that meets environmental loading criteria. The funding limits design criteria are not consistent with the environmental loading design criteria in "design_criteria_info.doc."

Note that a 50 year project life does not necessarily mean one should apply a 50 year return period event for the design environmental criteria. For example, a petroleum development platform may have only a 35 year project life, but the project may be designed to withstand a 100 year return period storm event or longer. The consequences of jetty failure should be considered in establishing the design criteria. ISO standards are sometimes applied in practice, but do not seem to be included in this work. Additionally, USACE (1995; paragraph 2-4) states rubblemound structures should be designed to successfully withstand the conditions that have a 50% probability of being exceeded during the project's economic service life. The economic service life needs to first be established as a criterion and then the design storm formulated to meet the acceptable risk level for that service life.

A span of 50 years may be appropriate for an economic planning horizon; however, a 50 year project life or a 50 year return period storm event does not seem reasonable for engineering design considering the importance of navigation through the MCR. The structures should be designed to last indefinitely, as permanent structures, with regular maintenance requirements estimated and included in an economic analysis.

The 50 year criterion may not be consistent with parts of the report that mention a longer period of time. The SRB model discussion in Appendix A2, p. 78 states, "The period of analysis for future condition simulations was 64 years (2006 to 2070) for the North Jetty and Jetty A and 63 years (2007 to 2070) for South Jetty."

Appendix A2 (p. A2-8) states, "The MCR jetties were constructed to achieve an expected service life of 50-100 years," and concludes that 0.7% per year is the expected maintenance cost based on the 50-100 years service life. The 50-100 years service life, and associated 0.7% figure is used to inform the analysis and to demonstrate a lack of maintenance. However, the original 50-100 years service life, and 0.7% annual expected maintenance cost are arbitrary assumptions. The historic assumed service life and maintenance needs are not supported by the information presented, and largely irrelevant to today's design and maintenance criteria.

The design criteria, if any, from 100 years ago when the jetties were built are not presented and previous maintenance are considered an operational cost. Analysis of past maintenance also may distract from the main problem afflicting the jetties: poor design 100 years ago, not deferred maintenance.

The original builders, working before the development of modern coastal engineering methods, underdesigned the jetties with only 7 ton armor rock, at their angle of repose of 1.25h:1v, or steeper. In addition, they constructed the immense structures on ever shifting sand shoals, locating them where the shoal happened to be at the time of construction, without adequate design features to account for shifting channels and currents.

The starting assumptions and criteria and alternatives are so narrowly constrained that there is questionable value in much of the analysis. The Major Rehabilitation Evaluation study is set up so that the end result is always the same; more rock within the existing jetty footprint.

Conventional coastal engineering practice for a project of this scope would include the following:

1. Analysis to determine how much jetty is really needed today to maintain the navigation channel at reasonable cost. The Panel questions whether all 9+ miles of jetty are optimal. There has been no upward trend in maintenance dredging volumes since 1956, despite continued jetty tip recession, which indicates shorter jetty lengths would be equally functional at less cost.
2. Evaluation of alternatives that are not constrained to the original footprint, not built to the maximum crest elevation and authorized length feasible, not constrained only to rock, and discussed or considered beneficial use of dredged material as a design element.
3. Evaluation of durability issues and lessons learned from related projects. For example, the Dover Pier in England has lasted well over 100 years. Similarly, the Humboldt Bay jetties and Crescent City jetties in Northern California have effectively stopped jetty head recession using 40 ton dolos concete armor units, and the Japanese are building breakwaters with 90 ton dolos concrete armor units.

Significance – High:

The lack of criteria prevents NED analysis and evaluation of whether the structure design meets standards.

Recommendations for Resolution:

1. Establish conventional project criteria including project life, standards of performance and function to be met, and environmental loads and return period events, which are part of conventional coastal engineering design practice. Document in a Preliminary Design Report.
2. Establish Design Environmental Conditions that have a specific return period.
3. If unable to meet the design criteria due to budget limits, state the budget limits as a criterion, and estimate what the equivalent design life or expected performance will be for the compromised design.
4. Expand the starting assumption to allow:
    a. Beneficial use of dredged material as a component of jetty rehab.
    b. A design outside the existing jetty footprint
    c. A design that may allow jetty head recession up to a point when maintenance dredging needs increase.
    d. A design that can include a partially submerged jetty cross-section.

5. Use a longer return period than 50 years for the design environmental criteria and consider ISO standards.
6. Consult with Dover Pier representatives and other jetty builders to discuss durability issues and lessons learned from their project in order to benefit the MCR project.

USACE Final Evaluator Response (#7)

NON-CONCUR

Feasibility level design templates were developed using standard deterministic analysis techniques, supplemented by physical model input. The goal of the study is to identify the optimum repair and rehabilitation strategy contrasting initial and up-front costs vs recurring maintenance costs over the 50 year life cycle.

We have an ensemble of offshore storm wave events and nearshore water levels spanning from the sub-annual to the 50 year occurrence interval for the MCR project area. Various cross section alternatives (varying levels of robustness and maintenance strategies) were evaluated and then assessed in terms of their least cost and reliability characteristics over the planning period. Alternatives analyzed in this phase of study were commensurate with a feasibility level of study providing enough detail to identify key differences between performance and cost of alternatives. A more detailed, focused and rigorous design effort will be conducted in the next phase of study, the detailed design phase.

In the MCR climate, zero damage design is not achievable. Rubblemound structures in the PAC NW will incur heavy overtopping and can also suffer from foundation scour and below water slope adjustment. However, the flexibility of the rubblemound structure and its ability to heal itself after incurring some damage is critical. In contrast, a concrete armor unit structure would be more vulnerable to individual armor unit movement as well as overtopping forces.

In terms of cost optimization, cross section alternatives seek to avoid requiring a higher crest, a flatter sideslope, or extremely large armor units since all of these issues result in either much higher up-front costs and/or constructability issues. The feasibility design cross sections developed utilize standard design criteria to withstand the expected environmental loads and forces. Staying on the relic stone base minimizes the cost of repair or rehabilitation and ensures a stable base to tie in the alternative with the existing structure.

Beyond that ,we have to be able to identify a range of reasonable repair options over the planning horizon for the MCR jetties which is 50 years, commensurate with maintaining jetty function and performance. This was accomplished starting with the identification of a minimum template application along the jetty length which specifically fits on top of the existing structure. Graduated levels of cross section application above that minimum template were then applied along the jetty length as well as various combinations of the cross section graduated levels.

The composite alternatives (shown in figures 3-49 and 3-54) and discussed in section 3.10.3, provide alternative transition points along each structure from a less robust cross section application to a more robust cross section application. The study evaluated 5 composite alternatives for the South Jetty and 4 composite alternatives for the North Jetty in an effort to optimally address the variable loading climate along each structure.

The period of analysis for this study is the future economic service life (50 years) plus the project implementation period, as prescribed by the planning guidance (ER-1105-2-100). The PDT has developed a range of alternatives that optimize life cycle metrics over that period of analysis and that have the additional criteria of minimizing the risk of unsatisfactory project performance (loss of project function). The project event tree simulation and risk-based analysis as dictated by Major Rehabilitation guidance translates the various repair and maintenance strategies into their respective life cycle cost streams.

The evaluation procedures for major rehabilitation require the Districts to use risk-based benefit-cost analysis incorporating the existing and future risk of "unsatisfactory performance" of structures and equipment. These risks are then combined with estimates of the costs of unsatisfactory performance to generate an expected reliability based cost. Alternative rehabilitation strategies are then proposed to reduce this cost. Each alternative can either change the risk, change the cost of unsatisfactory performance or both. A complicating difficulty is that the analysis must be carried out over the "life-cycle" of the project, up to 50 years. That is, the cost estimated is the present value of all costs associated with the operation, maintenance, and repair of the facility where each cost is weighted by the probability of occurrence. (EP 1130_2_500).

The period of analysis analyzed in the SRB model starts from a point of knowledge of the jetties present condition connected to the last full survey of the jetty structures (2006), includes the implementation time frame and the economic service life. However, all alternatives are compared over the same time frame.

Despite the formidable challenges faced by the engineers for the original MCR jetties (severe working environment), lack of established design criteria, and limitations encountered during initial construction, the MCR jetties have performed rather well during their previous life-cycle. While the original project authorization was expected to be for a 50 year life, by default the service life of the original jetty structures has extended to an approximate life of 100 years. The jetties were originally constructed and repaired over the life cycle using progressively larger stone sizes and larger design templates as design criteria changed and equipment capacity evolved. At the same time, the surrounding loading climate was being altered. The 0.7% per year of expected maintenance cost was estimated to attempt to quantify how well the structures have survived. Standard practice is to expect a certain annualized replacement rate on a rubblemound structure. We calculated the approximate repair rate to determine how well the project appeared to be performing in relationship to the realized maintenance rate.

Since the original design criteria for the construction of the jetties over 100 years ago was not available and could very possibly have been constrained by stone size availability as well as transport and equipment restrictions, the information available to assess jetty performance was the maintenance history along the jetty length. While the design criteria were not known, we do have a complete record of the cross section construction parameters. Through the course of this study we have determined how well have the jetties have performed to date. This provides context to necessary stone sizes and cross section dimensions along the length of each structure, answering the question of whether the jetties have adequately performed over their life span under the historical maintenance scenario. We needed to be able to answer if it is feasible to continue to maintain the jetties in the present and historical manner without other extreme measures.

While it was important to identify a potential range of alternative options, fully utilizing the existing structure and existing federal investment in order to minimize the additional repair/rehabilitation cost was essential. That goal as well as the relative success of the past 100 years in jetty stability led to a range of alternatives that built on top of the existing structure and fully utilized the relic stone base. Other similar Pacific west coast jetty rehabilitation examples illustrate the critical design alternatives characteristics: (1) maintain compliance and flexibility under significant design loading and (2) take full advantage of the already established stable relic base. In the more heavily loaded reaches of the structures, either modifying the cross section to extend off of the existing footprint for added cross section stability and/or utilization of other armor types have been included as options.

The major rehab guidance directs comparison of maintenance strategies for the structures we have in place. Modifying the project layout is not part of the Major Rehab goal. Extensive hydrodynamic modeling was conducted to evaluate re-building a portion of each jetties authorized length. The model results showed that the project performance improvements connected with rebuilding the jetty length were not sufficient to offset the extreme costs of building out into the Pacific. Early on in the Major Rehabilitation study it was determined that for this study, stabilization of the jetty heads at the current location was recommended in order to not impact navigation as well as environmental and sedimentary processes.

We include several alternatives that extend beyond the existing footprint. We also adjust the crest elevation at various locations below the previously-constructed crest elevation; however, a minimum crest elevation is required to limit overtopping damage and allow safe construction access. The decision was made not to rebuild the jetties out to previously authorized lengths. While the majority of the repair work can be accomplished by the more cost-effective stone armor units, in some locations, concrete armor units may be considered. This will be evaluated specifically for the jetty heads during the next detailed design phase. While the use of dredged material as an additional benefit for the morphology is being pursued under a parallel effort, it cannot be guaranteed to be implemented due to regulatory challenges and in addition, if implemented the immediate short term benefits will not take the place of structural fortifications of the jetties. We are considering concrete armor units for the more heavily loaded jetty head designs to be more fully explored in the next detailed design phase.

1. **ADOPT NOW.** by providing additional design documentation and clarification. This report represents a feasibility design pursuant to Major Rehabilitation guidance. The more detailed design effort will occur in subsequent detailed design reports. The design wave and nearshore water level environment will be defined in terms of estimated return intervals. A table will be prepared that summarizes the design attributes for alternatives as defined by the assumed loading (event) parameters, including the expected maximum loading event. Additional explanation will be provided that clarifies why alternative development (for rock armor alternatives) cannot be limited by a “0 damage” design requirement: Due to the severity of the forcing environment, armor production, transport, handling limitations, and construction equipment/placement limitations. Because of these limitations, some areas of the MCR jetties have alternatives that can sustain damage and still function for a given period of time before requiring maintenance. Along some of the most extreme jetty areas, CAUs may need to be used in place of rock armor. M-CASES cost estimates for CAU cross-sections have been made, which show that CAUs may be cost effective when compared to the maximum-sized rock armor units that are constructible. However, if CAUs are used, then the “0 damage” design requirement will be enforced for alternative development: CAUs become ineffective if damaged or

displaced.

2. **ADOPT NOW**. by providing definition of design environmental conditions that have already been established and have been used in this study. It is worthwhile to note that when the estimated 50-year and 100-year offshore wave event is transformed to the jetties, the nearshore wave height (Hmo) at the jetties increases less than 0.1 meters as compared to the 25-year observed offshore storm condition (largest observed storm condition). A discussion will be added to integrate the description for the return period of the present offshore wave environment, the return period of the storm induced water levels along the MCR jetties, the depth-limited natures of large waves approaching the nearshore waters along the jetties, and the estimated return interval for waves affecting the jetties.

3. **NOT ADOPT**. The event tree and the SRB model were used to estimate life cycle costs relative to initial investment and repair strategies.

4. **NOT ADOPT.** Beneficial use of dredged material is being evaluated along a parallel effort but cannot take the place of structural repair in this loading environment. Several alternatives already extend beyond the existing jetty footprint. Jetty head recession beyond the current station was determined to be unacceptable due to potential navigation, sedimentary, and environmental impacts.

5. **NOT ADOPT**. This Major Rehabilitation feasibility design follows normal Corps guidance for rubblemound structure design. A description of the maximum estimated loading event to affect the MCR jetties (in terms of water level and wave height) will be added to an appropriate location within the report.

6. **ADOPT in FUTURE**. The MCR jetties have over 100 years of performance and evolution to inform the current and future maintenance strategies at this location. Stone durability has not been found to be an issue with the damage processes. Further design investigations and development will occur during the detailed design phase. The PDT will review the available literature for Dover Pier, and assess lessons learned from that project as they may be applied to the MCR jetties"

Panel Final BackCheck Response (#7)

Concur

The report and SRB model do not incorporate specific design elements such as a 100 year return period wave or water level.

Note the following from USACE "Engineering and Design: Life-Cycle Design and Performance. Engineering Regulation", 1997, 1110-2-8159.
"...design decisions will be consistent throughout all project phases, including value engineering studies, and will be based on a minimum project service life of 100 years for major infrastructure projects such as locks, dams and levees.", and
"Major Civil Works projects can have an indefinite service life."

The report is not consistent with this guidance. However, it is understood that USACE may interpret the regulations differently, and the project team sees a 50 year service life as acceptable if there are no life-safety issues involved.

The standard of practice for coastal engineering requires defining a storm event, such as the 100 year return period waves and water levels, then designing the structure to withstand that event.

The assumption that stone durability is not an issue is not consistent with standard coastal engineering practice.

Literature Cited:

USACE. (2005). Design of Coastal Revetments, Seawalls, and Bulkheads. Department of the Army, U.S. Army Corps of Engineers. Manual EM 1110-2-1614. June.

Comment (#8):

The models and analyses of jetty failure do not include all significant processes.

Basis for Comment:

The SRB and STWAVE models cover many significant processes and variables that affect long-term jetty stability; however, some variables and processes are missing that should be presented in the SRB model and the Major Rehabilitation Evaluation Report:

- Armor rock breakage, rounding and wear, which can significantly affect jetty performance, do not appear to be included in the analysis.
- Deep seated slip surface failures through the jetty section, a global failure similar to a landslide, also do not appear to be analyzed and may be a significant risk.
- Wave height in combination with currents can cause significantly higher sediment transport rates than waves only or currents only. It is not clear if sediment transport analysis, considering both waves and currents acting together, has been done.
- Long-term changes in outlet channel morphology do not appear to be analyzed. The process of jetty decay through tidal channel scour appears different at Jetty A than at the North or South Jetties. Tidal channel scour at the tip of Jetty A will not be mitigated by adding spur groins, therefore a different system will need to be designed at Jetty A and accounted for in the jetty performance analysis.

The STWAVE model is not sufficient for modeling detailed wave transformations. Important processes such as wave structure interactions, refraction, and diffraction are incorporated in STWAVE using approximate methods. Other models like BOUSS-2D and CGWAVE are readily available and model the physics of these important processes more directly. STWAVE is appropriately applied as a regional wind-wave generation model for regions without a complex bathymetry. However, the Mouth of the Columbia River morphology near the jetties and navigation channel is complex. A phase-resolving wave transformation model such as BOUSS-2D or CGWAVE should be applied at this level of design in addition to STWAVE.

Significance – High:

The analysis of potential jetty failures, waves, currents, and sediment transport is incomplete for this level of design, and may result in significant errors in the evaluation of alternatives. Errors could include underestimating the design wave height, leading to undersized armor rock, excessive maintenance requirements and structure failure.

Recommendations for Resolution:

1. Estimate future repair needs and armor rock characteristics based on past performance of rock at the jetties. This requires a more detailed survey of existing condition, including quantifying existing armor rock size, gradation, and shape.
2. Analyze foundation stability based on measured geotechnical properties. A subsurface geotechnical investigation, including borings and soil testing, is recommended.
3. Provide a design concept for scour protection at Jetty A and check its stability against design environmental criteria, including specific current speed and wave height.
4. Apply models and use analysis methods to investigate sediment transport patterns and jetty foundation erosion under a combination of both waves and currents.
5. Supplement the STWAVE model with a wave transformation model such as BOUSS2D or CGWAVE to help determine design wave heights near the jetties.

USACE Final Evaluator Response (#8)
NON-CONCUR The performance and failure modes analyzed in this study are representative of the significant failure modes impacting the structures. We can add discussion which clarifies the relative role of armor rock durability in overall structure performance, however, this has not been found to be a significant process on the MCR structures. The deep seated slip surface failure mode was investigated and also found to not be a contributing factor to the failure processes at the MCR jetties. Refer to Appendix B for a discussion. We have an extensive amount of existing geotechnical information in the area that provides us with a good understanding of the nature and properties of the subsurface conditions and enables us to conduct a preliminary design without the need for additional site-specific explorations. This information includes recent vibracoring in multiple areas around the jetties, geophysical studies including subbottom profiling, side scan sonar, and multibeam surveys, all which provide both direct and inferred information on the subsurface material properties. These investigations suggest materials on which the jetties were built consist of well sorted fine- to medium-grained sand with some thin interbedded mud layers. While some jetty subsidence may have occurred during or shortly after original construction, little to no additional settlement is expected during future repairs indicating the foundation is firm under the jetties. Damage to the jetties has been documented by over 100 years of past performance, with numerous repairs having been conducted through the years. The type of damage observed is consistent with wave loading and scour damage affecting the toe of the jetty, as stated in Appendix B. The proposed alternative actions are consistent with previous repairs, adding stone to the existing cross-section by less than 5% of the total mass. Under these conditions, it is unlikely that the extra weight would affect the existing rubblemound base. No instances of deep-seated slip surface failures have been recorded during the life of the jetties, and are considered unlikely to occur as a result of upcoming repairs. The USGS DELFT model and the ERDC CMS model included the interaction of waves with currents when evaluating the potential for sediment transport within the inlet and around the jetties. In addition, historically-observed scour rates were applied along the length of the jetties in order to project into the future, see tables A2-6 through A2-7 for projected future scour rates along each jetty. Additional text will be provided that explains how the scour rate values in the tables were estimated. Bathymetric comparisons have shown that the tidal channel morphology at the end of Jetty A has stabilized. This analysis will be further clarified in the report. The spurs at Jetty A are intended to influence the scour and rip currents that occur along Jetty A. The future scour that will occur along jetty A has been estimated and is incorporated in the life cycle assessment of Jetty A. The vertical extent of the scour hole at the head of Jetty A has reached an equilibrium condition based on the current configuration of all of the jetties and the configuration of the MCR inlet, which is another reason to stabilize all of the jetty lengths at their present location. The seaward end of Jetty A has been rebuilt numerous times resulting in a relic stone base that has stabilized along with the scour hole. Our proposal to not rebuild the Jetty A head out to authorized length prevents the complications of trying to build out into the scour hole and avoids increasing circulation forces at that location. The significant relic stone base as well as the addition of the spur groins will add resilience to the morphology surrounding Jetty A. ERDC conducted a comparison of BOUSS-2D results to STWAVE results at the MCR. The

model results compared favorably for this level of study. While STWAVE may slightly over-predict some of the incident wave heights, this application was appropriate at the feasibility level and for the comparison of the alternatives, STWAVE results compared more favorably to the actual wave observations at the project site. For the extreme events modeled, no wave observations were available for comparison. Use of STWAVE allows for the incorporation of wind and for the transformation from the offshore to the project site. Use of STWAVE results was selected in order to provide conservative results and will be followed up in the more detailed design phase with further analysis.

1. ADOPT NOW. This has already been calculated. Further documentation of analysis and results will be provided. A table will be provided that documents existing condition of the structure, template deficit, template and armor stone characteristics, and future repair needs. Portland District rock standards ensure that rock durability is not a significant issue regarding jetty cross section longevity and/or failure. The life cycle performance analysis that has been conducted during this study already estimates future repair needs based on historical performance, existing conditions, damage and failure modes, site specific loading, and graduated levels of repair robustness.

2. NOT ADOPT. Appendix B identified the foundation and geotechnical factors impacting jetty stability. The geotechnical information requested in the comment to be presented in this report is beyond the level of effort normally required for a feasibility level study such as this, where only preliminary designs are identified, as indicated in EM-1110-2-1100, Coastal Engineering Manual. Damage to the jetties has been documented by over 100 years of past performance, with numerous repairs having been conducted through the years. The type of damage observed is consistent with wave loading and scour damage affecting the toe of the jetty, as stated in Appendix B. We anticipate that a more extensive review and analysis of the foundation parameters will be accomplished in the DDR phase, which may allow us to optimize the alternatives.

3. ADOPT in FUTURE. We have accounted for the historical evolution of Jetty A and its surrounding morphology to the extent necessary for this feasibility level analysis. The substantial relic stone base at Jetty A and the construction of the new jetty head at 400 ft landward of the authorized length will provide sufficient stability for the alternative suggested.

4. NOT ADOPT. This has already been done. The USGS DELFT model and the ERDC CMS model included the interaction of waves with currents when evaluating the potential for sediment transport within the inlet and around the jetties. In addition, historically-observed scour rates were applied along the length of the jetties in order to project into the future. See tables A2-6 through A2-7 for projected future scour rates along each jetty. Additional text will be provided that explains how the scour rate values in the tables were estimated. Further analysis can be conducted in the final design effort.

5. ADOPT in FUTURE. ERDC conducted a comparison of BOUSS-2D results to STWAVE results at the MCR. The model results compared favorably for this level of study. BOUSS – 2D tends to under-predict the waves slightly and STWAVE tends to over-predict the waves. STWAVE results compared more favorably to the actual wave observations at the project site. For the extreme events modeled, no wave observations were available for comparison. Use of STWAVE allows for the incorporation of wind and for the transformation from the offshore to the project site. We chose STWAVE results in order to provide conservative results and will

follow up in the more detailed design phase with further analysis.
Panel Final BackCheck Response (#8)
Non-concur. It is good to see that the BOUSS-2D wave model was applied. Adding this to the report will add a lot of value. However, there remain many problems with the proposed USACE plan to resolve the issues. The panel does not share the project team's assessment that "We have an extensive amount of existing geotechnical information". Appendix B is not adequate as a sub-surface geotechnical investigation for a project of this scope. Appendix B is not consistent with conventional engineering practice, including guidance in USACE manuals: TM 541-1I, EM 1110-1-1802, and EM 1110-1-1804 "Engineering and Design - Geotechnical Investigations". Appendix B is not consistent with the basic standards described in EM 1110-1-1804. Missing information includes boring logs, laboratory and in-situ test results and recommended design values for shear strength and other properties. Future work should be based on quality field data and there is much to be done, not just borings. Panel recommends that project time and budget going forward should prioritize collecting quality field data as a first step, not revising and adjusting the SRB model.

Literature Cited:

Demirbilek; Z., and V. Panchang (1998). CGWAVE: A Coastal Surface Water Wave Model of the Mild Slope Equation. USACE Coastal and Hydraulics Laboratory, Report CHL-TR-98-26, 120 pp.

cgwave_man3.pdf (3 MB .pdf)

Nawogu; O. G., and Z. Demirbilek (2001). BOUSS-2D: A Boussinesq Wave Model for Coastal Regions and Harbors - *Report 1: Theoretical Background and User's Manual*. USACE Coastal and Hydraulics Laboratory, Report ERDC/CHL TR-01-25, 92 pp.

BOUSS-2D.pdf (2.2 MB .pdf)

Comment (#9):
The alternative selection process may fail to meet the requirements of NEPA Section 1502.14.
Basis for Comment:
The design alternatives presented in the document are limited to the repair and rehabilitation of the jetties within the present configuration. The Panel is concerned about the adequacy of the alternatives analysis and the limited range of alternatives considered. NEPA Section 1502.14 requires a rigorous examination of all reasonable alternatives to any proposal and justification of eliminated design alternatives. The Panel finds that there is little examination of alternative approaches to the principal function of the MCR jetties, which is to secure a consistent navigation channel across the bar at the MCR. As such, the narrow scope of alternatives presented weakens this project. Insufficient information is provided to justify limiting the improvements to the existing footprint. For example, the report does not provide the technical basis for maintaining the 1895 jetty design, length, and orientation to the exclusion of considering other configurations. Considering reasonable alternatives, under NEPA guidance, would allow USACE to use hydrodynamic modeling tools to evaluate alternatives such as the use of weir jetties (Seaburgh, 2002) and other sediment management methods that facilitate bypassing sediment at coastal inlets, as well as low wave and high wave depositional basins in a manner which may reduce long term operation and maintenance costs. The impact of not considering additional alternatives leaves the overall justification of the project less defensible and may lead to questions of the overall merit of the rehabilitation project
Significance – Medium:
Consideration of alternatives beyond rehabilitating the original jetty structures within their existing footprint would comply with NEPA directives, and provide critical information that may reduce long-term costs and improve jetty life and efficacy.
Recommendations for Resolution:
1. Assess, and validate or reject, the technical basis for the initial jetty design, length, and orientation using appropriate physical coastal process models. 2. Assess structural efficacy and cost of alternatives which are not constrained by the existing footprint. 3. Develop modeling efforts for hydrodynamic models and/or sediment transport models that would provide insights into the following areas: a. Thorough analysis of the existing jetty structures focusing on why some areas have survived without repair and others have needed repeated repairs b. Examination of why Jetty A had such a large O&M cost relative to predictions. c. Addition of subsurface berms potentially created through the beneficial use of project dredged material that may reduce wave impact and subsequently reduce wave overtopping and toe scour.

USACE Final Evaluator Response (#9)
NON-CONCUR The alternatives evaluated do meet the requirements as specified in 1502.14 of NEPA since as stated in 1502.13 the alternatives to be selected and evaluated by the Agency are bounded

by the Purpose and Need Statement for the project. As stated in the Purpose Statement for the project: "The purpose of the proposed action is to perform modifications and repairs to the North and South jetties and Jetty A at the MCR that would strengthen the jetty structures, extend their functional life, and maintain deep-draft navigation." Consequently, we are limited to alternatives that meet these needs.

Major Rehabilitation guidance recommends that the alternative plans developed address alternative maintenance options and re-construction alternatives dealing with the present configuration of the infrastructure. We looked at incremental and graduated improvements through cross sections that extend off of the footprint and supplementary engineering features that locally extend off of the footprint. Based on the magnitude of the environmental and physical processes at this project and the cost of implementation, other forms of infrastructure that do not utilize/maximize the existing structure and footprint are not feasible. Some basic cost analysis comparisons can be used to demonstrate this. Reorienting the jetties or constructing an alternative form of structure off of the footprint would be expected to have significant cost and environmental consequences. In addition, potential negative consequences to the surrounding underwater shoals would be expected.

The alternatives proposed do not maintain the entire 1895 (full authorized) jetty length for any of the jetties. The hydrodynamic modeling results and reasoning for this is presented in the report.

Pursuant to Major Rehabilitation study guidance, the alternatives were formulated to maximize stability of the existing shoals, minimize induced scour, perform in an extreme loading environment, and minimize construction and future repair costs. Other more rigid structures have more vulnerability as well as potential negative consequences on the foundation shoals. This inlet is too energetic and the morphology is too dynamic (vulnerable) to changes in the flow field to make weirs and sediment basins viable primary alternatives at this location. Measures taken to improve the sediment deposition environment include stabilizing the jetty head locations and the addition of spur groins as well as North Jetty backshore improvement.

1. **NOT ADOPT** The purpose of a Major Rehabilitation study is not to re-justify the original design and layout of the project. Documentation can be identified and provided that illustrates how the project layout was incrementally improved over time to meet its intended navigation purpose and how that purpose is still being served now by the present jetty configuration.
2. **NOT ADOPT** Alternatives are included which extend beyond the existing footprint where merited by the loading environment.
3. **NOT ADOPT** The hydrodynamic modeling conducted throughout this study has provided sufficient and relevant information regarding the present project pertinent to the evaluation of reasonable maintenance alternatives. Historical analysis of jetty repair magnitude and location has been performed and will be further annotated for clarity. Jetty A incurred higher O&M costs at least in part due to the utilization of under-sized but readily-available repair materials. Beneficial use of dredged material in order to feed the underwater sand shoals is being pursued under a parallel effort. In addition, this type of action is subject to regulatory constraints and cannot be relied upon to stabilize the rubblemound jetties over the long term.

Panel Final BackCheck Response (#9)
Concur. The Panel understands more clearly the limitation of the project description and concurs with the USACE.

Literature Cited:

Seaburgh, W. C. (2002). Weir Jetties at Coastal Inlets: Part 1, Functional Design Considerations. U.S. Army Corps of Engineers, ERDC/CHL CHETN-IV-53. December.

Comment (#10):
A failure analysis for the original structure design and past trends of Operation and Maintenance (O&M) costs has not been provided.
Basis for Comment:
The extent of structure failure or partial failure is well documented and the repairs made to the structure are well documented, as shown in Figures 1-12, 1-15, and 1-16. These figures, however, do not distinguish between areas repaired and areas that are substandard but have not failed and so were not actually repaired. Failure analyses for the groin tips and the runnel formation weakening Jetty A (p. 3-5) are presented, but the report does not include a general failure analysis. A failure analysis would be helpful in determining why one section of jetty failed/degraded whereas another remained intact. This information is needed to derive alternatives that resist both degradation and failure, and result in an informed design of jetty repairs. Maintenance histories (Figures 1-21 through 1-23) show that actual O&M costs have trended significantly above and below the expected O&M costs, based on annual expenditures equivalent to 0.7% of the initial construction costs. Specific causes of actual O&M costs being higher or lower than the assumed 0.7% annual average cost have not been analyzed but can be presumed to be directly related to full or partial failure of portions of the structures. Knowledge of the specific causes of failure combined with the cost of constructing a jetty resistant to these causes taken in consideration of maintaining a jetty less resistant to these causes may be useful in determining or presenting the most cost effective alternative design. A specific presentation of individual jetty failure events would serve to bolster the alternative selection process and the projections of future maintenance costs.
Significance – Medium:
Uncertainty regarding the specific causes of failure and their relationship to trends of past O&M costs creates a functional uncertainty in the corrective measures in the alternatives for repair and rehabilitation.
Recommendations for Resolution:
1. Include an analysis of the causes of failure for each repair event (e.g., Figure 1-15) even if only a statement of "storm intensity" in order to provide assurance that the repairs address the actual causes of previous jetty failures. 2. Relate construction costs of more resistant designs to repair costs of less resistant designs for each causal condition of failure and the associated selected alternative.
USACE Final Evaluator Response (#10)
NON-CONCUR The below excerpt from Appendix A2 summarizes some of the information that is requested above for Jetty A. Other similar information has been included for the North Jetty and the South Jetty "To date, the average annual rate of maintenance actually expended on the Jetty "A" has been 2% of structure's initial construction cost. This is considerably higher than a value of 0.7%, which is the expected value for MCR jetties. A high level of maintenance was expended on jetty "A" soon after construction, to address extreme foundation scour and low resiliency of initial jetty construction. Initial repair actions implemented for Jetty "A" during the 1940s-50s also produced a low level of resilience, requiring rehabilitation of the jetty during 1961-1962 following a breach event during the 1950's."

Different areas of the jetties were constructed to a variety of templates and then maintained in various levels of robustness. Degradation of the jetty reaches were a function of how they were originally constructed, how they were repaired, and how environmental conditions changed around them. Extensive effort was expended in the analysis of the wave climate and projected future changes to the loading environment. We have identified where scour has occurred and where wave action has controlled the degradation of the jetty cross section. Alternatives have been proposed to address these concerns including stone size, side slope, toe berm size, etc. Please see the attached chart showing historical repairs by location and cost in 2010 dollars. 1. ADOPT NOW. . A summary table will be provided which pulls together in one location the repair history, design attributes and ongoing deficiencies leading up to the repair for each area of each jetty. 2. ADOPT NOW. This has already been included in the report, however, we will adjust its location and content to ensure that it is covered adequately.
Panel Final BackCheck Response (#10)
Concur.

Comment (#11):
Sea level rise and potential increases in wave height have not been examined sufficiently under different model scenarios.
Basis for Comment:
The issue of climate change, sea level rise, and increased wave action is important to consider in the evaluation of long-term projects (USACE, 2009). There is no discussion in the main report of sea level rise and its impact on this project over the 50+ year project timeline. There is a limited discussion of climate change in Appendix D (p. 5), where the conclusion is that since the projected historical trend of sea level at the project site is estimated to be -0.05 feet in 50 years, sea level rise is not projected to be a significant climate change factor at the project site. Appendix D states the "comprehensive analysis of historical storm events is expected to adequately capture the present deep water contribution of potential wave height variation for this project site. The above approach forms the basis for estimating the potential changes in wave climate that could affect the MCR jetty system." However, this discussion on wave height trends is not compelling. The main report states (p. 1-6), "As the tidal shoals continue to recede (erode), the MCR jetties will be exposed to larger waves and more vigorous currents. To make matters worse, the regional wave climate along the Northwest Pacific Coast has become more severe in the last 10 years. The offshore 100-year wave height has been revised from 41 to 55 feet." (see also Appendix D). The main report states (p. 3-42), "The limit of cross-section resiliency is reached for jetties when the core stone becomes exposed to wave attack." Therefore, this issue may affect jetty erosion and a larger range of wave heights should be included in both the SRB and STWAVE model scenarios. Wave overtopping is central to the environment deteriorating the existing jetties. As the planning horizon of this project is 50+ years, it seems that a discussion would be useful of sea level rise and modeling potential wave heights and the wave overtopping impacts on the jetties given different rates of recession under a wider range of wave heights. Jetty height and crest elevation are variables that should be modeled given the potential larger wave heights possible under sea level rise. Although the selection of the recommended plan may not change, long-term maintenance costs may be affected, therefore consideration is warranted. Appendix B states that transient internal hydraulic effects of wave impact may be the most important parameter in the stability of the jetties. However, it is the least certain of all of the parameters. Internal hydraulic pressures in jetties have not been measured. Given this, it seems especially important to consider more extreme wave heights beyond the wave height analyzed, with respect to sea level rise and potential increasing wave height.
Significance – Medium:
The discussion of potential impacts of sea level rise and increased wave action on jetty structures is critical to understanding the potential impacts to the project and in designing a project with lower long-term maintenance costs.

Recommendations for Resolution:
1. Add a separate section to the Major Rehabilitation Evaluation Report that examines climate change, sea level rise, potential wave height changes, and resulting wave overtopping impacts on the jetties given different rates of recession under different model scenarios.
USACE Final Evaluator Response (#11)
NON-CONCUR Discussion of potential sea level rise as well as its impact on potential future loading on the MCR jetties has been included in Appendices A1 and A2. Portions of that discussion can be moved to the Main Report for completeness. All of the factors discussed above have been incorporated into the wave height loading for the structures. An extremal analysis has been performed utilizing the period of record for the Columbia River NDBC buoy producing the expected long-term estimates of extremes at the project area. This estimate compares well with the recent analysis conducted by Ruggiero for the Oregon coast wave climate. An incremental increase in wave height has also been included to reflect the potential for an upward trend in storm intensity. The project event tree simulation includes a function that gradually increases the depth-limited wave height incident to the structure as the scour increases and the water depth at the structure increases. The potential for sea level rise was incorporated in the project event tree simulation and life cycle analysis of the project. As directed by USACE (2009), three separate potential sea level curves were estimated placing the potential sea level change at the project site over the 50 year planning horizon somewhere between -0.05 ft to +1.6 ft. Each life cycle run for the project utilized one of the sea level change curves in order to factor in that potential change in project loading and its impact on maintenance requirements and effectiveness. With the slightly greater water level at the project site during these realizations, the incident wave height was also adjusted accordingly. So the future case scenarios incorporate both a higher water level as well as the impact of wave height. **1. ADOPT NOW** by moving the sea level rise section of the report to the Main report for better clarity. In the analysis, the waves are currently estimated at three different potential water levels. The relative mildness of sea level change at the project site makes the inclusion of sea level change in the total loading environment less of a driving factor in a long-term maintenance strategy. In addition, due to the uncertainty of future sea level rise scenarios, the most likely approach for very large rubblemound structures for future maintenance would be to develop an adaptable maintenance strategy that could be modified as the gradual change is observed.
Panel Final BackCheck Response (#11)
Concur.

Literature Cited:

USACE (2009). Water Resource Policies and Authorities Incorporating Sea-Level Change Considerations in Civil Works Programs. Department of the Army, U.S. Army Corps of Engineers, Washington, D.C. Engineer Pamphlet EC 1165-2-211. 1 July.

Comment (#12):
Construction cost estimates cannot be evaluated because the assumptions and details have not been provided.
Basis for Comment:
A detailed construction cost estimate summary should be provided for the recommended plan, otherwise the basis for the total cost values provided in Section 6.5.9 cannot be reviewed and assessed to determine if they are realistic and complete. The cost estimate information provided in the main report (Section 6.0) and in Appendix E is not sufficient to support the recommended plan: • Table 6-3 provides a detailed summary of stone volumes for each jetty by construction year, but there is no correlation with construction costs or to the cost estimates provided in Section 6.5.9 or Appendix E. • Specific cost estimating details are provided in Sections 6.5.7 and 6.5.8, but the assumptions and criteria defining the basis for the cost estimates do not include any summary unit costs for the individual work items. • Unit costs are provided in Tables A2-9 to A2-11 but pertain to the SRB modeling effort. There is no discussion regarding how they relate to the final project costs presented in Section 6.5.9. • Appendix E includes budget summary costs for construction, planning/engineering, construction management, and land acquisition. Detailed cost estimates for the Civil Works construction budget numbers are not provided and the basis for the costs cannot be reviewed or verified. • Costs for the barge offloading and material re-handling area facility installation and maintenance are not described, yet they could be a large direct and indirect cost to the project based on wave exposure (for type and size of barge offload facility structures). The structural requirements (and corresponding construction costs) for an exposed vessel berth will be many orders of magnitude larger than the same berth in protected waters. Stone delivery cost represents a very large percentage of the total cost. Ensuring a cost feasible method of delivery to the jetty structures is critical for development of an accurate cost estimate.
Significance – Medium:
Detailed construction cost estimates need to be provided in order for the cost analysis to be complete and verifiable.
Recommendations for Resolution:
1. Provide a detailed cost breakdown by work item for the Civil Works project item, Breakwater & Seawalls. Provide detailed cost estimates for each major element of work (e.g., mobilization, stone supply and install, site preparation, material re-handling facility installation, maintenance of re-handling facilities, etc.). Give details regarding work item quantity, unit costs, contingency, and escalation. 2. Provide a detailed cost summary within Appendix E, and an additional detailed description of the basis for the costs estimates in Section 6. 3. Conduct an additional investigation of re-handling facility requirements to adequately determine the costs for facility installation and maintenance.

USACE Final Evaluator Response (#12)
CONCUR 1. **Adopt Now**: Appendix E was not included in the report and includes an MII summary report, narrative, schedule, cost and schedule risk analysis, and TPCS. 2. **Adopt Now**: The basis for the cost estimate is noted in the narrative section of Appendix-E. 3. **Adopt Later**: Reference the MII summary report in Appendix E. The estimate assumes construction of an off loading facility at the beginning of the construction season and removal at project closeout. Yearly roadway, ramp, dredging, and storage area maintenance are also included. Jetty crest haul road and turnout re-construction materials are included in the yearly cost and labor and equipment is assumed in the jetty stone production rate of 100T/Hr. Costs and contingency have been assumed for the MMR phase and will be further refined in the DDR phase of the project.
Panel Final BackCheck Response (#12)
Concur. The Panel was not able to answer Charge Questions which were "Comment on the overall adequacy and reasonableness of the detailed cost estimates" and "Are the Cost Estimates Complete and Consistent?" since detailed cost estimates were not provided. It is our understanding a separate Corps cost review processes will be conducted during the next phase of the project which will answer these questions.

Comment (#13):

Potential environmental impacts on sensitive species, upland habitats, and water quality have not been thoroughly discussed or specifically mitigated in the document.

Basis for Comment:

Appendix D and main report (pp. 5-17—5-20) list potential in-water, wetland, and upland impacts. These impacts should be addressed in the mitigation plan. The mitigation plans currently address these three general categories, but do not provide mitigation for potential impacts to specific species, upland habitats and water quality. The mitigation plans are incomplete because the final wetland delineation for the project has not been conducted, and the impact to wetlands and upland habitat is uncertain and therefore not quantified. A vegetation restoration plan is needed to address potential impacts to upland habitats, especially the rare and vulnerable species discussed below. At a minimum, the mitigation plan should state that these plans will be prepared prior to construction activities. Although the extent of the upland impact on this habitat is uncertain, a replanting contingency plan and a clear plan for avoidance are important to include in the mitigation plan. Similarly, potential water quality impacts from spills should be addressed in the mitigation plan with a statement about the spill prevention plan, as discussed below.

Section 5.1 (Environmental Effects) of the main report provides details on biological resources, but is missing a vegetation section. Appendix D contains two reports including the Wetland and Waters of the U.S. Delineation Report and The Plant Communities Investigation Report, April 2007, which provides details on the vegetation communities; however, this information is not presented in the main report and therefore the main report lacks a definition of the plant species of concern within the project area. The revised EA states (p. 6) that at least three of these vegetative communities (shorepine-slough sedge, shorepine-Douglas fir, and coast willow-slough sedge) "have been ranked globally and by the State for their rarity and vulnerability to extinction and should be protected from impacts." This information on sensitive species should be integrated into Section 5.1. Furthermore, potential land construction activities as shown on Figure 5-1 of the main report may affect plant communities, including sensitive habitats, warranting a discussion of existing vegetation in the project area. Vegetation impacts that may result from construction are not detailed in the document, and just briefly mentioned in regards to the South Jetty. Mitigation plans should include specific protective measures to avoid potential impacts to these rare and vulnerable species.

In general, the main report discusses Endangered Species Act (ESA) species, but does not provide detailed data on specific animal or plant populations. In 2005, critical habitat was designated for all Columbia River steelhead and Columbia River salmon evolutionarily significant units (ESU), with the exception of lower Columbia River coho salmon ESU. Although a wide range of potential impacts are discussed (p. 5-16), ranging from loss of habitat to an increase in perching and in-water habitat for predators that prey on listed species, the mitigation section of the Major Rehabilitation Evaluation Report does not address these impacts. The main report concludes (pp. 5-19 – 5-20) that there will be overall benefits to these species from this project. Additional details would be helpful to ensure that these species suffer no impacts. The Panel realizes that as a specific mitigation plan is developed, this may likely be incorporated.

Water quality may also be affected over the project duration due to the large volume of container ships, construction dredges, barges, and cruise ships operating in the area, sometimes in adverse extreme weather conditions. For example, there may be a loss of hydraulic fluid or oil spills (p. 3-70). In the discussion of the mitigation plan in Section 5.4 (p. 5-17), the increased risk of pollutant release and spill potential is raised as a potential impact on ecosystem function. A sentence earlier in the document (p. 5-2) states that the Contractor "will provide a spill prevention plan to include measures to minimize the potential for spills and to respond quickly should spills occur." This sentence belongs in Section 5.4 of the main report as well.

Any history of spills in the Mouth of Columbia River area should also be reported in the document. Providing these details will enable a more thorough analysis of environmental impacts and enable additional protective actions to be implemented.

Significance – Medium:

Additional biological resources data and potential impacts to sensitive species, upland communities and water quality is needed to adequately protect the environment and define the mitigation needed to reduce these impacts to less than significant.

Recommendations for Resolution:

1. Incorporate additional information into Section 5 of the report:
   a. A vegetation section defining the sensitive species within project area.
   b. A statement to ensure that stockpiling activities shown in Figures 5.1 – 5.3 of the main report minimize the land impacts to sensitive habitats and wetlands. State whether a survey will be conducted prior to construction activities with sensitive habitats flagged to ensure avoidance.
   c. Provide detailed data on specific animal or plant populations that are listed species
   d. Specific text in the mitigation section for potential impacts to steelhead and salmon.
2. Add the wording from p. 5-2 into Section 5.4 of the mitigation plan regarding the contractor's requirement to prepare a spill prevention plan to address potential water quality impacts. Document any known history of spills in the area.

USACE Final Evaluator Response (#13)

CONCUR

Chapter 5 of the Major Rehabilitation Report has been updated and supplemented with the requested information. Analyses of effects to listed species, water quality, and socio-economic resources have been completed in the associated Biological Assessments, draft Final EA, and the draft 404(b)(1) documents. There is also currently a wetland delineation under completion, and results will be incorporated into the EA, 404(b) (1) evaluation, and final designs, as appropriate.

1. **Incorporate additional information into Section 5 of the report:**
   a. **ADOPT NOW:** A vegetation section (Section 5.1.7) has been added to Section 5 of the main report. This new section describes the sensitive habitats and wetlands in the project area. It also includes an illustration of these areas for the Clatsop Spit.

   b. **ADOPT NOW:** The following text has been added at the end of the new Section 5.1.7: "Construction staging/storage and rock stockpile areas shown in Figures 5-1 to 5-4 were sited to minimize land impacts to sensitive habitats and wetlands as much as possible. Wetland delineations are underway and sensitive habitats will be flagged prior to construction activities to ensure their avoidance." Additional figures have been added to illustrate stockpile locations relative to higher-value habitat.

c. **ADOPT NOW:** Detailed information has been added to Section 5 about listed animal and plant species with the potential to be in the project area. Specifically, Section 5.1.2 has been expanded for anadromous salmonids, green sturgeon, eulachon, and bull trout; Section 5.1.5 has been expanded for marine mammals and sea turtles; Section 5.1.6 has been expanded for terrestrial wildlife and seabirds; and new Section 5.1.7 (Vegetation) includes listed plant species.

d. **ADOPT NOW:** Additional text has been added early in Section 5.4 to discuss that the Corps has incorporated habitat improvement features into the proposed action to assist with the recovery of ESA-listed salmonid habitats and ecosystem functions and processes. These actions are not proposed to directly mitigate or compensate for any project-related impacts to ESA-listed salmonids. The habitat improvement features of the overall ecosystem restoration action are proposed as conservation measures under Section 7(a)(1) of the ESA. These actions are the Corps' affirmative commitment to fulfill responsibility to assist with conservation and recovery of ESA-listed salmonids. In addition, a table with possible wetland mitigation and habitat improvement features has been added. The wetland mitigation totals will be updated when current delineations are completed.

2. **ADOPT NOW:** The statement, "the contractor will provide a spill prevention plan to include measures to minimize the potential for spills and to respond quickly should spills occur," has been added to Section 5.4 (mitigation plan), as requested. Also, the environmental staff is attempting to determine the history of spills in the MCR area and what information is available will be incorporated into this report as well as the EA and 404(b) (1) evaluation.

Panel Final BackCheck Response (#13)

Concur.

Comment (#14):

Potential impacts to recreational use during project construction, as identified in public comments, are not adequately discussed or mitigated.

Basis for Comment:

The Major Rehabilitation Evaluation Report does not provide detail on the impact of the project construction activities on recreational use, an issue that came up in public comment letters (main report, Section 5.4). The last sentence in Section 5.3 states that there will be no significant impacts on recreation.

Appendix C states that there is a growing cruise ship industry and it is unclear how construction activities will affect passenger cruise ship access. On p. C-3 it states that 5/7 day cruise ship tours carry 15,000 passengers annually, and thousands of tour boat passengers take day trips and dinner cruises. These activities generate about $15 to $20 million in revenue annually for local economies. Public access during construction may be an issue. In addition, other recreational uses of the area may be reduced, such as kayaking and hiking.

These impacts should be defined, rather than concluding that no recreational or economic impacts to tourism are expected. Omitting this issue may lead to unforeseen consequences for the cruise ship and tourism industries.

Significance – Medium:

Recreational impacts are not adequately presented in the report and subsequently, no mitigation is identified for this potential impact.

Recommendations for Resolution:

1. Add a discussion of the cruise ship industry and other recreational uses at the project site.
2. Examine potential impacts on cruise ships and other recreational activities that may result from the dredging operations and jetty repair operations.
3. Provide potential mitigation options to reduce recreational impacts to less than significant levels.
4. Make a distinction between recreational impacts during construction and after construction.

USACE Final Evaluator Response (#14)

CONCUR

The Major Rehab Report will be updated and clarified with the information requested. Though cruise ships utilize the navigation channel, they will not be docking anywhere near the bulk of the jetty work, and instead debark upriver in Astoria. Recreational impacts will be included in the draft final EA.

1. **ADOPT NOW:** Section 5.1.9 has been revised to better reflect the recreational uses in the project area, including cruise ship passage through the MCR.
2. **ADOPT NOW:** Section 5.19 has been revised to discuss the potential impacts to recreational activities and cruise ships during construction of the proposed action.
3. **NOT ADOPT:** Recreational impacts are not expected to be significant enough to warrant mitigation.
4. **ADOPT NOW:** Section 5.19 has been revised to better discuss the recreational impacts during and after construction of the proposed action.

Panel Final BackCheck Response (#14)
Concur.

Comment (#15):
There is not sufficient information on the evaluation of barge offloading and material re-handling facilities to ensure these sites can operate as intended and to ensure the construction costs are adequately represented.
Basis for Comment:
Contract-provided barge offloading facilities for the South and North Jetties are described in Sections 6.3.3 and 6.3.4 and shown in Figures 5-1 and 5-3 of the main report. Based on the information presented, it is not clear that these sites have been adequately investigated and are suited for their intended use. The barge offloading and material re-handling facilities at these outer exposed locations should be further investigated to ensure they are economically and operationally feasible. The proposed facilities are referred to as "temporary," but this is questionable if they will be in place for 20 years. The life-cycle costs of the docks and other structures are not trivial and do not seem adequately analyzed. The largest cost and a substantial risk for the recommended plan involves the purchase, transportation, delivery, and offloading of the stone in a very difficult environment over a relatively long time. The USACE-provided sites also need to be operationally feasible in order to use a permitted method of delivering material to the site. Providing contractors with better information on the limitations and usability of these sites at the time of bidding could result in substantial cost savings. There is no discussion in the report of any engineering work performed to evaluate the feasibility of installing structures at these exposed locations, nor any mention of operational feasibility for the size of vessels and wave climate for the periods of construction. These locations are subject to wave heights of more than 15 feet, which will impose very large wave impact loads on fixed structures (dolphins and sheet pile walls), resulting in high risk and cost facilities. USACE intends to permit these sites and provide them to the contractor as the primary point of access. This establishes a certain level of perceived usability to bidders. If they are later determined not to be feasible (i.e., during contract bidding or during construction), it would result in substantial cost and schedule changes. Use of the re-handling facilities will be limited to a "summer" work period (April to October). There is no analysis of sedimentation rate in the report to verify whether the floatation channels will remain open for the summer construction work period. Maintenance dredging estimates for barge offloading facilities are provided in Table 6-1, but it is not clear for what time period (annually or total over the entire duration of the project). Jetty A is listed at 80,000 cubic yards for maintenance dredging. Other options, such as dredging within the Ilwaco channel to the trunk end of Jetty A and developing an offloading facility adjacent to the staging area could be considered.
Significance – Medium:
Insufficient information on the limitations and usability of the offloading and re-handling sites could affect construction cost estimates and project schedule due to operational and physical environment constraints.
Recommendations for Resolution:
1. Conduct a feasibility level engineering analysis and design for the contract-provided offloading and rehandling sites to ensure that selected sites and facilities are feasible and provide reliable estimates of construction cost. The feasibility evaluation should at a minimum include the following: a. Evaluate feasibility of constructing pile supported structures within an extreme hydrodynamic environment. This includes wave/current loads on moored vessels

during the construction period and wave/current loads berth structures during extreme winter conditions.

   b. Evaluate downtime of barges at the proposed sites relative to the wave and current climate during the proposed construction work period.
   c. Refine the type of structure that is feasible for these locations for inclusion into project permits and cost estimates.

2. Evaluate the need for alternative barge offloading and material re-handling site locations based on the results of the feasibility analysis.
3. Evaluate design concepts for permanent barge/dock facilities, possibly incorporated into the inside face of the jetties near their root.
4. Develop environmental data specific to the proposed offloading site locations for bidders/contractors to use in developing their estimates of downtime and infrastructure requirements at USACE provided rehandling sites. Extreme event offshore wave data and jetty structure design criteria will not be sufficient for contractors to use in evaluating short-term operational and design requirements.

USACE Final Evaluator Response (#15)

CONCUR

Further analyses for evaluation of barge-offloading facilities will be conducted as needed during the final design and plans & specification stage of study. The current estimate is based on historical repair activities at the project, knowledge of the wave environment during the normal construction season, and experience at similarly exposed locations. Site specific information will be provided to the contractor for their use in evaluating their equipment and capabilities with respect to the site conditions. MCACES estimates already include a reasonable estimate for offloading site construction, dredging, and maintenance. Allowances have been included for additional dredging during the construction season and between construction seasons.

1. **ADOPT in FUTURE**: The design of the barge offloading and material re-handling facility will be conducted during the DDR phase of the project. General coordinated locations have been graphically noted in figure 5-1 to 5-4 and conservative costs have been included in the cost estimate.
   a. A site design for the facility described will be performed during the DDR for establishing a fair and reasonable cost for the government cost estimates. Design criteria will be established during the DDR phase but specific designs and implementation will be up to the contractor
   b. Usability of the site will be examined.
   c. A feasibility study will be conducted for inclusion in project permits and cost estimates.
2. **ADOPT in FUTURE**: Barge offloading and material re-handling site locations will be addressed in the DDR phase.
3. **NOT ADOPT**: Permanent barge/dock facilities were not considered due to environmental and hydraulic considerations.
4. **ADOPT in FUTURE:** Engineering and environmental data specific to the offloading site locations will be developed in the DDR phase.

Panel Final BackCheck Response (#15)

Concur.

With respect to Recommendations #1 and #2, the Panel agrees detailed design should be done in the next phase of the project but some details associated with these material re-handling sites should be further investigated during this phase and not deferred to the future. The Mouth of the

Columbia River is an extremely dangerous area for vessel navigation and mooring. If the barge facilities are located in conditions later determined by Contractors to not be safe or to have significant operational downtime, it will greatly affect the projects cost and schedule. The panel assumes that the Corps has adequately investigated the barge offloading facilities with sufficient adequacy that it was determined that they are safe and usable for the purpose of delivering stone materials onto the jetty for the proposed rehabilitation work.

With respect to Recommendation #3, the Panel recognizes the material re-handling facilities are temporary but USACE has stated in their response to Panel comments the barge terminal will be installed at the start of the project and removed at the conclusion. If the project duration is 2012 to 2030 (18 years), the facility should be treated more like a semi-permanent facility (remains in place for entire calendar year versus temporary inferring removal each year) for the purpose of structural engineering design and determination of feasibility of construction and operations. This has very big implications on the structural design since it needs to withstand large winter storm wave conditions for a design criteria associated with a longer service life than most temporary construction facilities. The panel assumes that the Corps has adequately investigated the barge offloading facilities with sufficient adequacy that it was determined that they are safe and usable for the purpose of delivering stone materials onto the jetty for the proposed rehabilitation work.

Comment (#16):
The requirements, costs, and history associated with emergency dredging compared to scheduled maintenance dredging activities have not been specified.

Basis for Comment:

Dredging is a substantial component of this project and has been historically, yet there is no clear discussion of the role of dredging in the Major Rehabilitation Evaluation Report. Typical annual dredging rates are not presented in the document itself, although Appendix A1 (p. A1-3) states, "Each year, the Portland District dredges 3 to 5 million cubic yards (MCY) of sand at MCR to maintain the 5-mile long deep draft navigation channel." It is unclear if the Portland District dredging is conducted exclusively at MOCR. Analysis of the project area maintenance dredging requirements – past, present, and future – have not been presented.

Controlling dredging costs is critical to this project. The EPA publishes a report annually analyzing dredged sediment disposal in the nation. About 4 million cubic yards is dredged at the MCR every year at an annual cost of about $10 million. The fact that maintenance dredging volumes in the project area have not increased (no clear trend) since 1956, despite ongoing jetty tip recession, raises the question of how much jetty is now needed to maintain the MCR navigation channel. However, the main report does not discuss details of the maintenance dredging. Appendix B states the geological history includes 225 million cubic yards of dredging from the MCR navigation channel since 1956. The volumes, history, and fate of these dredged sediment volumes should be described in the main report and are missing from the analysis. The fact that most of this sediment was dumped far offshore and lost to the nearshore may have something to do with the erosion experienced in the area. This large quantity of dredged material warrants discussion and additional consideration of strategies to reduce this volume.

The discussion of emergency dredging is also lacking in the main report. The historical downtime for dredging at the dock and jetty repair work during the time period of October to March (peak period for large waves) is not provided. Page 3-70 states, "Given the winter wave conditions that the dredges would be performing in, it is highly likely that damage would occur to the drag arm of the dredge while working." Page A2-65 states that within the SRB model "there is a 0.3 probability that one dredge will lose a drag-arm while performing dredging during winter or a 0.7 probability that one dredge would realize equipment damage," thereby increasing dredging costs. Several places reference the difficulty of dredging in the winter. Conditions may preclude effective dredge use, or the dredge may break and become inoperable, suggesting dredging may be postponed until summer. In terms of dredge operation, p. 1-48 gives the operational limitations of hopper dredges, and admits that operating a hopper dredge at the MRC during winter months has not yet been attempted. Therefore, the inadequate demonstration of equipment effectiveness, lack of documentation of the basis of dredge damage probabilities, and lack of historic utilization increases the risk associated with estimating costs associated with emergency dredging.

The document states on p.1-50 that the rate of shoaling within the MCR channel would not be high enough to require emergency dredging; therefore, the increased shoaling volume could be dredged the following summer and would not be considered emergency dredging. The document never presents operational triggers for when emergency dredging would occur.

The main report indicates that there are four dredges capable of working in winter (p. 3-111), but these dredges are not mentioned earlier, when it was presented that only one or two dredges are available in the short term. A discussion of emergency dredging history, success in other areas, and a description of the equipment available is warranted.

The analysis considers long-term O&M costs of dredging, but does not explain the criteria used in the calculation estimates.

There is no mention of any historic environmental impacts from the dredge operations, such as spills. If spills have occurred, data should be presented.

Significance – Medium:

Additional information on dredging may enable better analysis and lead to a long-term reduction in dredging costs and the development of a contingency plan to successfully avoid navigation impacts.

Recommendations for Resolution:

1. Develop a paragraph on dredging in the main report that specifies clearly what the maintenance dredging program has been, rates, and frequencies, and if they are scheduled or "as needed." Present all the historic maintenance costs, schedules, and frequencies.
2. Provide a detailed history of emergency dredging with success and failures and costs.
3. Add information to specify what rate of shoaling requires emergency dredging compared to scheduling maintenance dredging activities.
4. Present the criteria used in the calculations of dredging O&M costs.
5. Provide any information on historic spills related to dredging operations.

USACE Final Evaluator Response (#16)

CONCUR

Historical dredging efforts can be explained in more detail for the main report. Our objective under this study is to try to avoid an increase in dredging above the current condition. Stabilization of the heads of the jetties should limit changes in the dredging impacts. The model simulates in the without project condition, the continued recession of the jetty heads and the resultant impact on dredging requirements within the MCR.

Holding the present jetty head at its current position will reduce the amount of future dredging compared to letting the jetty heads recede back . Our present O&M dredging is reflective of many processes operating within the inlet; transport of sediment from the estuary, transport of sediment from the ocean, re-distribution of sediment within the sand shoals in the inlet.

We know that sediment is transported into the inlet by migrating past the jetty heads as the heads of the jetties recede landward. This method of sediment transport and subsequent shoaling within the channel persists. The objective of limiting the rate of landward recession of the jetty head is two-fold; it maintains the morphology along the jetty which protects the jetty itself and reduces the rate of channel shoaling associated with jetty head recession. This study was an incremental analysis of channel shoaling related to jetty head stabilization or recession. We will continue to see the same rate of channel shoaling as we have in the past if we do nothing, however, if the jetty head recedes faster, more shoaling will be exhibited. This is a reasonable estimate and not overly conservative.

Changes to the inlet have occurred since 1956. We have also deepened the channel during that time frame. The occurrence of the same amount of dredging is because the jetties have been receding since 1956. Since the last channel deepening , the volumes have been variable but relatively consistent including the effect of jetty head recession. If we prevent jetty head recession, the component of shoaling associated with jetty head recession will be reduced, decreasing the long-term average of sediment entering the channel.

We did not look at all of the dredging history details because we believe the recent past to be the baseline condition from 1986 forward. There are various levels of maintenance and incremental deepening activities between 1956 and 1986. Our potential impact on this process through the jetty maintenance proposals is intended to stabilize current condition of the jetties and thereby reduce over the long-term the amount of shoaling associated with jetty degradation.

Jetty Length options were discussed at the beginning of the study. The decision was made that the rehabilitation and repair plans would stabilize the jetty head at the most cost-effective location in order to not negatively impact the stability of the surrounding shoals, hydrodynamic and environmental processes, and navigation at the MCR entrance.

Over the time period of 1956 to 1996, more than half of the dredged material was placed in the nearshore zone, water depth of 60 ft or less. All of this information can be referenced and explained based on previous studies. The inlet has been eroding because it was thrown out of balance at the time of navigation inlet improvement. Our goal is to manage the rate of morphology change by implementing regional sediment management (RSM) so that we can sustain navigation through the inlet through jetty maintenance and shoal and shoreline management.

Equipment abilities and emergency response times at the MCR during winter conditions were determined to be feasible, but at a reduced efficiency rate during winter conditions. This situation and a reasonable response was discussed with the Operations office in the Portland District. Appropriate response times and resultant equipment, mobilization and delay costs were included in the model and have been documented in tables located in appendix A2.

For the South Jetty situation and in some cases also for the North Jetty if the shoaling volume into the inlet is less than 250,000 cy, dredging would be expected to be performed the following summer. This can be clarified in sections of the main report

Descriptions of dredging capabilities and availability can be improved in the main report. The assumption is that the government dredge would be available depending on repair schedule and that a second contract dredge could also be mobilized but with a longer deployment time period.

1. **ADOPT NOW**. This information will be provided in the main report (with assistance from Operations).
2. **ADOPT in FUTURE**. Operations can assist in further defining the emergency dredging constraints, failures and expected costs.
3. **ADOPT NOW.** Bring discussion from Appendix A2 up to main report.
4. **ADOPT NOW**. Bring discussion from Appendix A2 up to main report.
5. **ADOPT NOW**. Information will be investigated and provided (with assistance from operations)

Panel Final BackCheck Response (#16)

Concur.

Comment (#17):
The current jetty structure condition is not well described, making it difficult to confirm the confidence of the SRB model analysis and selection of a recommended plan.
Basis for Comment:
Although there is a good description of historical failures and repair actions for each jetty, there is no discussion or documentation of current jetty condition or detailed condition assessments of structure and functional condition. A condition assessment of each jetty structure should be conducted through a combination of visual inspection (stone size, gradation, slope defects, stone defects, loss of armor stone, core exposure, etc.) and evaluation and comparison of historical electronic surveying results (single beam, multi-beam, or side scan sonar data). These elements will provide the basis for determining the present condition, assess risk of current condition to failure, and help classify structure along various reaches of each jetty. These data would enable better assessment of vulnerabilities, analyzing why some areas in the jetty have maintained without repair and other areas have needed multiple repairs. A better understanding of these dynamics may reduce O&M costs over the long term. Rubble-mound structures have a tolerance for deterioration before suffering catastrophic failure. A thorough understanding of current and historical structure condition is critical to developing an estimate of the mechanisms causing failure, establishing the timeframe for catastrophic failure, and conducting maintenance/repair work. The SRB model evaluation of alternatives using the base condition depends upon an adequate understanding of current jetty conditions and corresponding impact on estimated future repair and maintenance. The current SRB analysis is based on a “hindcasting” of jetty performance relative to historical performance, but without consideration of the details of condition and causes of failure. The current and historical condition relative to structural and functional rating should be conducted following USACE procedures (USACE, 1998) to establish the baseline conditions for the SRB model analysis. Evaluation of stone source and quality relative to length of service on the structure should be conducted as part of the jetty condition assessment.
Significance – Medium:
A detailed description of the current jetty structure as part of a condition assessment is necessary to understand the accuracy of the SRB model.
Recommendations for Resolution:
1. Conduct a detailed condition assessment of each jetty structure, including visual inspection and historical survey comparison. 2. Compare historical survey data for the validation of interpreted historical conditions and corresponding perceived modes of failure. Incorporate results into the development of baseline conditions for the SRB model. 3. Use a condition rating system such as that outlined in the USACE Manual REMR-OM-24 (USACE, 1998) for evaluation of current condition. Assess both the structural and functional condition of the structures and incorporate the results into the SRB model analysis. 4. Incorporate the results of the condition assessment into Section 1.4, description of project history. 5. Provide an additional description of existing condition in Section 1.4 and 3.3.2 of the

main report, including the service life of stone sources used for previous repair and maintenance activities.

6. Based on the results of the condition assessment, the relation between the stone sources reviewed (in Appendix B, Section 5) and the corresponding observed service life of that stone should be discussed and incorporated in the SRB analysis.

USACE Final Evaluator Response (#17)

CONCUR

At numerous locations in the report, reference is made to jetty condition, cross section template deficit, vulnerability and damaging modes of jetty reaches. Various tables and plots also provide information. Information provided includes existing crest elevation and crest width, toe elevations on either side of structure, as well as general condition and design concerns for each reach. Environmental loading and project condition changes along both sides of each jetty length were also evaluated to assist in evaluating cross section capacity.

As a requirement of the Major Rehabilitation guidance, stability equations and performance modes are required to be assessed for the structure being analyzed. The 2006 multi-beam and above water structure survey was utilized in providing the existing conditions relevant to the application of the jetty stability equations and the production of structural reliability values for each 100 ft segment of each of the jetties.For each jetty, given the primary design and performance modes, structural reliability was calculated for each 100 ft length of jetty. This information can be provided along the length of each structure. At present this information has been calculated but rather than displayed along the length it has been incorporated in the project event tree simulation. A table will be provided with summarizes this information.

The SRB model execution in hindcast mode includes the original and all subsequent repair cross section parameters per 100 ft of jetty including stone size parameters. Project/structure changes, environmental loading, and damages incurred were all included in assessing cross section capacity.

The condition of the structure (original, repair, existing) are all inputs to the model so that each 100 ft segment can be based on true physical capacity parameters. The causes of failure are typical rubblemound modes of failure (see attachment 2) and are documented in historical cross sections, observed damages on the structures, physical modeling, as well as a good hindcast representation using those standard damage modes. The resiliency and ability for a rubblemound structure to incur some damage and still function is simulated in the model , the mechanism causing failures explained, performance modes identified.

1. **ADOPT NOW.** The latest MCR jetty inspection as well as consolidating existing condition and vulnerability information are already provided in the report. Attachment 1 summarizes locations in the report where information on existing condition and design concerns can be found. Attachments 3 to 5 illustrate the minimum template deficits along each jetty length. Attachments 6 through 9 illustrate the latest MCR inspection report.

2. **ADOPT NOW**. A better summarizing of the hindcast and the existing condition stability and reliability assessments already conducted and provided in the report will be included.

The SRB model execution in hindcast mode includes the original and all subsequent repair cross section parameters per 100 ft of jetty including stone size parameters. Project/structure changes, environmental loading, and damages incurred were all included in assessing cross section

capacity. For the existing condition for each jetty, given the primary design and performance modes, structural reliability was calculated for each 100 ft length of jetty. That information will be better summarized in the final report. 3. **NOT ADOPT**. The condition rating system is intended for use as a preliminary assessment tool that can inform decision-makers when it is feasible to move into a more intensive analytical phase for the project. In the case of the MCR structures, that intensive analytical phase is represented by the Major Rehabilitation life cycle analysis including a complete performance and stability mode analysis per 100 ft of jetty structure for each of the primary jetty structures. 4. **ADOPT NOW.** Adopt by better summarizing and describing the existing condition of the MCR structures. 5. **ADOPT NOW.** Adopt by moving some of the quarry and stone source information from Appendix B into the main report. 6. **NOT ADOPT.** Stone durability has not been found to be an issue for any of the stone sources that have supplied stone in the past to the MCR structures.
Panel Final BackCheck Response (#17)
Concur. Condition assessment should be better described and incorporated into a failure analysis summary. This combined information could be included in a summary table which pulls together in one location the repair history, design attributes and ongoing deficiencies leading up to the repair for each area of each jetty.

Literature Cited:

USACE (1998). Condition and Performance Rating Procedures for Rubble Breakwaters and Jetties. REMR Management Systems—Coastal/Shore Protection System Devices. Technical Report REMR-OM-24, U.S. Army Corps of Engineers, Washington, D.C.

Comment (#18):
The mechanisms causing jetty head scour have not been sufficiently analyzed to allow selection of the appropriate jetty head repair measure.
Basis for Comment:
Causes of jetty head scour have not been sufficiently investigated. Tidal shoal and outlet channel geomorphic processes should be further evaluated and analyzed to ensure that proper jetty head repair measures are selected. The mechanisms causing the "scour holes" and undermining of the jetty in the vicinity of the jetty tips (North Jetty and Jetty A) have not been sufficiently analyzed for selection of the jetty head repair measure. Figure A1-32 indicates a progressive erosion of ebb tidal shoals in the vicinity of the North Jetty (between Stations 60 and 90) undermining the south toe of the structure. The report understates the situation when it notes (Appendix A1, p. 28), "If the jetty foundation washes away, jetty reconstruction is problematic." A solid understanding of the environment and bathymetry changes is essential for development of a reliable design alternative. Spur groins installed along the south slope of the North Jetty will assist in addressing scour generated by localized currents, but will not provide protection from overall MCR tidal shoal and channel morphological changes. Continued ebb shoal erosion and potential tidal channel movement could undermine the head of the proposed offshore spur groins (located near Stations 90 and 70). It seems likely that scour holes are related to the observed jetty tip recession. The 100 foot deep scour hole at the end of Jetty A is particularly alarming from a structural design perspective. Equally alarming is the discussion of "Vertical scour along the toe of the MCR jetties has exceeded 10 meters in some reaches" (Appendix A2, p. A2-11). If there really is, or was, a more than 30 foot high underwater scarp in places along the toe of the jetties, then more investigation is warranted. Figures showing typical sections often do not extend to the toe of slope, and show details that aren't feasible, such as rock limits ending in a small angle without an engineered toe. (See Appendix A1, Figure A1-258). Strategies to deal with scour, especially at the jetty tips appear undeveloped. Design features could include scour blankets, launched toes, or a program of regular fill using dredged material.
Significance – Medium:
Inadequate evaluation of the geomorphic processes responsible for the deterioration at the jetty tips (North Jetty and Jetty A) could lead to an incorrect approach to rehabilitation of those areas of damaged structures.

Recommendations for Resolution:
1. Conduct a more detailed evaluation of historical geomorphic changes in the outlet channel and shoals in order to evaluate tidal shoal erosion and tidal channel migration. Comparative analysis of historical bathymetric surveys would be helpful in developing a better understanding of historical trends and associated correlation with jetty structure historical damage, failure, and repair activities. Additionally, use historical geomorphic change analysis and hydrodynamic analysis to estimate long- term changes and impacts to the North Jetty and Jetty A to formulate jetty head rehabilitation alternatives and development of design criteria. 2. Do not limit the jetty repair preliminary designs to the footprint of the authorized jetties. Evaluate scour protection alternatives extending past the jetty tips. 3. Draft plans, profiles, and sections at this level of design using suitable software, such as AutoCAD® or MicroStation®. Microsoft Excel® is not an adequate substitute for drafting software. 4. Draft the jetty design typical sections to scale and extend past the scour holes and navigation channel. 5. Conduct a subsurface geotechnical investigation to obtain the geological properties needed to verify or design an adequate foundation.
USACE Final Evaluator Response (#18)
CONCUR There are many processes that drive scour effects along the toe of coastal structures. In the past, motivation of jetty scour at MCR has been due to many interacting processes. Initially, tidal channel re-alignment due to jetty construction was the dominate motivation for morphology change and scour. As the inlet responded to jetty incremental jetty construction during 1885 to 1939, channel re-alignment stabilized as the inlet equilibrated to its present configuration. Rip currents, tidal currents, vortex shedding and other secondary flow effects, and wave action are now the processes that are believed to affect scour along the jetties. Even if the hydrodynamic aspects of scour are fully understood, there remains the difficulty of coupling the hydrodynamics with sediment transport. Consequently, most scour prediction techniques consist of rules of thumb and fairly simplistic empirical guidance developed from laboratory and field observations. If consistent hydrodynamic conditions persist over a sufficient time span, scour holes and trenches eventually reach a stable configuration. What is known about jetty scour at MCR is based primarily on observation of bathymetry change over time and space, with insight being supplemented by hydrodynamic modeling. The scour depth realized at the terminus of the originally constructed jetties has stabilized to a point of equilibrium; scour depth is no longer increasing along the jetty tips. The scour at areas inshore of the jetty tips continue to evolve along each jetty, but a rate reduced from the initial stages of inlet response to jetty construction. Table A2-6 to A2-8 summarizes scour depths that have been observed to date along each jetty. This will be better explained in the report. The maximum vertical extent of scour is believed to have equilibrated, but the scour zone is believed to migrate along each jetty based on jetty head recession and landward recession of the shore-jetty root interface. Future projection of scour depth is presented in these tables, based on past scour trends. It is likely that the proposed spur groins will be subjected to some scour as the seabed locally adjusts to the presence of these elements. A given percentage of overbuild (10-

20%) has been included within the MCASES cost estimate to account for natural reshaping of the groins as they are placed.

For this study, the proposed implementation of Jetty Head features will occur on existing relic stone which is the remnant from previous jetty construction and repair sequences. Relic stone has been in its present configuration for more than 10 years at the areas proposed for jetty head features. Construction of jetty head features on relic stone serves two purposes, A) Keep the jetty head feature on the relic stone base and to avoid constructing the jetty features on scour-susceptible sand, and B) Minimize material cost and construction complexity by maximizing the use of a relic stone. If the jetty head template extends beyond (off) the relic stone, the quantity of material needed to complete the cross-section rapidly increases and the operating radius requirement (reach) for material placement rapidly increases. For all three jetties, the proposed jetty head feature would terminate significantly shoreward from the originally constructed jetty head. For the North and South jetties, the proposed "new" jetty head feature would be placed at a location 200 ft offshore from the present above water jetty terminus. For Jetty "A", the proposed jetty head feature would be placed at a maximum distance of 400 ft from the present jetty terminus. In all cases, the catch point for the jetty head feature is intended to be set back at least 10 ft from the fall line of the relic stone. The final location and configuration of the proposed jetty head features will be re-evaluated using detailed survey data and physical model studies (and refined) during the design documentation report phase prior to construction. Because the jetty head features will be constructed on a relic stone base, jetty head features are not expected to require scour blankets or launched toes.

The effect of toe scour on future life-cycle performance of jetty head features, has been evaluated using future scour depths presented in table A2-6 to A2-8. Future scour depth along proposed jetty head locations is estimated to extend below the present seabed elevation by 10-20 ft, depending on jetty location. The strategy for dealing with scour along the jetty head feature locations is to minimize the exposure of these features to scour by keeping the feature entirely on the relic stone AND to account for toe continued scour of the relic stone base in assessment of the jetty head feature.

Information relevant to assessing the scour processes include historical and present rate of scour at the jetty head, evolution of adjacent morphology, historical and present rate of recession of the jetty head, and expected stability of the relic stone base. Better explanation can be provided on the expected evolution of the adjacent morphology and the expected stability of the jetty head features proposed.

1. **ADOPT NOW**. Adopt by better summarizing the historical geomorphic changes in the vicinity of the jetties as well as the apparent stabilization of the most significant scour hole processes. The effect of toe scour on future life-cycle performance of jetty head features, has been evaluated using future scour depths presented in table A2-6 to A2-8.
2. **NOT ADOPT**. The jetty head repairs recommended in the Major Rehabilitation report are placed some distance back from the authorized jetty head location and are placed on large existing relic stone bases. The reasoning for building on top of the relic stone base is threefold: (1) set the jetty head back away from the more damaging

forces further toward the ocean (inlet), (2) build on top of a reworked and stabilized base, and (3) minimize construction costs by not extending the cross section into a deep and uncertain foundation.

3. **ADOPT in FUTURE**. The final design for the jetty head stabilization will be developed after physical model studies and a final detailed design report. At that time, more detailed design drawings will be developed.
4. **ADOPT in FUTURE.** Detailed design drawings will be part of the detailed design phase.
5. **NOT ADOPT.** Appendix B investigates the foundation issues related to the jetty repair alternatives. The vast majority of the jetty repair work builds on top of existing relic stone base which has been stabilized over years of existence at the MCR inlet

Panel Final BackCheck Response (#18)

Concur.

For Recommendation #3, development of conceptual design details were recommended as a typical planning level tool to ensure the proposed improvements are adequately represented for regulatory permitting and cost estimating. Errors in cross sectional configuration could result in substantial differences in volumes and costs. If they have been developed for the preferred alternative, they should be provided in the final report.

For Recommendation #5, additional information (multi-beam survey results, graphics, data, etc...) should be provided in the final report to show the extent and location of relic stone and graphically show the proposed footprint of improvements is within the zone of relic stone foundation.

Comment (#19):
Risk thresholds for selected alternatives are not clearly defined.
Basis for Comment:
Risk thresholds are used in repair frequency predictions as triggers for maintenance response and subsequently in maintenance cost predictions. The frequency of reaching degradation thresholds is predicted by risk thresholds. Combining degradation thresholds with repair costs (minor vs. major) can also be used to determine the threshold for triggering maintenance actions, balancing multiple small repairs against the cost of a single major repair. The Major Rehabilitation Evaluation Report includes extensive discussions of risks related to different portions of the project; however, while this discussion of risk is extensive, defined thresholds are not presented in the document. It is to be expected that the risk (probability) of surpassing thresholds may vary among alternatives in both configuration (number and placement of spurs, jetty length) and in cross sections considered. The risk associated with each alternative considered should be assessed based on materials, cross sections, supporting geological features, currents, and storms. It is also proper procedure to examine how the risk of one design component may be altered by the inclusion or exclusion of a second design component.
Significance – Medium:
Undefined risk thresholds may serve to undermine the logic of the cost and maintenance predictions and, to a lesser extent, the alternatives selected.
Recommendations for Resolution:
1. Define risk thresholds for alternatives, including source of risk and effect of exceeding the threshold.

USACE Final Evaluator Response (#19)
CONCUR Within the project event tree (and SRB model), there are three specific threshold parameters used to inform project performance or response actions. Two of the three threshold parameters pertain to jetty reliability. Reliability thresholds define when the structural and functional reliability for a given jetty transitions from a likelihood of satisfactory performance to a likelihood for unsatisfactory performance. Reliability thresholds are defined in table A2-3 and A2-4, and provide a time-varying indicator of overall jetty performance. Repair (maintenance) thresholds define when a given jetty segment will be repaired, based on the degradation of the jetty cross-section. The maintenance threshold serves to a trigger a life-cycle repair action, to minimize the chance of losing the function of a given jetty segment. Although there are no specific risk thresholds identified within the event tree simulation, the maintenance threshold is intended to manage (or reduce) the risk cross-section loss. The maintenance threshold serves to trigger a life-cycle response, and can vary depending upon the selected maintenance strategy. Table A2-12 list thresholds for activating maintenance response. These are conditional thresholds which are expressed in terms of the fraction of jetty cross-section area remaining within the upper part of the jetty cross-section that resists wave action. Using a cross-section area based threshold for triggering jetty maintenance actions emulates how the district monitors

the jetties and activates maintenance actions. The timing and frequency of jetty repairs, for a given maintenance threshold, is based on the rate of jetty cross-section degradation. Jetty degradation is a function of cross-section type (repair or rehab), materials & construction technique, exposure to wave action, and exposure to scour effects. 1. **ADOPT NOW**: PDT will supplement the report to describe how different maintenance thresholds address life-cycle performance.
Panel Final BackCheck Response (#19)
Concur.

Comment (#20):
It is not clear how uncertainty and derived risk analyses were considered in the structure and application of the model.
Basis for Comment:
Project life-cycle cost analyses should consider the risk of construction cycle and operational cycle downtime, which does not appear to be included. However, risks cannot be evaluated without understanding the level of uncertainty associated with the SRB model result. The uncertainty associated with actual future conditions, which may deviate from the modeled future conditions, is not apparent. The SRB model includes 600 variables (Section 9, p. A2-91) each of which has a data set which can be expected to reflect an associated variance. Depending on the calculation stream, these variances, applied geometrically, will lead to accumulated statistical errors and uncertainties. These cumulative internal variances can be expected to result in high uncertainty in the output of the SRB model, which should be considered in the evaluation of alternatives.
Significance – Medium:
Potentially wide error bars (uncertainty) may compromise life-cycle maintenance and repair schedules.
Recommendations for Resolution:
1. Quantify and explain the uncertainty (i.e., error bars) associated with each variable when analyzing processes that involve a chain of events. 2. Identify, analyze, and define errors that may accumulate to assess model reliability.
USACE Final Evaluator Response (#20)
CONCUR The cost data used within the SRB model to estimate future life-cycle costs associated with jetty construction are based on M-CASES estimates. The M-CASES estimates accounted for interruptions to the construction operations reflecting a non-optimistic production rate for jetty construction activities. The MII cost estimates identified specific cost and schedule risks elements for each alternative plan, to reflect a fully funded risk-based cost estimate for each plan. Refer to Appendix E for MII construction cost estimate details. The project event tree simulation (SRB model) included the MII uncertainties, when utilizing MII cost data within the model. Many of the 600 variables are constants, serve as conditional statement indicators, or are used for plotting and output synthesis. Approximately fifty variables serve as "variable" input used by the model. The PDT has performed a sensitivity analysis on 11 primary variables that affect life-cycle performance. 1. **ADOPT NOW**: Isolate the variable input parameters, provide updated and additional discussion of sensitivity analysis for 11 primary input variables. 2. **ADOPT NOW**: Provide additional information showing output metrics with uncertainties.
Panel Final BackCheck Response (#20)

Concur.
Comment (#21):
The model output parameters and wave height components are not clearly explained and supported.
Basis for Comment:
The meaning of the following SRB model output parameters is not clear: • Functional Reliability • Structural Reliability • Probability of Unsatisfactory Structure Performance. For example, the main report (Section 3.6.1, p. 3-43) includes the following: "Functional reliability is the likelihood that a structure will satisfactorily perform its intended function within a given time interval. Functional reliability is derived by combining structural reliability metrics with metrics that describe the present structure cross-section configuration." One difficulty is that the understanding of "Functional Reliability" requires first understanding "structural reliability metrics", (which are not to be confused with "metrics that describe the present cross-section configuration"). However, the "structural reliability metrics" are not clearly defined either. A word search of Appendix A2 for the term "Structural Reliability" does not reveal a set of equations for calculating the parameter or a clear explanation. Similarly, much of the SRB model includes terminology and variables that are hard to understand. For example, Table A2-12, Jetty Maintenance Thresholds, (p. A-60) consists of numbers and parameters not connected to anything that has a physical meaning. Conventional calculations and metrics such as volumes, areas, and depths are parameters with physical meaning that would improve the understanding of the SRB model. Understanding the SRB model outputs would be improved with graphics that are connected to parameters with physical meaning. The wave height component of the SRB model is not supported by standard coastal engineering practice. Progressive jetty damage in the SRB model is based on a stochastic time series of wave heights, which is derived from "An ensemble of 52 storm events … recorded at NDBC buoys… during 1998 to 2008." It is unclear why only 10 years of buoy data were used when a longer record of more than 17 years with gaps removed is available (Appendix A1, pp. 34 and 37). It is also not certain that extreme wave height events were properly included in the SRB model process. It is common industry practice to test a coastal engineering design using a specific design environmental criterion, such as the 100 year return period wave height.
Significance – Medium:
The model parameters that compare alternatives lack a physical meaning, such as a volume of rock or depth of scour. It is therefore difficult to verify, calculate, or evaluate whether the parameters used or model results are reasonable.

Recommendations for Resolution:
1. Explain and demonstrate how the model output parameters relate to physical performance measures, with graphics or figures. 2. Measure jetty damage and performance with conventional calculations, and commonly applied metrics, for example: a. Volume of sediment entering the navigation channel, or dredge volume, b. Depth or volume of scour at the jetty toe c. Volume or area of armor rock displaced from the jetty. 3. Test the design against a specific storm event, such as the 100 year return period event. 4. Calculate the return period of extreme events using the complete record of measured offshore wave data.

USACE Final Evaluator Response (#21)
CONCUR Structure reliability is estimated using the dynamic performance functions as described in A2-Section 3. Those stability performance functions include frontside slope stability and backside slope stability (from overtopping). The various equations that went into this calculation can be found on pages A2-25 to A2-36, and include the Hudson Equation, Van der Meer Equations, Walker-Palmer-Duhnam, and Van Gent equations. The functional reliability as it is utilized in the project event tree simulation combines the projected structural reliability of the cross section with the volume left in the above water portion of the cross section (i.e. the robustness of what is left) to translate that to a parameter that estimates the likelihood of that part of the structure losing its ability to function. This approach follows Corps Major Rehabilitation guidance on calculating probability of failure and risk. The thresholds in Table A2-12 are conditional thresholds which are expressed in terms of the fraction of cross-section area remaining within the upper part of the jetty cross-section. The upper region is the area of the jetty that resists wave action (Page A2-23 and A2-53 to A2-56). The threshold values in Table A2-12 are the decimal fraction of the "standard template"; i.e. 0.15 is 15% of the upper cross section. The "standard template" for each jetty is defined on page A2-62 and in Table A2-13. When the jetty cross-section is damaged to a level that exceeds (is lower than) the prescribed threshold values, the jetty cross-section is repaired. Using a (remaining) cross-section area based threshold for triggering jetty maintenance actions emulates how the district monitors the jetties and activates maintenance actions. A supplemental discussion of jetty damage thresholds (Table A2-12) and the standard cross-section template (Table A2-13) will be provided. It is important to note that the SRB model is a project event tree life cycle simulation model. The basic and progressive steps of jetty cross section damage, accumulated damage with successive events, identification of a maintenance action or failure event are all stepped through on an annual basis for the three jetties as required by Major Rehabilitation guidance. Existing SRB output graphics show the simulated reduction in jetty cross-section area over time (for hindcast conditions due to wave and scour damage processes) for a selected cross-section (figure A2-18a-c, A2-25b, A2-26b, A2-27b). Figure A2-18a shows simulated cumulative toe-scour depth for a given North Jetty cross-section hindcast (Sta 84+50). The observed values for toe scour realized at this location are shown in Table A2-6. The description of SRB scour estimates will be expanded to compare simulated scour values to observed values. We will supplement the report with graphics and added discussion that

show simulated tonnage of jetty damage sustained by the cross-section corresponding to the cross-section area reduction for a given cross-section. Jetty damage (area) simulated by the SRB model will be compared to other calculations (Hudson). Graphics and discussion will be added to compare repair tonnage simulated by the SRB model vs. observed values for the hindcast. Graphics and discussion will be added to compare SRB forecast values of jetty repair tonnage vs. other estimating techniques. Supplemental information will be provided to describe the incremental volume of sediment predicted to enter the navigation channel due to jetty head recession and shore edge recession.

The report will be modified to better explain the above extremal wave height information. The offshore wave height history utilized encompasses the entire period of record for the Columbia River NDBC buoy (1987-2008) and the estimates of annualized return interval (Figure A1-70 and A1-71) match closely with those developed by Ruggiero recently for the Oregon coast. The transference of observed offshore wave conditions to the MCR jetties is problematic without using the observed wave spectra (directional) as an offshore boundary condition (BC). The offshore wave environment in the PAC-NW is too complex to describe by parameterized spectra. Directional offshore wave data (spectra) for the MCR is available from 1998 onward. This is why the ensemble of 52 offshore wave events (BCs) is pooled from 1998-2008. The BC ensemble included the three largest observed wave events on record for the MCR offshore region (1987-2008), which are shown in figure A1-68. Appendix A1 describes how the 52 storm wave conditions were used to emulate the sub- to inter-annual nearshore storm wave climate, as imposed by the offshore storm wave climate shown in figure A1-70-71 (see page A1-39 to A1-43). The project event tree life cycle analysis simulates on an annual basis both the range of potential incident deep water wave heights as well as the number of storms occurring per year. Additional graphics and discussion will be provided to demonstrate that the above process is reproduced by the SRB model. An estimate (graphic) of the return period from nearshore storm wave conditions will be provided, based on the featured ensemble of offshore wave conditions. The high-end of return period for nearshore waves (from above graphic) will be used to assess the design alternatives for survivability.

1. **ADOPT NOW**. Adopt now. All of the output model parameters are intended to contribute to an annual cross section condition, volumes and frequency of repair stone needed, volume and frequency of dredged material volume expected. A supplemental discussion of jetty damage thresholds (Table A2-12) and the standard cross-section template (Table A2-13) will be provided. The physical performance measures simulated by the model will be better explained and verified. When applied to a coastal structure such as a rubblemound structure, the design equation indicates when the armor stone is expected to be mobilized. Subsequent to that we calculate how much stone we expect to be taken off of the structure and whether or not the whole cross section is compromised. Normally, and within the model, the damage accumulates from year to year until a more severe damage state occurs. This whole damage evolution process is not captured in any conventional design equation, however, I believe the SRB model captures that process very well and also reproduces 100 years of hindcast evolution of the structure.

2. **ADOPT NOW** Adopt now by better explaining the physical processes simulated in the model and comparing to other reasonable calculations of the processes. The description

of SRB scour estimates will be expanded to compare simulated scour values to observed values. We will supplement the report with graphics and added discussion that show simulated tonnage of jetty damage sustained by the cross-section corresponding to the cross-section area reduction for a given cross-section. Jetty damage (area) simulated by the SRB model will be compared to other calculations (Hudson). Graphics and discussion will be added to compare repair tonnage simulated by the SRB model vs. observed values for the hindcast. Graphics and discussion will be added to compare SRB forecast values of jetty repair tonnage vs. other estimating techniques. Supplemental information will be provided to describe the incremental volume of sediment predicted to enter the navigation channel due to jetty head recession and shore edge recession. The calculations utilized in the model are conventional and according to USACE Major Rehabilitation reliability analysis methods. Explanation will be provided which ties jetty and shoreface recession estimates with the channel infill volume volumes noted in table A2-5. Standard damage and performance modes were applied to all three primary structures. Attachment 1 illustrates the primary damage modes. Physical modeling results helped in quantifying the actual progression of damage for a given cross section. Tables A2-5 through A2-14 provide some of the information referred to in this recommendation. (See attachment 2.) Attachment 3 summarizes various locations in the report that address the physical processes incorporated in the analysis.

3. **ADOPT NOW** Adopt now by demonstrating how the current analysis exposes the jetty structures to typical extreme events and quantifies the respective damages to the events.
4. **ADOPT NOW** Adopt now by better explaining the analysis already performed for the study which includes the complete record of measured offshore wave data. The cumulative distribution curves provided for incident wave height along the jetty lengths will be compared to the extremal analysis results to demonstrate the appropriate exposure to extreme conditions within the annual loading processes in the model.

Panel Final BackCheck Response (#21)

Concur.

The additional analysis described in the Evaluator Response partially addresses the issue; however, the fundamental problems with the SRB model remain.

Some of the “adopt now” statements include a description of future work that is not consistent with the recommendation. Recommendation No. 3 is to “Test the design against a specific storm event such as the 100 year return period event”. The corresponding adopt now statement discusses how to clarify that the existing analysis includes “typical extreme events”. They are not the same thing.

Comment (#22):

The culvert installation details, as well as potential impacts, need further clarification.

Basis for Comment:

The Major Rehabilitation Evaluation Report states that the existing culvert has increased scour and adversely affected the North Jetty, and that it will be relocated. There are a few sentences in the main report and in Appendix D that mention the culvert, but there is not enough information provided in the main report to determine if there will be any potential impacts from the new discharge location. The table at the end of Appendix D provides the most detail anywhere in this report regarding the culvert relocation. On p. 6-6 in the main report there is a sentence stating work will begin in 2014 to install a culvert to divert overland flow to another area that will not impact the North Jetty root stability. While this sounds like a reasonable approach to protect the North Jetty, more information is needed to clarify the impact such as the source of the water, an assessment of the water quality, and an estimate of the flow rate involved. Without knowing the exact new location, it is not possible to assess the potential environmental impact of relocating this water flow.

Significance – Medium:

More detailed information on the new location of the culvert as well as water quality, flow rates, and source of the water is necessary to determine the environmental impact of the relocation.

Recommendations for Resolution:

1. Add one paragraph in the main report that addresses the culvert relocation.
2. Present any available data on the water quality, flow rates, and water source of water discharged through the culvert.
3. Provide the specific location planned for new culvert.

USACE Final Evaluator Response (#22)

CONCUR

The purpose of the culvert, the size and the method of replacement will be expanded on in the main report. The existing culvert is failing and replacement is not anticipated to vary extensively from the original installation. The lagoon fill project is intended to stabilize The North side of the North Jetty by preventing scour that is caused by water flowing parallel to the jetty.

1. **ADOPT NOW.** A paragraph will be added to the main report discussing the culvert relocation.
2. **ADOPT in FUTURE**. Available data on the water quality, flow rates and water source as well as detailed design information will be presented in the Design Document Report for this portion of the project.
3. **ADOPT NOW.** The specific location of the culvert will be shown in the report.

Panel Final BackCheck Response (#22)

Concur.

Comment (#23):
The various base years cited in the report and the difference between project life and period of analysis require additional explanation.
Basis for Comment:
The terms "project life" and "period of analysis" are not defined or differentiated, and the project base year varies throughout the report: • In the economic spreadsheet models, the NPVs are calculated for differing periods of analysis (2009-2070 for South Jetty, 2008-2070 for Jetty A, and 2008-2070, 2008-2057 and 2008-2069 for the North Jetty); whereas the AACs are based on a 50 year period of analysis. • The period of analysis extends 50 years beyond the base year of 2011 when discussing sea level rise (pp. A1-38 and A2-68). • The period of analysis for future condition simulations is 64 years (2006 to 2970) for the North Jetty and Jetty A and 63 years (2007 to 2070) for the South Jetty (p. A2-78). • The AAC is calculated using an amortization factor applied to the present year cost stream from the NPV implementation year (2006/2007) to 2069 (p. A2-51). • The base year of the economic analysis is not identified in Section 2 or Appendix C, but is stated as 2014 elsewhere in the report (pp. ES-3 and A2-78). • Within the SRB model, the base year is stated as 2011 when discussing sea level rise (pp. A1-38 and A2-68). • Within the SRB model, the base year for NPV cost discounting is 2006 for the North Jetty and Jetty A, and 2007 for the South Jetty (p. A2-51).
Significance – Low:
Inconsistencies in terminology and periods of analysis can lead to misunderstanding of findings and results.
Recommendations for Resolution:
1. Define and differentiate between the terms "project life" and "period of analysis." 2. Revise the report to eliminate inconsistencies between the varying periods of analysis. 3. Use a consistent base year throughout the analysis, and revise the report to reflect consistency. 4. Revise Section 2 and Appendix C of the report to state the year that is considered to be the base year, the length of the period of analysis, and the calendar years that are included in the period of analysis. 5. Provide definitions of all terms in a Glossary.

USACE Final Evaluator Response (#23)
CONCUR **1. ADOPT NOW.** Each term will be clarified and used consistently. **2. ADOPT NOW.** The report will be revised to reflect that all NPVs and AACs are calculated using the same base year and period of analysis. Spreadsheets used for these calculations will be revised and archived with the appropriate calculations shown. **3. ADOPT NOW.** The base year for each jetty will be the same, and the Year labels in the

spreadsheets will be modified to reflect that each stream of costs begins and ends at the same time. **4. ADOPT NOW.** Section 2 and Appendix C of the report will be revised to state the year that is considered to be the base year, the length of the period of analysis, and the calendar years that are included in the period of analysis. **5. ADOPT NOW.** A glossary of terms will be included in the report.
Panel Final BackCheck Response (#23)
Concur.

Comment (#24):

Cargo tonnage and vessel trip statistics presented throughout the report are inconsistent.

Basis for Comment:

Data presented throughout the report have inconsistencies that should be corrected. The following are examples of inconsistencies in values for cargo tonnages, vessel trips, and value of cargo:

- Page ES-1 – cargo on the MCR is 45 million (M) tons and 3,500 vessel crossings based on 2008 Waterborne Commerce Statistics Center data. These data are not cited in the body of the report.
- Page 1-2 – cargo on the MCR is 40 M tons worth $17 billion, with 12,000 commercial vessels navigating the MCR annually.
- Pages 2-1 and C-1 – cargo on the MCR is 40 M tons valued at $17 billion based on a 2009 Pacific Northwest Waterways Association (PNWA) factsheet cited in Appendix C.
- Pages 1-4 and C-4 – cargo on the MCR is 32 M tons in 2003 and projected at 43 M tons in 2020 based on 2005 Center for Economic Development and Research (CEDER) data, cited as a footnote in Appendix C.
- Page C-5, Table C-1 – 5,364 total vessel trips on the MCR based on 2005 Waterborne Commerce Statistics Center data.
- Page A1-3 – cargo on the MCR is 48 M tons worth $16 billion, with 12,000 commercial vessels navigating the MCR annually.

The cargo and vessel trip statistics presented in the report appear to include all traffic on the MCR and Lower Columbia River (LCR). The report assumes all traffic accessing the MCR is dependent on the MCR jetties. The without-project condition channel depths are not adequately described. The cargo and vessel trips that would be impacted by the jetties, that is, the portion of the fleet transiting the MCR that would be restricted by the without-project condition channel depths, is not described.

Significance – Low:

Consistent cargo and vessel trip data for the MCR are needed in order to develop an understanding of the significance of the jetties.

Recommendations for Resolution:

1. Describe the cargo tonnages, vessel trips, and value of cargo consistently throughout the report, or supply an explanation of the differences and why various data sources were used.
2. Describe the portion of the fleet accessing the MCR that is dependent on the jetties (i.e., what are the without-project condition channel depths and what portion of the fleet transiting the MCR would be restricted by the without-project condition channel depths).

USACE Final Evaluator Response (#24)

CONCUR

The various sources and presentations of the cargo volume will be reviewed for consistency.

1. **ADOPT NOW** A table containing the different sources for cargo data will be included in the Main Rehab. Report.

2. NOT ADOPT The MCR Jetties have an extensive affect on the morphology of the MCR, not just the channel depth. It is not practicable to attempt to estimate the overall condition of the River Mouth if the Jetties were not there.
Panel Final BackCheck Response (#24)
Concur. In addition to including a table showing the different sources of cargo data, include an explanation of why different data sources were used.

Comment (#25):
Terminology related to jetty rehabilitation and failure is defined inconsistently or vaguely in some places.
Basis for Comment:
Inconsistencies in terminology can make understanding the project difficult. Commonly used terms in the document, such as “failure,” are not clearly and qualitatively defined. Phrases such as “close to failure” appear frequently, in a qualitative sense, but without an understanding of how much jetty damage, if any, constitutes a “failure.” Another example is in the SRB model where “fix-as-fails” repairs are described as, “To defer jetty maintenance for as long as possible, the jetty is maintained close to the margin of functional loss.” The concept makes sense but how the model deals with terms like “as long as possible” and “close to the margin of functional loss” is unclear. Other phrases, such as “scheduled repair” and “rehabilitation” seem to be inconsistent as well. For example, “scheduled repair” includes “head capping” in the executive summary of the main report, but does not include “head capping” in some alternatives analyzed by the SRB model.
Significance – Low:
Without clear, consistent definitions of terminology, it is difficult to understand exactly what is being proposed or analyzed and can lead to misinterpretations.
Recommendations for Resolution:
1. Add a Definitions list or Glossary to the document.
USACE Final Evaluator Response (#25)
CONCUR The discrepancy in the naming conventions for the jetty repair and rehabilitation plans will be reviewed and clarified. **1. ADOPT NOW**. A glossary will be added to clarify terminology.
Panel Final BackCheck Response (#25)
Concur.

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Attachment 4

(Appendix H)

DEPARTMENT OF THE ARMY
U.S. ARMY CORPS OF ENGINEERS
441 G STREET, NW
WASHINGTON, DC 20314-1000

REPLY TO
ATTENTION OF

CECW-P

15 August 2011

MEMORANDUM FOR Director, Deep Draft Navigation Planning Center of Expertise (DDPCX)

SUBJECT: Request for Approval of the Stochastic Reliability-Based Model for the Major Rehabilitation of the Jetty System at the Mouth of the Columbia River.

1. The Columbia River model is a stochastic reliability-based (SRB) model designed to determine the most cost-effective and reliable method of maintaining and repairing the jetties at the mouth of the Columbia River. The model has been reviewed to determine if it satisfies the certification criteria in EC 1105-2-412. Because the model is used to evaluate the potential effects of alternatives, EC 1105-2-412 is applicable. The HQUSACE Model Certification Panel has determined that the certification criteria have not been met and the model is therefore not certified or approved for use at this time.

2. As stated in the Memorandum from the DDPCX, this was a Level 1 review, meaning that a highly complex model was used in the decision making and that there could be a high risk of making an incorrect investment decision. Several shortcomings were identified by an independent external peer review panel. The HQUSACE Model Certification Panel generally agrees with the findings and recommendations of the external panel and suggests that the district use the ATR and IEPR comments to develop a path forward.

3. The IEPR panel commented that the SRB model by itself has very limited value for analyzing alternatives and is not a substitute for conventional economic and engineering analysis. It further commented that the SRB model functions as a "black box" and does not allow an analysis of alternatives that is clearly based on sound technical evidence of engineering design performance. The model lacks clarity and support for the interaction between economic consequences and engineering function. The panel commented that while many elements of the SRB model are appropriate and required per USACE guidance and standard engineering practice. The SRB model does not have to fully incorporate all engineering reliability modeling components. However, the reliability modeling output must be consolidated with economics within the model, particularly in terms of hazard or fragility curves and how they respond to repairs. The ATR reviewer strongly recommended that the SRB process and results be validated with a simpler model using hazard functions from the SRB reliability curves and the development of consequences using a traditional economic simulation model. The IEPR Panel further commented that the model seems inappropriate based on USACE published guidance, does not support the project goals, has not been verified and validated, and should not be relied upon.

4. The HQUSACE Model Certification Panel understands that ATR suggestions were not implemented and the IEPR comments were submitted after the DDPCX's request for model approval. The model and IEPR concerns are significant, and it is not expected that the concerns could adequately be addressed without considerable additional effort. If the district chooses to

address the ATR and IEPR comments, the DDPCX must submit additional supporting information for panel consideration. Otherwise, the district has indicated that the results of the model will not be used in the Major Rehabilitation Report if the model is not approved for use. In the absence of an approved model, the district, MSC, and DDPCX should collaborate on the analyses required for a technically (engineering, economics, environmental) sound and policy compliant decision document.

HARRY E. KITCH, P.E.
Deputy Chief, Planning and Policy Division
Directorate of Civil Works

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Attachment 5

(Appendix H)

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DEPARTMENT OF THE ARMY
CORPS OF ENGINEERS, PORTLAND DISTRICT
PO BOX 2946
PORTLAND OR 97208-2946

REPLY TO
ATTENTION OF

CENWP-PM-F

MEMORANDUM FOR Chief, NWD-PDD

SUBJECT: Request for vertical team concurrence on path forward for approval of the MCR Major Rehabilitation Report

1. Request your concurrence and endorsement of this memo defining the Portland District's path forward.

2. Based on a draft memo regarding disapproval of the SRB model from CECW-P, the district has developed a proposed path forward to ensure approval of a Major Rehab Report (MRR) in time for the FY 14 budget submittal. The district is requesting NWD, DDPCX and HQUSACE concurrence—from both a technical and policy standpoint.

3. The Portland District will partner with an A-E contractor to revise the planning model and complete the MCR Major Rehabilitation Report. Upon completion of the revised model, the district will submit a request and supporting documentation for model approval for use to the DDPCX and HQUSACE.

4. A district intends to perform a new ATR on the revised final MRR. In addition, the PDT will thoroughly document how the three outstanding IEPR comments (2, 4 and 8) have been resolved and request concurrence through the vertical team. Sediment analysis concerns noted in comment 2 will be addressed by citing a comprehensive, multi-agency study that is ongoing. Comments 4 and 8 will be directly addressed through the actions described above to fully document the engineering analysis.

5. The PDT will also change and update appropriate parts of the following MRR information: (a) the base condition will incorporate Major Maintenance Report (MMR) changes for critical NJ repairs and lagoon mitigation; (b) stone quantities and MCACES cost estimate and fully-funded cost; (c) the economic analysis; (d) plan formulation; and (e) upon vertical approval of the path forward, the review plan and project management plan.

6. The following MRR information from the 90-percent draft document will not be altered unless the engineering analysis results in substantive changes to the selected plan: (a) draft FONSI signed on 31 May 2011; the Mitigation Plan, 404(b)(1), Final EA and BA/BiOp; (b) Geotechnical Studies; and (c) Cost-Schedule Risk Analysis.

7. To execute the actions discussed in paragraphs 2 through 5, the District will develop a detailed Plan of Study including project schedule and milestone check-ins with the vertical team. Pending vertical team approval of the district's path forward, the PDT plans to have a 90-percent draft MRR completed by 30 November 2011 and a final MRR by 28 March 2012.

8. Point of contact for this is Eric Bluhm, at 503-808-4759.

Kevin J. Brice, P.E. PMP
Deputy District Engineer
For Project Management

Attachment 6

(Appendix H)

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MODEL APPROVAL PLAN
(Supplemental)

STOCHASTIC RELIABILITY BASED
MATLAB MODEL
MCR JETTIES

for

Mouth of the Columbia River
Major Rehabilitation Report

North West Portland District
CENWP

US Army Corps
of Engineers ®

Model Approval Plan
(Supplemental)

Stochastic Reliability Based
MATLAB model
MCR jetties

Mouth of the Columbia River
Major Rehabilitation Report

CENWP

1. Purpose

The purpose of this Model Approval Plan is to outline the review process and requirements necessary to assure the quality of the Stochastic Reliability Based MATLAB model for the MCR jetties (SRB), as submitted from the CENWP to the DDPCX in support of the Approval for Single Use of the model in the Mouth of the Columbia River, Major Rehabilitation Report (MCR MRR). This review plan is based on the requirements contained in *EC 1105-2-412 Assuring Quality of Planning Models* and the *Standard Operating Procedures for the Processing of Planning Model Certification/Approval Actions,* which complements Engineering Circular 1105-2-412 (EC) and provides a guideline for implementation of the EC. The MCR SRB model has been in development since 2005, significantly pre-dating the EC, therefore the model is in the latter stages of the review/approval process. This plan is intended to capture what has already been done and describe how the PDT intends to complete the model approval process.

2. Reference and Guidance

2.1. Engineering Circular 1105-2-412, Assuring Quality of Planning Models, 31 March 2011.
2.2. Budget Engineer Circular (EC) 11-2-199, dated 31 March 10
2.3. Standard Operating Procedures for the Processing of Planning Model Certification/Approval Actions dated 16 November 2010

3. Background

Stochastic Reliability Based (SRB) model developed for the Mouth of the Columbia River (MCR) evaluates the expected reliability of different alternative cross-sections of the three existing jetties. The wave climate and damage function currently used in the model are specific to the MCR. EC 1105-2-412, Assuring Quality of Planning Models makes a distinction between model certification and model approval based upon the origin of the model and the extent of the model's intended use; Section 5. c stipulates that models that have been developed by the corps (or outside entities) and are viewed by the vertical team as single-use or study specific models require model approval. Models which will be used over a wider range of conditions and locations require certification. At this time the PDT recommends that the MCR SRB model be considered a Regional/Local Model as defined EC 1105-2-412 section 5. a. (2) and that it be reviewed for approval, not certification due to it being specific to the MCR jetties in its current form.

The MCR SRB model has been developed over several years and has been subjected to an Agency Technical Review (ATR). After incorporating comments the model was reviewed during the Independent Engineering Peer Review (IEPR) of the MCR Major Rehab Study (Attachment 1). The MCR SRB model has not received approval for use from HQUSACE and two IEPR comments that were specific to the model have not been resolved. In order to address the IEPR team's unresolved comments CENWP solicited the assistance of the firm Moffat and Nichol via a two phase task order to review the model, associated documentation and engineering regulations and identify specific changes that need to be made in the model code and assist CENWP in making those changes. Phase I of the task order produced a letter report (Attachment 2) that evaluates the functionality of the MCR SRB model and identified nine specific improvements to the model code that address the outstanding concerns regarding the model. All nine of the recommendations were adopted by the PDT and two additional tasks related to including the updated model and the results into the MCR Major Rehabilitation Report (MRR) were incorporated into the task order modification for phase II (Attachment 3).

3.1 Previous Reviews

A review plan for the MCR Major Rehabilitation Report was last revised in September 2010 and submitted to the DDPCX for consideration. The review plan described the series of reviews for the different elements required for the report.
This Review Plan (RP) outlined the reviews as required by EC 1105-2-410. The RP supplements the Project Management Plan (PMP) and identified three levels of peer review: District Quality Control (DQC), Agency Technical Review (ATR), and Independent External Peer Review (IEPR) based on the scale, impacts, and cost of this project.
All decision documents and their supporting analyses have undergone DQC, ATR and IEPR, to "ensure the quality and credibility of the government's scientific information", in accordance with EC 1105-2-410 and the quality management procedures of the responsible command. The Circular addresses review of the decision document as it pertains to both approaches and planning coordination with the appropriate Center. The Circular also requires that DrChecks be used to document all ATR and IEPR comments, responses, and associated resolutions accomplished. These requirements have been met for the multiple components of the MCR MRR and the comments and responses are attached to this model review plan for consideration.

The types of technical reviews that were conducted are provided below.

3.1 a District Quality Control (DQC).

DQC is the review of basic science and engineering work products focused on fulfilling the project quality requirements defined in the Program Management Plan (PMP). It was managed in the home district and may be conducted by staff in the home district as long as they are not doing the work involved in the study, including contracted work that is being reviewed. Basic quality control tools include a Quality Management Plan providing for seamless review, quality checks and reviews, supervisory reviews, Project Delivery Team (PDT) reviews, etc. Additionally, the PDT is responsible for a complete reading of the report to assure the overall integrity of the report, technical appendices and the recommendations before approval by the District Commander. It is expected that the MSC/District quality management plans address the conduct and documentation of this fundamental level of review. DQC is not covered by this Review Plan. The MCR MRR was assigned a separate DQC review team to present an unbiased opinion of the technical merits of the report. The DQC team was led by the Deputy Chief of Engineering and Construction and the review resulted in XXXX comments and responses which had a dramatic improvement on the report.

3.1 b Agency Technical Review (ATR).

ATR (which replaces the level of review formerly known as Independent Technical Review) was an in-depth review, managed within USACE, and conducted by a qualified team outside of the home district that was not involved in the day-to-day production of a project/product. The purpose of this review was to ensure the proper application of clearly established criteria, regulations, laws, codes, principles and professional practices. The ATR team reviewed the various work products and assures that all the parts fit together in a coherent whole. The ATR team was comprised of senior USACE personnel, the ATR team roster is attached. To assure independence, the leader of the ATR team was chosen from outside the home MSC.

3.1 c Independent External Peer Review (IEPR).

This is the most independent level of review, and is applied in cases that meet certain criteria where the risk and magnitude of the proposed project are such that a critical examination by a qualified team outside of USACE is warranted. The criteria for application of IEPR include, but are not limited to (1) the total project cost exceeds $45 million; (2) there is a significant threat to human life; (3) it is requested by a State Governor of an affected state; (4) it is requested by the head of a Federal or state agency charged with reviewing the project if he/she determines the project is likely to have a significant adverse impact on resources under the jurisdiction of his/her agency after implementation of proposed mitigation (the Chief has the discretion to add IEPR under this circumstance); (5) there is significant public dispute regarding the size, nature, effects of the project; (6) there is significant public dispute regarding the economic or environmental cost or benefit of the project; (7) cases where information is based on novel methods, presents complex challenges for interpretation, contains precedent-setting methods or models, or presents conclusions that are likely to change prevailing practices; or (8) any other circumstance where the Chief of Engineers determines IEPR is warranted. IEPR may be appropriate for feasibility studies; reevaluation studies; reports or project studies requiring a Chiefs Report, authorization by Congress, or an EIS; and large programmatic efforts and their component projects. It was determined that MCR MRR warranted an IEPR. The IEPR was managed by Bechtel, an eligible outside organization. The scope of review addressed all the underlying planning, engineering, including safety assurance, economics, and environmental analyses performed, not just one aspect of the project. A review of the attached charge questions given to the IEPR team indicates that the MATLAB model received a comprehensive review by qualified programmers and ocean engineers. The IEPR charge questions and comments and responses are attached. Three of the IEPR comments resulted in comments and responses dialogues where the IEPR team and the PDT were unable to reach concurrence.

3.2 Post IEPR Activity

In an effort to resolve the non-concur items identified in the IEPR, CENWP engaged the services of Moffatt & Nichol and together with the PDT has outlined a path forward to resolve the open IEPR comments by improving the model code, allowing for the transparency, compliance with current technology and corps policy, documentation, practicality with data inputs and outputs and clearly identifying the use and limitations of the model consistent with EC 1105-2-412. Following is a list of the steps contained in EC 1105-2-412 and the actions that the PDT has either taken or propose to take to satisfy those steps:

Step 1: Proponent Identifies model to be used for a national, regional or local application and PCX determines the need for certification or approval.

Response: The proponent is CENWP, and we have identified the model as Regional/Local model developed by USACE with assistance from a non-corps entity (Moffat & Nichol) as a study specific model, therefore the PDT believes model approval not certification is required.

Step 2: Proponent submits model and documentation to the appropriate PCX.

Response: PDT has forwarded the model code, ATR and IEPR comments to the DDPCX. DDPCX determined that the model was not approvable via memo indicating that the PDT should resolve outstanding IEPR comments prior to approval. PDT has engaged an expert modeling team from a qualified AE firm. Updated model and documentation will be sent to DDPCX for review and approval.

Step 3: PCX determines appropriate level of review utilizing the criteria outlined in EC. PCX has final approval on level of review.

Response: The MCR SRB model development predates the EC, so a formal review level was never assigned. It is assumed by the PDT that the model will require a level 1 or level 2 review.

Step 4: PCX establishes a review team, team leader and defines the anticipated charge scope of review. The review charge and scope should guide the product reviewers and direct them to key issues, assumptions, routines and aspects for review. A team selected from the roster of qualified reviewers maintained by the appropriate PCX, including external and internal reviewers, will conduct Level 1 and Level 2 reviews. Level 3 and Level 4 reviews may be conducted by Corps internal experts, but the review team, as deemed appropriate by the PCX, could include external individuals as well. Protocol and procedures for the model review process will be specified in the PCX standard operating procedures (SOP) and will reflect prevailing industry practices.

Response: The MCR PDT worked with the PCX (if it wasn't DDPCX then list who please) to conduct the model ATR and the overall MCR Major Rehabilitation Report (MCR MRR) IEPR, which included an extensive number of PCX recommended questions regarding the model, modeling process and interpretation of the results into the MCR MRR. The results of both reviews have been received by the DDPCX. Outstanding comments from the IEPR are being resolved as previously described and it is the belief of the PDT that the resolution of the comments shall conclude the review process and provide the DDPCX with the information and documentation required to render approval.

Step 5: The PCX develops a certification plan to include to include the information from steps 1-4, defining the scope of the review. The certification plan (and accompanying model documentation materials) is submitted to CECW-P for approval. Written approval from CECW-P must be received by the PCX prior to proceeding with the certification review.

Response: The MCR PDT has been pursuing an overall Major Rehabilitation Report approval process, of which the model approval is a component. The MCR PDT engaged the vertical team as well as the relevant PCX(s) to develop a review and approval plan early in the development stages of the project. The review plan included DQC, ATR (model specific and report) prior to conducting an IEPR. The PDT would like the DDPCX to give consideration to the previously conducted reviews, the changes generated from the reviews and the future actions described in this plan. If there are additional steps required that has not been completed or proposed in this plan please identify and the PDT will include them prior to submission for approval.

Step 6: Once the PCX has received approval to proceed, the PCX will hold an initial meeting to begin the certification process to assure that all participants understand the nature of the effort, as well as to discuss any particular technical or administrative issues that will be important in the review. The meeting (which can be held by teleconference) will include representatives of the PCX, the model proponent and the review team. CECW-P will be notified of the meeting and invited to attend.

Response: The goal of the project's proponent, CENWP, is to complete the revised MCR MRR in time for submission in the FY 14 budget request. In order to accomplish this goal the PDT requests that the PCX forward the review plan to CECW-P as soon as possible and schedule the teleconference to assure that the actions proposed by the PDT are consistent with the requirements for model approval.

Step 7: In fulfilling it's role, the review team will provide to the PCX a consolidated documentation of review comments and recommendations. The review should adhere to the review charge and scope provided by the PCX. The PCX will strive for consensus, but one or more reviewers may not concur with the views of the majority. Matters of disagreement should be addressed forthrightly in the report. As a final recourse, a reviewer may choose to prepare a brief dissent describing the issues of contention and arguments in support of the minority view. To encourage reviewers to express their views freely, the review comments are treated as panel responses and are given to proponents with identifiers removed.

Response: This process was conducted during the rigorous IEPR conducted from November 2010 through March 2011. The review team was comprised of external experts and the review was conducted according to the process described in EC 1165-2-209 and supplemental implementation guidance. The charge questions were developed with the assistance of the PCX and are attached to this plan as appendix D. A review of the charge questions will demonstrate that the IEPR team was directed to review the model carefully and render a professional opinion on the quality and to make recommendations on how to overcome deficiencies noted. The PDT is currently pursuing their recommendations.

Step 8: Review comments are provided to the PCX within 90 days after submittal of the model for review to the review team. (Ninety days is the estimated maximum time for review of models in level 1. For models in other categories, the review time will be adjusted accordingly, and is expected to be less than 90 days.) The PCX then assesses whether the review team fulfilled the charge and scope provided. When the PCX determines that the review charge and scope have been met, the comments are provided to the proponent for review and response, and a checkpoint meeting is scheduled to discuss the review comments and issues for response. The checkpoint meeting will be held with the same parties as the initial meeting in Step 6, above.

Response: The IEPR process is in the final stage, resolution of outstanding comments. The charge questions provided and agreed upon by PCX and PDT were the basis of the IEPR.

Step 9: Feedback from the proponent, within 30 days after receipt of the comments, is transferred through the PCX back to the review team until all comments are either resolved or all parties reach an agreement on outstanding issues. The PCX will strive to resolve all comments, but not all comments may be resolved. CECW-P in consultation with the HQ Model Certification Panel, the proponent and the PCX will have the final decision on comment resolution and product certification/approval. The final decision on model certification/approval should be made within 90 days after initial submittal of review comments to the proponent. (In cases where substantial revisions are made to the model, this time period may be longer).

Response: The project is currently at this stage. The outstanding comments are being resolved by streamlining the model, increasing transparency and reconfiguring the model code into modules in order to track interim results. The SRB model will be reconfigured in order to provide the ability to utilize an input files that generate discrete output results. This process will increase the ability of the PDT to evaluate alternatives quickly and efficiently.

Step 10: The PCX will furnish Headquarters Planning Community of Practice Leader the documentation of the review, model documentation, and a recommendation for or against certification/approval. CECW-P, in consultation with the Model Certification HQ Panel, will make the determination to certify/approve or not certify/approve the model. Upon certification/approval, CECW-P will issue a certification/approval memorandum and (for certified models) instruct the PCX to add the model to the National toolbox of certified models.

Response: The documentation has been submitted. Additional documentation describing the changes made and actions taken, along with the model code will be re-submitted as soon as it is available.

4. Documentation Provided by Proponent

Notification to DDPCX from CENWP-P	Attachment 4
MCR SRB Model Certification Memo	Attachment 5
Deep Draft PCX Approval for Use	Attachment 6

4.1. Model Technical Documentation

- **Calibration Results Documentation**

Moffat and Nichol, working with the PDT is currently reviewing the model calibration and will produce a calibration report with the PDT. Document will be available when received and approved. (see task 3 MCR MN SOW MOD2 attachment 3).

4.2. Model User Documentation

- The PDT and Moffat and Nichol are currently reviewing the model operations and establishing code that will allow the model to accept and produce input/output files. Upon completion of this task the Model User Guide will be updated and forwarded.

4.3. Model Support Literature

-

4.4. Model QA/QC Documentation/Activities

- Notification to DDPCX from CENWP-P — Attachment 4
- MCR SRB Model Certification Memo — Attachment 5
- Deep Draft PCX Approval for Use — Attachment 6

5. Type/Scope of Review

Per EC-1105-2-412, 31 March 2011, the PCX recommended an Extensive Review. The model is currently undergoing an extensive review and the PDT recommends continuing, but not re-initiating, this process

The following language defines the scope of the review and will be provided to the model reviewers:

5.1. Preliminary charge for reviewers of the MCR Stochastic Reliability Based Model

The initial charge given to the ATR review and IEPR review team is shown below. In addition to the underlying theory, conceptualization, and computational aspects of the model, reviewers are asked to comment on aspects of the model that potentially affect its usability and reliability as a potential producer of information to be used to influence planning decisions.

While the specific review questions included below were intended to prompt the reviewer for information specific to the efforts to Approve for Single Use, the reviewers were encouraged to offer comments believed relevant and appropriate to any elements of the technical quality and usability of the model, Major Rehab Report and appendices as documented in the provided review materials. Accordingly, please provide responses to the sought scientific and technical topics listed below and perform a broad review of the focusing on your areas of expertise, experience, and technical knowledge. Listed below are the model review charge questions.

IEPR Charge Questions relevant to the Model Provided by PDT

1. Is the purpose of the model clearly defined?

2. Is the model diagram easily understood.

3. Does the model follow a logical programming path.

4. Is the model free from programming errors that would alter the model results significantly enough to skew the plan selection?

5. Does the model adequately capture and evaluate all of the relevant variables.

6. Can the model described achieve the stated purpose?

7. Does the model accurately describe (model) repair activities and sequences? Is it modeling the repair activities similarly to how the repairs will be sequenced and performed.

Technical Quality

8. Comment on the overall technical quality of the model.

9. Is the model based on well-established contemporary theory?
    a. Is the available science applied correctly?
    b. Are the models empirically supported?

10. Is the model a realistic representation of the actual system?

11. Are the analytical requirements of the model properly identified?

12. Does the model address and properly incorporate the analytical requirements?

13. Are the assumptions clearly identified, valid, and do they support the analytical requirements?

14. Are the formulas used in the model mathematically correct and are the model computations appropriate and done correctly?

15. Comment on the ability of the model to address risk and uncertainty.

16. Comment on the ability of the modes to calculate benefits for total project life.

17. Does the model adequately assess the full range of costs associated with the three jetties?

18. Will the model be useful in capturing and quantifying the full extent of benefits expected to be obtained from anticipated repairs?

System Quality

19. Has the model been sufficiently tested and validated, or do critical errors still exist?

Usability

20. Comment on the models' usability.

21. Comment on the availability of the data required by the model.

22. How easily are model results understood?

23. Comment on how useful model results are for supporting project objectives.

24. Is user documentation available, user friendly, and complete?

25. Is the model transparent and does it allow for easy verification of calculations and outputs?

OTHER GENERAL QUESTIONS

26. Can the model be adapted to other geographic regions?
    a. If so, how much can the model be modified before they need to be reviewed again?

27. Is it clear where the model's geographic boundaries fall?

28. Is the approach to the development and use of the model described clearly enough to allow the approach to be repeated and obtain the same or similar results?
    a. If not, why?
    b. If not, what needs to be done to make the approach repeatable?

29. Comment on the ability of the model to calculate benefits for total project life.

30. Is the application of the model defensible?

31. Comment on whether there are any resolution issues with the model (i.e., size of the area that can effectively be evaluated).
    a. At what scale (e.g. acres, hundreds of acres) can the models be effectively applied?

32. Comment on whether all of the most important variables are included in the model.
    a. Are variables that are both stressors and drivers included in the model?
    b. Should additional variables be included?
    c. Are some of the variables more sensitive than others?

33. To what extent is best professional judgment used in the model?

34. To what extent is the model developed specifically for the MCR Jetties?

35. Are error checks built into the model?

36. Are USACE policies and procedures related to the model clearly identified?

37. Does the model properly incorporate USACE policies and accepted procedures?

38. Is sea level change addressed by the model?
    a. If yes, is it internal to the model or does it need to be addressed externally?

5.2 Follow-On review charge.

The reviewers will not be charged with initiating a new review of the product in its entirety. The reviewers are charged with reviewing the IEPR comments and responses, and the PDT's subsequent actions, edits and changes in order to confirm that the PDT has adequately addressed the IEPR panel's questions. Follow-up questions made by the reviewers will also be addressed by the PDT until the reviewers, and the PDC, are satisfied that all outstanding issues have been resolved.

6. DN**N-PCX Summary.**

The DDN-PCX will provide a summary of review findings, which will include a summary of comments, and a strategy for implementing any necessary actions to remedy any additional or remaining deficiencies. The DDN-PCX will close-out the review when it determines identified issues have been resolved to its satisfaction.

Final Independent External Peer Review Report Columbia River at the Mouth, Oregon and Washington Major Rehabilitation Evaluation Report

Prepared by
Battelle Memorial Institute

Prepared for
Department of the Army
U.S. Army Corps of Engineers
Deep Draft Navigation Planning Center of Expertise
Mobile District

Contract No. W912HQ-10-D-0002
Task Order: 0007

March 9, 2011

Final Independent External Peer Review Report
Columbia River at the Mouth, Oregon and Washington
Major Rehabilitation Evaluation Report

by

Battelle
505 King Avenue
Columbus, OH 43201

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FINAL
INDEPENDENT EXTERNAL PEER REVIEW REPORT
for the

Columbia River at the Mouth, Oregon and Washington
Major Rehabilitation Evaluation Report

EXECUTIVE SUMMARY

Project Background and Purpose

The Mouth of the Columbia River (MCR) navigation project is located at the confluence of the Columbia River with the Pacific Ocean on the border between Washington and Oregon. Navigation is maintained by three primary navigation structures, North Jetty, South Jetty, and Jetty A. The North Jetty and Jetty A are located in Pacific County, Washington, near Ilwaco and Long Beach on the Long Beach Peninsula. The North Jetty was completed in 1917. Jetty A, positioned on the south side of the North Jetty, was constructed in 1939 to a length of 1.1 miles. Jetty A was constructed to direct river and tidal currents away from the North Jetty foundation. The South Jetty is located in Clatsop County, Oregon near Warrenton/Hammond and Astoria. The initial 4.5-mile section of the South Jetty was completed in 1895, with a 2.4-mile extension completed in 1913. Jetty construction realigned the ocean entrance to the Columbia River, established a consistent navigation channel that was 40 feet below MLLW across the bar, and significantly improved navigation through the MCR. Improvements made from 1930 to 1942 (including addition of Jetty A and Sand Island pile dikes) produced the present entrance configuration. Each year, ocean-going vessels on the Columbia River carry about 40 million tons of cargo with an estimated value of $17 billion on an annual basis. More than 12,000 commercial vessels and 100,000 recreational/charter vessels navigate through the MCR annually.

Prior to improvement in 1885, the tidal channels through the MCR shifted north and south between Fort Stevens and Cape Disappointment, a distance of about 5.5 miles. The controlling depth of dominant channel through the ebb tidal delta varied between 18 to 25 feet deep below MLLW. The ebb and flood tidal deltas at MCR entrance were distributed over a large area immediately seaward and upstream of the river mouth. Ships often had difficulty traversing the Columbia River bar, the area in which the flow of the estuary rushes headlong into towering ocean waves. On many occasions, outbound ships had to wait a month or more until bar conditions were favorable for crossing. To make navigating through the MCR even worse, sailing ships had to approach either of the two natural channels abeam to the wind and waves. The natural channels often shifted widely within the course of several tidal cycles. At best, crossing the bar was dangerous. At worst, it was not possible. Offshore of the MCR lies the vast expanse of the northeast Pacific Ocean. Inshore of the MCR lies the Columbia River and estuary, the coastal outlet for a drainage basin of 250,000 square miles.

Despite intermittent repair and partial rehabilitation efforts, all of the MCR jetties are currently in an unacceptably deteriorated condition. This project was undertaken to address problems related to the structural stability of the MCR jetty system in order to extend the functional life of the jetties and maintain deep-draft navigation.

Independent External Peer Review Process

USACE is conducting an Independent External Peer Review (IEPR) of the Columbia River at the Mouth, Oregon and Washington Major Rehabilitation Evaluation Report (hereinafter Mouth of Columbia River IEPR). Battelle, as a 501(c)(3) non-profit science and technology organization with experience in establishing and administering peer review panels for USACE, was engaged to coordinate the IEPR of the Mouth of Columbia River Major Rehabilitation Evaluation Report. Independent, objective peer review is regarded as a critical element in ensuring the reliability of scientific analyses. The IEPR was external to the agency and conducted following USACE and Office of Management and Budget (OMB) guidance described in USACE (2010), USACE (2007), and OMB (2004). This final report describes the IEPR process, describes the panel members and their selection, and summarizes the Final Panel Comments of the IEPR Panel (the Panel).

Five panel members were selected for the IEPR from more than 28 identified candidates. Based on the technical content of the Mouth of Columbia River Major Rehabilitation Evaluation Report and the overall scope of the project, the final panel members were selected for their technical expertise in the following key areas: design and construction engineering (coastal engineering), plan formulation, biology NEPA, hydrology and hydraulics engineering/coastal engineering, geomorphology, and economics. USACE was given the list of candidate panel members, but Battelle made the final selection of the Panel.

The Panel received electronic versions of the Mouth of Columbia River IEPR documents, totaling more than 1,000 pages, along with a charge that solicited comments on specific sections of the documents to be reviewed. The charge was prepared by USACE according to guidance provided in USACE (2010) and OMB (2004). Charge questions were provided by USACE and included in the draft and final Work Plans.

The USACE Project Delivery Team briefed the Panel and Battelle during a kick-off meeting held via teleconference prior to the start of the review. In addition to this initial teleconference, a second teleconference with USACE, the Panel, and Battelle was conducted halfway through the review period to provide the Panel an opportunity to ask questions of USACE and clarify uncertainties. The Panel produced more than 500 individual comments in response to the 78 charge questions.

IEPR panel members reviewed the Mouth of Columbia River IEPR documents individually. The panel members then met via teleconference with Battelle to review key technical comments, discuss charge questions for which there were conflicting responses, and reach agreement on the Final Panel Comments to be provided to USACE. Each Final Panel Comment was documented using a four-part format consisting of: (1) a comment statement; (2) the basis for the comment; (3) the significance of the comment (high, medium, or low); and (4) recommendations on how to resolve the comment. Overall, 25 Final Panel Comments were developed. Of these, 8 were identified as having high significance, 14 had medium significance, and 3 had low significance.

Results of the Independent External Peer Review

The panel members agreed among one another on their "assessment of the adequacy and acceptability of the economic, engineering, and environmental methods, models, and analyses used" (USACE, 2010; p. D-4) in the Mouth of Columbia River IEPR document. Of primary significance, and as discussed in several of the Final Panel Comments, the Panel has serious concern with the SRB model and the potentially over-emphasized role it played in the evaluation of alternatives, engineering design, and economic analyses. Table ES-1 lists the Final Panel Comments statements by level of significance. The full text of the Final Panel Comments is presented in Appendix A of this report. The following statements summarize the Panel's findings.

Plan Formulation Rationale: From a planning perspective, the Major Rehabilitation Evaluation Report is well done and in compliance with all of the typical formulation steps; however, it was never clearly explained that the scope of work was limited to the repair and rehabilitation within the present configuration, nor why it was limited in this manner. Undefined risk thresholds may serve to undermine the logic of the cost and maintenance predictions and, to a lesser extent, the alternatives selected. The Panel agreed that the SRB model is not a substitute for conventional engineering and economic analyses and should not be a stand-alone analysis for selecting a recommended plan.

Economics: The Panel identified three major issues in the economic analysis: (1) inconsistencies in the Major Rehabilitation Evaluation Report and economic spreadsheet models; (2) the assumption that navigation would not be impacted; and (3) the formulation of the base condition. Inconsistencies in the report and economic spreadsheet models pertaining to the calculation of NPVs and AACs prevented the Panel from validating the economic analysis. Based on the assumption that navigation will not be impacted, a least cost analysis was used in lieu of a transportation cost savings analysis to calculate NED benefits. Conflicting assumptions concerning the ability to maintain navigation invalidate the logic behind calculating NED benefits using a least cost analysis. As the project is currently formulated, the base condition maintenance strategy for the MCR jetties conforms most closely with the fix-as-fails strategy, while the base condition life-cycle costs are the basis for estimating project benefits for all action alternatives. Inaccurate formulation of the base condition may increase life cycle costs, and may erroneously escalate project benefits. Each of these issues could impact the selection of the NED plan, which was selected as the recommended plan.

Engineering: There are serious technical difficulties with the Major Rehabilitation Evaluation Report and analyses. The report lacks a set of design criteria, including project life, standards of performance to be met, and environmental conditions with return period events. All are part of conventional coastal engineering design practice. The SRB model cannot be verified and does not include important processes. Major questions remain that have not been adequately investigated for this level of study, including subsurface geotechnical properties, feasibility of proposed barge offloading/material re-handling facilities, and the long term stability of the jetty foundations assuming continued erosion and loss of nearshore sediment. The report indicates that large volumes of sediment will move into the navigation channel after a breach event. However, the data and analysis do not support this conclusion. Additionally, is no clear discussion of the role of maintenance or emergency dredging, especially under extreme winter conditions. Detailed construction cost estimates also need to be provided in order for the cost analysis to be complete and verifiable. Although there is a good description of historical failures and repair actions for each jetty, there is no discussion or documentation of current jetty condition or detailed condition assessments of structure and functional condition.

Environmental: There is no discussion in the main report of sea level rise and potential wave height increases and its impact on this project over the 50+ year project timeline, given that the regional wave climate has been documented as more severe in the last 10 years. This has potential impacts to the project and in designing a project with lower long-term maintenance costs. Potential environmental impacts on sensitive species, upland habitats, and water quality as well as potential impacts to recreational use during project construction are not comprehensive nor adequately described in the mitigation plan. Finally, the alternatives are limited to armoring the existing configuration of the jetties and may not satisfy NEPA directive for alternative analysis.

Table ES-1. Overview of 25 Final Panel Comments Identified by the Mouth of Columbia River IEPR Panel

Significance – High	
1	The economic analysis used to select the National Economic Development (NED) plan cannot be validated, nor can it be determined if assumptions were applied correctly in the economic spreadsheet models.
2	The analysis of the sediment transport process is not comprehensive, and the data and analysis do not support the conclusions concerning large movement of sediment during a breach event.
3	The underlying assumption that navigational impacts will not occur is not substantiated.
4	The SRB model by itself has very limited value for analyzing alternatives and is not a substitute for conventional economic and engineering analysis.
5	The base condition, as formulated, does not represent the current O&M practice.
6	The reported analysis and design to mitigate a potential breach of the foreshore dune at the South Jetty root is not adequate.
7	The basis of design and design environmental criteria are vague, not consistent within the report, and not consistent with conventional coastal engineering design practice.
8	The models and analyses of jetty failure do not include all significant processes.
Significance – Medium	
9	The alternative selection process may fail to meet the requirements of NEPA Section 1502.14.
10	A failure analysis for the original structure design and past trends of Operation and Maintenance (O&M) costs has not been provided.
11	Sea level rise and potential increases in wave height have not been examined sufficiently under different model scenarios.

Table ES–1. Overview of 25 Final Panel Comments Identified by the Mouth of Columbia River IEPR Panel, continued

Significance – Medium	
12	Construction cost estimates cannot be evaluated because the assumptions and details have not been provided.
13	Potential environmental impacts on sensitive species, upland habitats, and water quality have not been thoroughly discussed or specifically mitigated in the document.
14	Potential impacts to recreational use during project construction, as identified in public comments, are not adequately discussed or mitigated.
15	There is not sufficient information on the evaluation of barge offloading and material re-handling facilities to ensure these sites can operate as intended and to ensure the construction costs are adequately represented.
16	The requirements, costs, and history associated with emergency dredging compared to scheduled maintenance dredging activities have not been specified.
17	The current jetty structure condition is not well described, making it difficult to confirm the confidence of the SRB model analysis and selection of a recommended plan.
18	The mechanisms causing jetty head scour have not been sufficiently analyzed to allow selection of the appropriate jetty head repair measure.
19	Risk thresholds for selected alternatives are not clearly defined.
20	It is not clear how uncertainty and derived risk analyses were considered in the structure and application of the model.
21	The model output parameters and wave height components are not clearly explained and supported.
22	The culvert installation details, as well as potential impacts, need further clarification.
Significance – Low	
23	The various base years cited in the report and the difference between project life and period of analysis require additional explanation.
24	Cargo tonnage and vessel trip statistics presented throughout the report are inconsistent.
25	Terminology related to jetty rehabilitation and failure is defined inconsistently or vaguely in some places.

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LIST OF TABLES

LIST OF ACRONYMS

AAC	Average annual cost
ATR	Agency Technical Review
CEDER	Center for Economic Development and Research
CE/ICA	Cost effectiveness/incremental cost analysis
CHL	Coastal and Hydraulic Laboratory
CMS	Coastal Modeling System
COI	Conflict of Interest
DEC	Design Environmental Conditions
DrChecks	Design Review and Checking System
EA	Environmental Assessment
EFH	Essential Fish Habitat
ESA	Endangered Species Act
ESU	Evolutionary significant unit
IEPR	Independent External Peer Review
LCR	Lower Columbia River
MCR	Mouth of Columbia River
MLLW	Mean lower low water
NED	National Economic Development
NEPA	National Environmental Policy Act
NPV	Net present value
NTP	Notice to Proceed
O&M	Operation and Maintenance
OMB	Office of Management and Budget
PNWA	Pacific Northwest Waterways Association
SWS	Shallow water site
USACE	United States Army Corps of Engineers
USEPA	United States Environmental Protection Agency
WRDA	Water Resources Development Act

1. INTRODUCTION

The Mouth of the Columbia River (MCR) navigation project is located at the confluence of the Columbia River with the Pacific Ocean, on the border between Washington and Oregon. Navigation is enabled by three primary navigation structures, North Jetty, South Jetty, and Jetty A, plus maintenance dredging of about 4 million cubic yards per year from the entrance channel. The North Jetty and Jetty A are located in Pacific County, Washington, near Ilwaco and Long Beach on the Long Beach Peninsula. The North Jetty was completed in 1917. Jetty A, positioned on the south side of the North Jetty, was constructed in 1939 to a length of 1.1 miles. Jetty A was constructed to direct river and tidal currents away from the North Jetty foundation. The South Jetty is located in Clatsop County, Oregon near Warrenton/Hammond and Astoria. The initial 4.5-mile section of the South Jetty was completed in 1895, with a 2.4-mile extension completed in 1913. Jetty construction realigned the ocean entrance to the Columbia River, established a consistent navigation channel that was 40 feet below mean lower low water (MLLW) across the bar, and significantly improved navigation through the MCR. Improvements made from 1930 to 1942 (including addition of Jetty A and Sand Island pile dikes) produced the present entrance configuration.

Prior to improvement in 1885, the tidal channels through the MCR shifted north and south between Fort Stevens and Cape Disappointment, a distance of about 5.5 miles. The controlling depth of dominant channel through the ebb tidal delta varied between 18 to 25 feet deep below MLLW. The ebb and flood tidal deltas at MCR entrance were distributed over a large area immediately seaward and upstream of the river mouth. Ships often had difficulty traversing the Columbia River bar, the area in which the flow of the estuary rushes headlong into towering ocean waves. On many occasions, outbound ships had to wait a month or more until bar conditions were favorable for crossing. To make navigating through the MCR even worse, sailing ships had to approach either of the two natural channels abeam to the wind and waves. The natural channels often shifted widely within the course of several tidal cycles. At best, crossing the bar was dangerous. At worst, it was not possible. Offshore of the MCR lies the vast expanse of the northeast Pacific Ocean. Inshore of the MCR lies the Columbia River and estuary, the coastal outlet for a drainage basin of 250,000 square miles.

The objective of the work described here was to conduct an Independent External Peer Review (IEPR) of the Mouth of Columbia River Major Rehabilitation Evaluation Report in accordance with procedures described in the Department of the Army, U.S. Army Corps of Engineers (USACE) Engineer Circular *Civil Works Review Policy* (EC No. 1165-2-209) (USACE, 2010), USACE CECW-CP memorandum *Peer Review Process* (USACE, 2007), and Office of Management and Budget (OMB) bulletin *Final Information Quality Bulletin for Peer Review* (OMB, 2004). Battelle, as a 501(c)(3) non-profit science and technology organization with experience in establishing and administering peer review panels, was engaged to coordinate the IEPR of the Mouth of Columbia River Major Rehabilitation Evaluation Report. Independent, objective peer review is regarded as a critical element in ensuring the reliability of scientific analyses.

This final report details the IEPR process, describes the IEPR panel members and their selection, and summarizes the Final Panel Comments of the IEPR Panel on the existing environmental, economic, and engineering analyses contained in the Mouth of Columbia River Major Rehabilitation Evaluation Report. The full text of the Final Panel Comments is presented in Appendix A.

2. PURPOSE OF THE IEPR

To ensure that USACE documents are supported by the best scientific and technical information, USACE has implemented a peer review process that uses IEPR to complement the Agency Technical Review (ATR), as described in USACE (2010) and USACE (2007).

In general, the purpose of peer review is to strengthen the quality and credibility of the USACE decision documents in support of its Civil Works program. IEPR provides an independent assessment of the economic, plan formulation, engineering, and environmental analysis of the project study. In particular, the IEPR addresses the technical soundness of the project study's assumptions, methods, analyses, and calculations and identifies the need for additional data or analyses to make a good decision regarding implementation of alternatives and recommendations.

In this case, the IEPR of the Mouth of Columbia River Major Rehabilitation Evaluation Report was conducted and managed using contract support from Battelle, which is an Outside Eligible Organization under Section 501(c)(3) of the U.S. Internal Revenue Code with experience conducting IEPRs for USACE.

3. METHODS

This section describes the method followed in selecting the members for the IEPR Panel (the Panel) and in planning and conducting the IEPR. The IEPR was conducted following procedures described by USACE (2010) and in accordance with USACE (2007) and OMB (2004) guidance. Supplemental guidance on evaluation for conflicts of interest (COIs) was obtained from the *Policy on Committee Composition and Balance and Conflicts of Interest for Committees Used in the Development of Reports* (The National Academies, 2003).

3.1 Planning and Schedule

After receiving the notice to proceed (NTP), Battelle held a kick-off meeting with USACE to review the preliminary/suggested schedule, discuss the IEPR process, and address any questions regarding the scope (e.g., clarify expertise areas needed for panel members). Any revisions to the schedule were submitted as part of the final Work Plan.

Table 1 defines the schedule followed in executing the IEPR. Due dates for milestones and deliverables are based on the NTP date of December 6, 2010. Note that the work items listed in Task 7 occur after the submission of this report. Battelle will enter the 25 Final Panel Comments developed by the Panel into USACE's Design Review and Checking System (DrChecks), a Web-based software system for documenting and sharing comments on reports and design documents, so that USACE can review and respond to them. USACE will provide responses (Evaluator Responses) to the Final Panel Comments, and the Panel will respond (BackCheck Responses) to the Evaluator Responses. All USACE and Panel responses will be documented by Battelle.

Table 1. Mouth of Columbia River IEPR Schedule

TASK	ACTION	DUE DATE
1	**NTP**	12/6/2010
	Review documents available	12/7/2010
	[a]Battelle submits draft Work Plan	12/15/2010
	USACE provides comments on draft Work Plan	12/20/2010
	[a]Battelle submits final Work Plan	12/28/2010
2	Battelle requests input from USACE on the conflict of interest (COI) questionnaire	12/8/2010
	USACE provides comments on COI questionnaire	12/9/2010
	[a]Battelle submits list of selected panel members	12/16/2010
	USACE provides comments on selected panel members	12/17/2010
	Battelle completes subcontracts for panel members	1/5/2011
3	[a]Battelle receives final charge from USACE (to be included in Work Plan)	12/10/2010
4	USACE/Battelle kick-off meeting	12/13/2010
	Battelle sends review documents to IEPR Panel	1/6/2011
	USACE/Battelle/Panel kick-off meeting	1/7/2011
	Battelle convenes mid-review teleconference for panel to ask clarifying questions of USACE	1/19/2011
5	Panel members complete their individual reviews	1/31/2011
	Battelle convenes panel review teleconference with IEPR Panel	2/10-2/11/2011
	Panel members provide draft Final Panel Comments to Battelle	2/21/2011
6	[a]Battelle submits Final IEPR Report to USACE	3/9/2011
7[b]	Battelle inputs Final Panel Comments to DrChecks; Battelle provides Final Panel Comment response template to USACE	3/10/2011
	Battelle convenes teleconference with USACE to review the requirements of the Evaluator Response process.	3/11/2011
	USACE provides draft Evaluator Responses and clarifying questions to Battelle	3/16/2011
	Battelle convenes teleconference between Battelle, Panel, and USACE to discuss Final Panel Comments, draft responses, and clarifying questions	3/23/2011
	USACE inputs final Evaluator Responses in DrChecks	3/30/2011
	Battelle inputs the Panel's BackCheck Responses in DrChecks	4/7/2011
	[a]Battelle submits pdf printout of DrChecks project file	4/8/2011
	Project Closeout	6/13/2011

[a] Deliverable

[b] Task 7 occurs after the submission of this report.

3.2 Identification and Selection of IEPR Panel Members

The candidates for the Panel were evaluated based on their technical expertise in the following key areas: design and construction engineering (coastal engineering), plan formulation, biology/ National Environmental Policy Act (NEPA), hydrology and hydraulics engineering/coastal engineering, geomorphology, and economics. These areas correspond to the technical content of the Mouth of Columbia River IEPR and overall scope of the Columbia River at the Mouth, Oregon and Washington Major Rehabilitation Evaluation Report project.

To identify candidate panel members, Battelle reviewed the credentials of the experts in Battelle's Peer Reviewer Database, sought recommendations from colleagues, contacted former panel members, and conducted targeted Internet searches. Battelle initially identified more than 28 candidates for the Panel, evaluated their technical expertise, and inquired about potential COIs. Of these, Battelle chose seven of the most qualified candidates and confirmed their interest and availability. Of the seven candidates, five were proposed for the final Panel and two were proposed as backup reviewers. Information about the candidate panel members, including brief biographical information, highest level of education attained, and years of experience, was provided to USACE for feedback. Battelle made the final selection of panel members according to the selection criteria described in the Work Plan.

The five proposed primary reviewers constituted the final Panel. The remaining candidates were not proposed for a variety of reasons, including lack of availability, disclosed COIs, or lack of the precise technical expertise required.

The candidates were screened for the following potential exclusion criteria or COIs.[1] These COI questions were intended to serve as a means of disclosure and to better characterize a candidate's employment history and background. Providing a positive response to a COI screening question did not automatically preclude a candidate from serving on the Panel. For example, participation in previous USACE technical peer review committees and other technical review panel experience was included as a COI screening question. A positive response to this question could be considered a benefit.

- Involvement by you or your firm[2] in the Major Rehabilitation of the Jetty System at the Mouth of the Columbia River, Major Rehabilitation Evaluation Report and technical appendices.
- Involvement by you or your firm[2] in any work related to deep draft navigation studies on the Columbia River.

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[1] Battelle evaluated whether scientists in universities and consulting firms that are receiving USACE-funding have sufficient independence from USACE to be appropriate peer reviewers. See OMB (2004, p. 18), "….when a scientist is awarded a government research grant through an investigator-initiated, peer-reviewed competition, there generally should be no question as to that scientist's ability to offer independent scientific advice to the agency on other projects. This contrasts, for example, to a situation in which a scientist has a consulting or contractual arrangement with the agency or office sponsoring a peer review. Likewise, when the agency and a researcher work together (e.g., through a cooperative agreement) to design or implement a study, there is less independence from the agency. Furthermore, if a scientist has repeatedly served as a reviewer for the same agency, some may question whether that scientist is sufficiently independent from the agency to be employed as a peer reviewer on agency-sponsored projects."

- Involvement by you or your firm[2] in projects related to the Major Rehabilitation of the Jetty System at the Mouth of the Columbia River, Major Rehabilitation Evaluation Report and technical appendices.
- Involvement by you or your firm[2] in the conceptual or actual design, construction, or O&M of any projects related to the Major Rehabilitation of the Jetty System at the Mouth of the Columbia River, Major Rehabilitation Evaluation Report and technical appendices.
- Current employment by the U.S. Army Corps of Engineers (USACE).
- Involvement with paid or unpaid expert testimony related to the Major Rehabilitation of the Jetty System at the Mouth of the Columbia River, Major Rehabilitation Evaluation Report and technical appendices.
- Current or previous employment or affiliation with members of any of the following cooperating Federal, State, County, local and regional agencies, environmental organizations, and interested groups: National Marine Fisheries Service, U.S. Fish and Wildlife Service, U.S. Geological Survey, Washington Department of Ecology, Oregon Department of Environmental Quality, Oregon Department of Land Conservation and Development, or Portland State University (for pay or pro bono).
- Past, current or future interests or involvements (financial or otherwise) by you, your spouse or children related to the mouth of the Columbia River.
- Current personal involvement with other USACE projects, including whether involvement was to author any manuals or guidance documents for USACE. If yes, provide titles of documents or description of project, dates, and location (USACE district, division, Headquarters, ERDC, etc.), and position/role. Please highlight and discuss in greater detail any projects that are specifically with the Portland District.
- Current firm[2] involvement with other USACE projects, specifically those projects/contracts that are with the Portland District. If yes, provide title/description, dates, and location (USACE district, division, Headquarters, ERDC, etc.), and position/role.
- Any previous employment by the USACE as a direct employee or contractor (either as an individual or through your firm[2]) within the last 10 years, notably if those projects/contracts are with the Portland District. If yes, provide title/description, dates employed, and place of employment (district, division, Headquarters, ERDC, etc.), and position/role.
- Previous experience conducting technical peer reviews. If yes, please highlight and discuss any technical reviews concerning deep draft navigation or coastal engineering, and include the client/agency and duration of review (approximate dates).
- Pending, current or future financial interests in contracts/awards from USACE related to the Major Rehabilitation of the Jetty System at the Mouth of the Columbia River, Major Rehabilitation Evaluation Report and technical appendices.
- A significant portion (i.e., greater than 50%) of personal or firm[2] revenues within the last 3 years came from USACE contracts.
- Any publicly documented statement (including, for example, advocating for or discouraging against) related to Major Rehabilitation of the Jetty System at the Mouth of the Columbia River, Major Rehabilitation Evaluation Report and technical appendices.

- Participation in relevant prior Federal studies relevant to this project, including:
  - U.S. Army Corps of Engineers. 1983. Columbia River at the Mouth Navigation Channel Improvement, Final Environmental Impact Statement, Oregon-Washington. Portland, Oregon.
  - Earth Sciences Associates and Geo Recon International. 1985. Geologic and Seismic Investigation of Columbia River Mouth Study Area, Report for U.S. Army Corps of Engineers, Portland District, Portland, Oregon.
  - Northwest Geophysical Associates, Inc. 1996. 1996 Columbia River Offshore Disposal Site Study, Sidescan Sonar Investigation, Report for U.S. Army Corps of Engineers, Portland District, Portland, Oregon.
  - U.S. Army Corps of Engineers. 1999. Integrated Feasibility Report for Channel Improvements and Environmental Impact Statement, Columbia and Lower Willamette River Federal Navigation Channel. Portland, Oregon.
  - NMFS. 2004. Endangered Species Act Section 7 Formal Consultation and Magnuson-Stevens Fishery and Conservation Management Act Essential Fish Habitat Consultation for the Columbia River North and South Jetties Rehabilitation, Columbia River Basin, Clatsop County, Oregon.
  - USACE. 2005. Interim Repair Decision Document for North and South Jetties at the Mouth of the Columbia River, Oregon and Washington. U.S. Army Corps of Engineers-Portland District, Portland, Oregon.
  - Global Remote Sensing. 2005. Mouth of the Columbia River Offshore Disposal Site Study, Multibeam Investigations, Report for U.S. Army Corps of Engineers, Portland District, Portland, Oregon.
  - Tetra Tech, Inc. April 2007. Wetland and Waters of the U.S. Delineation Revised Final Report: North Jetty, Mouth of the Columbia River, Pacific County, Washington. Prepared for U.S. Army Corps of Engineers, Portland, Oregon.
  - Tetra Tech, Inc. April 2007. Clatsop Spit Plant Communities Investigation and Mapping, Final Report: South Jetty, Mouth of the Columbia River, Clatsop County, Oregon. Prepared for U.S. Army Corps of Engineers, Portland, Oregon.
  - Ward, D. L., Melby, J.A., Myrick, G.B., and Henderson, W.G. 2007. Physical Model Study of Jetties at the Mouth of the Columbia River, Oregon and Washington. ERDC/CHL TR-07-XX. U.S. Army Corps of Engineers. Engineer Research and Development Center-Coastal and Hydraulics Laboratory. Vicksburg, Mississippi.
  - Demirbilik, Z., Lin, L, and Nwogu, O.G. 2008. Wave Modeling for Jetty Rehabilitation at the Mouth of the Columbia River, Oregon and Washington. ERDC/CHL TR-08-3. U.S. Army Corps of Engineers. Engineer Research and Development Center-Coastal and Hydraulics Laboratory. Vicksburg, Mississippi.
  - Moritz, H.R. and Moritz, H. P. 2009. Stochastic Risk-Based Life Cycle Simulation of Century Old Jetties at the Mouth of the Columbia River, USA. International Conference on Coasts, Marine Structures, and Breakwaters 2009. Proceedings of the Institution of Civil Engineers. Presented in Edinburgh, Scotland, September 2009.
- Participation in prior non-Federal studies relevant to this project.

- Is there any past, present or future activity, relationship or interest (financial or otherwise) that could make it appear that you would be unable to provide unbiased services on this project? If so, please describe:

In selecting the final members of the Panel from the list of candidates, Battelle chose experts who best fit the expertise areas and had no COIs. The five final reviewers were either affiliated with academic institutions or consulting companies or were independent engineering consultants. Battelle established subcontracts with the panel members when they indicated their willingness to participate and confirmed the absence of COIs through a signed COI form. USACE was given the list of candidate panel members, but Battelle made the final selections of the Panel. Section 4 of this report provides names and biographical information on the panel members.

Prior to beginning their review and within 2 days of their subcontracts being finalized, all members of the Panel attended a kick-off meeting via teleconference planned and facilitated by Battelle in order to review the IEPR process, the schedule, communication procedures, and other pertinent information for the Panel.

3.3 Preparation of the Charge and Conduct of the IEPR

Shortly after Battelle received NTP, USACE provided the following documents and reference materials. The documents and files in bold font were provided for review and the other documents were provided for reference or supplemental information only.

- **Columbia River at the Mouth, Oregon and Washington Major Rehabilitation Evaluation Report**
  - **Appendix A1: Coastal Engineering**
  - **Appendix A2: Reliability Analysis, Event Tree Formulation and Life-Cycle Simulation**
  - **Appendix B: Geotechnical**
  - **Appendix C: Economics**
  - **Appendix D: Environmental Documentation**
  - **Appendix E: M-CACES Cost Estimate for Recommended Plan**
  - Appendix F: Project Management Plan
  - Appendix G: Schedule of Fully Funded Project Costs
- USACE guidance *Civil Works Review Policy* (EC 1165-2-209) dated January 31, 2010
- CECW-CP Memorandum dated March 31, 2007
- Office of Management and Budget's *Final Information Quality Bulletin for Peer Review* released December 16, 2004.

In addition, throughout the review period, USACE provided additional documents at the request of panel members. These additional documents were provided as supplemental information only and were not part of the official review:

- Jetty Rehab, Mouth of the Columbia River, USGS Draft v01 Appendix Figures, Edwin Elias and Guy Gelfenbaum 2007
- Jetty Rehab, Mouth of the Columbia River, USGS Draft v02, Edwin Elias and Guy Gelfenbaum 2007

- Analysis of Jetty Rehabilitation at the Mouth of the Columbia River, Washington/Oregon, USA Part: 2 Regional Circulation, Sediment Transport, and Morphology Change June 2007 ERDC/CHL Kenneth J. Connell and Julie Dean Rosati
- 2009 MCR Jetty inspection reports and supporting documentation
- Summary of the Jetty heads and the physical model
- Model Documentation Report
- Additional documentation on design criteria
- Appendix b geotechnical studies (as listed in the file name)
- Exhibit M Economic Analysis of the Columbia River Channel Improvement Project, Final Supplemental Integrated Feasibility Report and Environmental Impact Statement
- Economic spreadsheet models for each jetty
- Three AVIs and videos showing the velocity vectors at the MCR
- a summary of the Jetty heads and the physical model
- Mouth of the Columbia River North Jetty, South Jetty, and Jetty A Rehabilitation Template Examples
- Documentation sent to USACE Headquarters to obtain model approval for use.

Charge questions were provided by USACE and included in the draft and final Work Plans. In addition to a list of 78 charge questions/discussion points, the final charge included general guidance for the Panel on the conduct of the peer review (provided in Appendix B of this final report).

Battelle planned and facilitated a final kick-off meeting via teleconference during which USACE presented project details to the Panel. Before the meeting, the IEPR Panel received an electronic version of the Mouth of Columbia River IEPR documents and the final charge. A full list of the documents reviewed by the Panel is provided in Appendix B of this report. The Panel was instructed to address the charge questions/discussion points within a comment-response form provided by Battelle.

3.4 Review of Individual Comments

Prior to completion of the review of the Mouth of Columbia River IEPR documents, a teleconference with USACE, the Panel, and Battelle was held halfway through the review period to provide the Panel an opportunity to ask questions of USACE regarding uncertainties requiring clarification. At the end of the review period, the Panel produced approximately 500 individual comments in response to the charge questions/discussion points. Battelle reviewed the comments to identify overall recurring themes, areas of potential conflict, and other overall impressions. As a result of the review, Battelle summarized the 500 comments into a preliminary list of 44 overall comments and discussion points. Each panel member's individual comments were shared with the full Panel in a merged individual comments table.

3.5 IEPR Panel Teleconference

Due to the number of comments and the complexity of the issues, Battelle facilitated two 3-hour teleconferences with the Panel so that the panel members, many of whom are from diverse scientific backgrounds, could exchange technical information. The main goal of the teleconferences was to identify which issues should be carried forward as Final Panel Comments in the IEPR report and decide which panel member would serve as the lead author for the development of each Final Panel Comment. This information exchange ensured that the Final IEPR Report would accurately represent the Panel's assessment of the project, including any conflicting opinions. The Panel engaged in a thorough discussion of the overall positive and negative comments, added any missing issues of high-level importance to the findings, and merged any related individual comments. In addition, Battelle confirmed each Final Panel Comment's level of significance to the Panel.

The Panel also discussed responses to seven specific charge questions where there appeared to be disagreement among panel members. The conflicting comments were resolved based on the professional judgment of the Panel, and each comment was either incorporated into a Final Panel Comment, determined to be consistent with other Final Panel Comments already developed, or determined to be a non-significant issue.

At the end of these discussions, the Panel identified 30 initial comments and discussion points that should be brought forward as Final Panel Comments.

3.6 Preparation of Final Panel Comments

Following the teleconference, Battelle prepared a summary memorandum for the Panel documenting each Final Panel Comment (organized by level of significance). The memorandum provided the following detailed guidance on the approach and format to be used to develop the Final Panel Comments for the Mouth of Columbia River IEPR:

- Lead Responsibility: For each Final Panel Comment, one Panel member was identified as the lead author responsible for coordinating the development of the Final Panel Comment and submitting it to Battelle. Battelle modified lead assignments at the direction of the Panel. To assist each lead in the development of the Final Panel Comments, Battelle distributed the merged individual comments table, a summary detailing each draft final comment statement, an example Final Panel Comment following the four-part structure described below, and templates for the preparation of each Final Panel Comment.
- Directive to the Lead: Each lead was encouraged to communicate directly with other IEPR panel members as needed and to contribute to a particular Final Panel Comment. If a significant comment was identified that was not covered by one of the original Final Panel Comments, the appropriate lead was instructed to draft a new Final Panel Comment.
- Format for Final Panel Comments: Each Final Panel Comment was presented as part of a four-part structure:
    1. Comment Statement (succinct summary statement of concern)
    2. Basis for Comment (details regarding the concern)
    3. Significance (high, medium, low; see description below)
    4. Recommendation(s) for Resolution (see description below).
- Criteria for Significance: The following were used as criteria for assigning a significance level to each Final Panel Comment:

1. High: Describes a fundamental problem with the project that could affect the recommendation, success, or justification of the project. Comments rated as high indicate that the Panel analyzed or assessed the methods, models, and/or analyses and determined that there is a "showstopper" issue.
2. Medium: Affects the completeness of the report in describing the project, but will not affect the recommendation or justification of the project. Comments rated as medium indicate that the Panel does not have sufficient information to analyze or assess the methods, models, or analyses.
3. Low**:** Affects the understanding or accuracy of the project as described in the report, but will not affect the recommendation or justification of the project. Comments rated as low indicate that the Panel identified information (tables, figures, equations, discussions) that was mislabeled or incorrect or data or report sections that were not clearly described or presented.

- Guidance for Developing Recommendation: The recommendation section was to include specific actions that USACE should consider to resolve the Final Panel Comment (e.g., suggestions on how and where to incorporate data into the analysis, how and where to address insufficiencies, areas where additional documentation is needed).

Battelle reviewed and edited the Final Panel Comments for clarity, consistency with the comment statement, and adherence to guidance on the Panel's overall charge, which included ensuring that there were no comments regarding either the appropriateness of the selected alternative or USACE policy. At the end of this process, 25 Final Panel Comments were prepared and assembled; four of the original 30 comments were merged with other existing Final Panel Comments and one was deleted because it did not meet the criteria for significance for Final Panel Comments. There was no direct communication between the Panel and USACE during the preparation of the Final Panel Comments; however, Battelle sent working drafts of the Final Panel Comments to USACE as a means to help them get a head start in providing responses to the Panel comments. Battelle informed USACE that these working drafts could be revised, merged, deleted, or new comments created prior to the submittal of the Final IEPR Report. The Final Panel Comments are presented in Appendix A of this report.

4. PANEL DESCRIPTION

Candidates for the Panel were identified using Battelle's Peer Reviewer Database, targeted Internet searches using key words (e.g., technical area, geographic region), searches of websites of universities or other compiled expert sites, and referrals. Battelle prepared a draft list of primary and backup candidate panel members (who were screened for availability, technical background, and COIs), and provided it to USACE for feedback. Battelle made the final selection of panel members.

An overview of the credentials of the final five primary members of the Panel and their qualifications in relation to the technical evaluation criteria is presented in Table 2. More detailed biographical information regarding each panel member and his or her area of technical expertise is presented in the text that follows the table.

Table 2. Mouth of Columbia River IEPR Panel: Technical Criteria and Areas of Expertise

	Phillips	Cuba	Rein	Sultan	Maher	Sultan
Civil Design/Construction [Coastal Engineering] (one expert needed)	**X**					
Minimum 10 years experience in civil design/construction and coastal engineering	X			X		X
Familiar with large, complex Civil Works projects with high public and interagency interests	X			X		X
Experience performing coastal engineering design and construction management for coastal projects	X			X		X
Familiar with similar projects across the United States and related coastal engineering	X			X		X
Experience in computer modeling including Matlab experience in coastal engineering	X			X		X
Familiar with construction industry and practices used in coastal construction in the Pacific Northwest	X			X		X
Degree in civil engineering	X			X		X
Plan Formulation (one expert needed)		**X**				
Minimum 10 years experience in the plan formulation process		X		X		X
Familiar with large, complex Civil Works projects with high public and interagency interests		X		X		X
Familiar with evaluation of alternative plans for coastal projects		X		X		X
Familiar with USACE standards and procedures		X		X		X
Degree in planning or a related field		See waiver*				
Biology NEPA (one expert needed)			**X**			
Minimum 10 years experience in biology		X	X			
Familiar with large, complex Civil Works projects with high public and interagency interests		X	X			
Particular knowledge of ecosystem restoration		X	X			
Familiar with all NEPA requirements		X	X			
Minimum of an M.S. degree in Biology		X	X			
Hydrology and Hydraulics Engineering/Coastal				**X**		

	Phillips	Cuba	Rein	Sultan	Maher	Sultan
Engineering (one expert needed)						
Minimum 10 years experience in hydrology and hydraulics engineering				X		X
Familiar with large, complex Civil Works projects with high public and interagency interests				X		X
Experience with sediment transport and engineering analyses related to design to include a variety of materials and cross-sections				X		X
Familiar with standard USACE hydrologic and hydraulic computer models used in jetty design				X		X
Minimum of an M.S. degree in civil engineering or hydrology and hydraulics				X		X
Registered professional engineer				X		X
Economics (one expert needed)					**X**	
Minimum 10 years experience in economics				X	X	X
Familiar with large, complex Civil Works projects with high public and interagency interests				X	X	X
Able to evaluate the appropriateness of cost effectiveness and incremental cost analysis (CE/ICA), as applied to USACE projects				X	X	X
Experience with National Economic Development (NED) analysis procedures, particularly as they relate to jetty construction projects					X	
Degree in economics or related field				X	X	X
Geomorphology (one expert needed)						**X**
Minimum 10 years experience in geomorphology				X		X
Familiar with large, complex Civil Works projects with high public and interagency interests				X		X
Experience with geological analyses related to project design to include a variety of materials and cross-sections used in jetty design				X		X
Minimum M.S. degree in civil engineering or geology				X		X
Registered professional engineer				X		X

* Dr. Tom Cuba has 28 years of experience in planning and biology/ecology. Dr. Cuba does not have his degree in planning or a related field. He has his Ph.D. in marine science/ecology. Battelle believes that his planning experience is commensurate with a degree in planning.

Shane Phillips, P.E.

Role: This panel member was chosen primarily for his coastal engineering design and construction management for coastal projects experience and expertise.
Affiliation: Coast and Harbor Engineering, Inc.

Shane Phillips, **P.E.,** a principal civil engineer at Coast and Harbor Engineering, Inc. in Edmonds, Washington, has 17 years of experience in marine and coastal engineering. He earned his B.S. in civil engineering in 1993 from Washington State University and is a registered professional engineer in Washington, California, Texas, Louisiana, and Florida. His specific engineering experience includes the feasibility evaluation, preliminary design, and final design of geotechnical, structural, and civil components of coastal and marine construction projects.

Mr. Phillips has applied his coastal engineering design expertise to a variety of coastal shore protection projects along the Pacific Northwest coast and has served as both on-site resident engineer and project manager on coastal construction projects including jetty, revetments, levees, dredging, and boating facilities. He served as project and design engineer for the North Jetty Beachfront Properties Coastal Erosion project in Ocean Shores, Washington, which involved the design and construction of a 1,000 foot long rock revetment structure.

Mr. Phillips has managed and executed feasibility studies, planning studies, and engineering of coastal and marine construction projects for port facilities, marinas, boating facilities, ferry terminals, marine terminals, navigation channels, and shoreline properties. He was Project Engineer for preliminary and final engineering design phase on the Willapa Bay, Washington SR-105 Emergency Stabilization Project consisting of a 1,400 foot long rock groin, 1,200 foot long submerged rock jetty and 1,100 feet of beach nourishment.

Coastal design experience includes the layout and design of floating breakwaters, groins, piers, bulkheads, beach nourishment, shoreline stabilization, dredging, water quality improvement, and nearshore restoration. Structural design experience includes the evaluation and engineering design of marine terminals, piers, bulkheads, retaining walls, breakwaters, and marinas using concrete, steel, and timber materials. Mr. Phillips has reviewed/verified computer modeling preparation and calibration and regularly works with engineering programs including AutoCad 2010, PCSTBLE, ACES, Surfer, SMS, Matlab, and Land Development.

Tom Cuba, Ph.D.

Role: This panel member was chosen primarily for his experience and expertise in the coastal plan formulation process.
Affiliation: Delta Seven, Inc.

Thomas R. Cuba, Ph.D., CEP, President and Chief Scientist at Delta Seven, Inc., serves as a Research Scientist at Stillwater Research Group, and is a research adjunct professor at the University of South Florida. He earned his Ph.D. in marine ecology from the University of South Florida in 1984. Dr. Cuba has 28 years of planning experience, which includes developing management plans for a variety of Florida watersheds and aquatic preserves, working on waterfront infrastructure feasibility plans, and designing wetland, pond, and seagrass restoration plans. Dr.Cuba’s six-year service as a Naval Intelligence Officer included plan formulation responsibilities, and he has been involved in civil and governmental plan formulation of engineered ecological restoration projects since 1984. Additionally, he conducted comprehensive conservation and public works plan formulation for Pinellas County, Florida and subsequently worked to enact these plans through public projects and codification in county ordinances.

Dr. Cuba has served as project manager and chief scientist on several watershed-based management and restoration projects (all of which included construction elements) and, for many of these, he acted as chair of the multi-stakeholder board. Dr. Cuba has assessed alternatives in beach nourishment and the placement of jetties and groins during his work with Pinellas County and in private practice. He is familiar with USACE plan formulation standards and procedures and has served on four USACE IEPR panels in the recent past as plan formulator (Clear Creek, C-111, Tamiami Trail, and LCA6).

Felicia Orah Rein, Ph.D.

Role: This panel member was chosen primarily for her biology/NEPA experience and expertise.
Affiliation: Watershed Solutions, Inc. and Florida Atlantic University

Felicia Orah Rein, Ph.D., is president and senior scientist at Watershed Solutions, Inc., an environmental consulting and restoration services firm specializing in environmental restoration, environmental assessments and impact analyses, ecological monitoring, water resource management, and reduction of sediment transport and erosion. She is also an affiliate professor at Florida Atlantic University. She earned her Ph.D. in ecosystem science/restoration ecology from the University of California at Santa Cruz in 2000 and has more than 20 years of experience managing and implementing large-scale multidisciplinary restoration ecology and resource protection projects.

Dr. Rein has extensive experience with large complex Civil Works projects with high public visibility, including assessment of environmental impacts of the New York/New Jersey Harbor deepening project for which she provided expertise in dredged material beneficial uses and source reduction and conducted vegetation and wetland mapping on coastal sites. Her NEPA expertise has involved collaboration with the National Marine Fisheries Service, California Department of Fish and Game, California State Water Resource Control Board, and U.S. Fish and Wildlife Service. She has a strong knowledge of ecosystem restoration, having worked on projects such as the Far Rockaway, Averne site park and housing development projects. Her role included wetland restoration areas and focused on water quality and vegetation impacts. Dr. Rein has prepared numerous Phase I (NEPA) environmental site assessments and is familiar with all NEPA requirements. As a senior project manager, she has provided scientific expertise on environmental documents according to NEPA guidelines and worked closely with local, state, and Federal government, as well as lawyers, environmentalists, and community groups on complex water rights assessments. She has experience in wetland ecology of urban regions, having worked in the initial phases of the fast-tracked wetland restoration projects in the NY/NJ region, including the hydrologic restoration of Liberty State Park and others.

She has conducted technical peer reviews, quality assurance/quality control (QA/QC) reviews, and acted as an expert consultant in environmental damage disputes for engineering and consulting firms. Dr. Rein is a member of Sigma Xi National Scientific Research Society.

Nels Sultan, P.E., Ph.D.

Role: This panel member was chosen to serve in a **dual role** for his hydrology and hydraulic engineering and geomorphology experience and expertise.
Affiliation: PND Engineers, Inc.

Nels Sultan, P.E., Ph.D., a coastal engineer at PND Engineers, Inc. in Seattle, Washington, has more than 20 years of experience specializing in the analysis and design of waterfront projects, including coastal geomorphology, coastal numerical models, and wave tank physical models. He earned his Ph.D. in ocean engineering from Texas A&M University in 1995. He is a registered professional civil engineer in Washington and Alaska and is a former officer in the Naval Reserve, Civil Engineering Construction Corps.

Dr. Sultan has worked on all aspects of design engineering for ports, harbors, shore protection, dredging, and other coastal and marine facilities projects. His extensive project experience includes preparing plans, specifications, and cost estimates through final design and construction (using a variety of materials including rock, geocontainers, stone masonry, and concrete), in addition to analyzing wave conditions, coastal processes, and sediment transport. Dr. Sultan's experience includes serving as the ocean engineer on the South Jetty Permeability project in Grays Harbor, Washington, where the jetty is subject to erosion of sediment at its landward end and has been completely severed from the mainland on occasion. Dr. Sultan analyzed aerial photographs, wind, wave, and tide conditions in order to determine whether the south jetty was permeable to sediment transport and contributing to erosion problems.

He served as project manager and coastal engineer for the Skagway Small Boat Harbor Dredging and Entrance Surge Control project in Alaska and led design and construction support services for a new 290 foot long, curved, partially penetrating vertical breakwater that provided surge control at the harbor entrance. Also for this project, Dr. Sultan prepared a wind and wave study for breakwater alternatives and provided computer modeling, using both desktop and CGWAVE modeling of wave transmission, wave diffraction, and reflected waves to evaluate waves at the adjacent ferry terminal floating dock and the shoreline north of the planned wave barrier. He also served as the ocean engineer for the Willapa Bay, WA SR-105 Stabilization Project Monitoring Program, which involved beach nourishment, an underwater dike, and a multi-purpose rock groin.

Dr. Sultan is a member of the Association of Coastal Engineers, American Society of Civil Engineers and the American Geophysical Union.

Daniel Maher, M.S.
Role: This panel member was chosen primarily for his experience and expertise in economics.
Affiliation: G.E.C., Inc.

Daniel Maher, M.S., is a senior economist and project manager at G.E.C., Inc. with 22 years of experience conducting large water resource/public works planning studies. He received his M.S. in agricultural economics from Louisiana State University in 1988. Mr. Maher has served as a project manager or economist on numerous regional economic impact, navigation, water supply, recreation, flood control, and ecosystem restoration projects. Mr. Maher has developed benefits and costs for National Economic Development (NED) analyses of large water resource planning efforts and navigation projects, which involved using methodologies estimating project benefits of coastal construction projects based on transportation savings. For example, Mr. Maher was the economist and project manager responsible for estimating NED benefits associated with increasing the current authorized depth of the federal central harbor and navigation channels to the Tenth Avenue Marine Terminal in San Diego, California. The primary benefits of deepening the harbor were the reduction in vessel operating costs by allowing deeper draft vessels to traverse the channel fully loaded, and the reduction or elimination of vessel tidal delays. Additionally, he was responsible for estimating the NED benefits and assessing the operational and environmental impacts resulting from the removal of several underwater natural obstructions in San Francisco Bay. These underwater pinnacles are considered a major hazard to navigation in the bay, especially regarding deep-draft oil tankers. The economic feasibility of removing these pinnacles was based on quantifiable transportation savings resulting from reduced bay transit distances of oil tankers and container vessels that frequent the ports on the bay.
Mr. Maher has also been responsible for cost effectiveness/incremental cost analysis (CE/ICA) for several USACE ecosystem restoration projects including Canonsburg Lake Ecosystem Restoration Project (Pittsburg District); Licking River Watershed and Dillon Lake Ecosystem Restoration Project (Huntington District); and Big Sunflower Ecosystem Restoration Feasibility Study (Vicksburg District). For each of these projects Mr. Maher worked with biologists and ecologists to define appropriate metrics for measuring environmental benefits and converting benefits to an average annual basis for each alternative considered. He also reviewed construction and operations and maintenance costs associated with each alternative, and conducted cost effective analysis and incremental cost analysis using IWR-PLAN. Mr. Maher has experience with numerous economic computer programs, including IMPLAN Economic Impact Software, IWR-Planning Suite, and IWR-MAIN Water Use Forecast System.

5. SUMMARY OF FINAL PANEL COMMENTS

The panel members agreed among one another on their "assessment of the adequacy and acceptability of the economic, engineering, and environmental methods, models, and analyses used" (USACE, 2010; p. D-4) in the Mouth of Columbia River IEPR. Table 3 lists the 25 Final Panel Comment statements by level of significance. The full text of the Final Panel Comments is presented in Appendix A. Of primary significance, and as discussed in several of the Final Panel Comments, the Panel has serious concern with the SRB model and the potentially over-emphasized role it played in the evaluation of alternatives, engineering design, and economic analyses. The following statements summarize the Panel's findings.

Plan Formulation Rationale: From a planning perspective, the Major Rehabilitation Evaluation Report is well done and in compliance with all of the typical formulation steps; however, it was never clearly explained that the scope of work was limited to the repair and rehabilitation within the present configuration, nor why it was limited in this manner. Undefined risk thresholds may serve to undermine the logic of the cost and maintenance predictions and, to a lesser extent, the alternatives selected. The Panel agreed that the SRB model is not a substitute for conventional engineering and economic analyses and should not be a stand-alone analysis for selecting a recommended plan.

Economics: The Panel identified three major issues in the economic analysis: (1) inconsistencies in the Major Rehabilitation Evaluation Report and economic spreadsheet models; (2) the assumption that navigation would not be impacted; and (3) the formulation of the base condition. Inconsistencies in the report and economic spreadsheet models pertaining to the calculation of NPVs and AACs prevented the Panel from validating the economic analysis. Based on the assumption that navigation will not be impacted, a least cost analysis was used in lieu of a transportation cost savings analysis to calculate NED benefits. Conflicting assumptions concerning the ability to maintain navigation invalidate the logic behind calculating NED benefits using a least cost analysis. As the project is currently formulated, the base condition maintenance strategy for the MCR jetties conforms most closely with the fix-as-fails strategy, while the base condition life-cycle costs are the basis for estimating project benefits for all action alternatives. Inaccurate formulation of the base condition may increase life cycle costs, and may erroneously escalate project benefits. Each of these issues could impact the selection of the NED plan, which was selected as the recommended plan.

Engineering: There are serious technical difficulties with the Major Rehabilitation Evaluation Report and analyses. The report lacks a set of design criteria, including project life, standards of performance to be met, and environmental conditions with return period events. All are part of conventional coastal engineering design practice. The SRB model cannot be verified and does not include important processes. Major questions remain that have not been adequately investigated for this level of study, including subsurface geotechnical properties, feasibility of proposed barge offloading/material re-handling facilities, and the long term stability of the jetty foundations assuming continued erosion and loss of nearshore sediment. The report indicates that large volumes of sediment will move into the navigation channel after a breach event. However, the data and analysis do not support this conclusion. Additionally, is no clear discussion of the role of maintenance or emergency dredging, especially under extreme winter conditions. Detailed construction cost estimates also need to be provided in order for the cost analysis to be complete and verifiable. Although there is a good description of historical failures and repair actions for each jetty, there is no discussion or documentation of current jetty condition or detailed condition assessments of structure and functional condition.

Environmental: There is no discussion in the main report of sea level rise and potential wave height increases and its impact on this project over the 50+ year project timeline, given that the regional wave climate has been documented as more severe in the last 10 years. This has potential impacts to the project and in designing a project with lower long-term maintenance costs. Potential environmental impacts on sensitive species, upland habitats, and water quality as well as potential impacts to recreational use during project construction are not comprehensive nor adequately described in the mitigation plan. Finally, the alternatives are limited to armoring the existing configuration of the jetties and may not satisfy NEPA directive for alternative analysis.

Table 3. Overview of 25 Final Panel Comments Identified by the Mouth of Columbia River IEPR Panel

Significance – High	
1	The economic analysis used to select the National Economic Development (NED) plan cannot be validated, nor can it be determined if assumptions were applied correctly in the economic spreadsheet models.
2	The analysis of the sediment transport process is not comprehensive, and the data and analysis do not support the conclusions concerning large movement of sediment during a breach event.
3	The underlying assumption that navigational impacts will not occur is not substantiated.
4	The SRB model by itself has very limited value for analyzing alternatives and is not a substitute for conventional economic and engineering analysis.
5	The base condition, as formulated, does not represent the current O&M practice.
6	The reported analysis and design to mitigate a potential breach of the foreshore dune at the South Jetty root is not adequate.
7	The basis of design and design environmental criteria are vague, not consistent within the report, and not consistent with conventional coastal engineering design practice.
8	The models and analyses of jetty failure do not include all significant processes.
Significance – Medium	
9	The alternative selection process may fail to meet the requirements of NEPA Section 1502.14.
10	A failure analysis for the original structure design and past trends of Operation and Maintenance (O&M) costs has not been provided.
11	Sea level rise and potential increases in wave height have not been examined sufficiently under different model scenarios.
12	Construction cost estimates cannot be evaluated because the assumptions and details have not been provided.
13	Potential environmental impacts on sensitive species, upland habitats, and water quality have not been thoroughly discussed or specifically mitigated in the document.
14	Potential impacts to recreational use during project construction, as identified in public comments, are not adequately discussed or mitigated.
15	There is not sufficient information on the evaluation of barge offloading and material re-handling facilities to ensure these sites can operate as intended and to ensure the construction costs are adequately represented.

Table 3. Overview of 25 Final Panel Comments Identified by the Mouth of Columbia River IEPR Panel, continued

Significance – Medium	
16	The requirements, costs, and history associated with emergency dredging compared to scheduled maintenance dredging activities have not been specified.
17	The current jetty structure condition is not well described, making it difficult to confirm the confidence of the SRB model analysis and selection of a recommended plan.
18	The mechanisms causing jetty head scour have not been sufficiently analyzed to allow selection of the appropriate jetty head repair measure.
19	Risk thresholds for selected alternatives are not clearly defined.
20	It is not clear how uncertainty and derived risk analyses were considered in the structure and application of the model.
21	The model output parameters and wave height components are not clearly explained and supported.
22	The culvert installation details, as well as potential impacts, need further clarification.
Significance – Low	
23	The various base years cited in the report and the difference between project life and period of analysis require additional explanation.
24	Cargo tonnage and vessel trip statistics presented throughout the report are inconsistent.
25	Terminology related to jetty rehabilitation and failure is defined inconsistently or vaguely in some places.

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APPENDIX A

Final Panel Comments

on the

Mouth of Columbia River IEPR

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Comment 1:
The economic analysis used to select the National Economic Development (NED) plan cannot be validated, nor can it be determined if assumptions were applied correctly in the economic spreadsheet models.
Basis for Comment:
Economics is the key consideration in evaluating the NED plan, which was selected as the recommended plan. Several issues were identified in the review documents and the economic spreadsheet models that could significantly change the outcome of the economic analysis and the selection of the recommended plan. These issues primarily pertain to the calculation of net present values (NPVs) and Average Annual Costs (AACs), and the presentation of the economic analysis results. **Calculation of NPVs and AACs** • The AACs, based on the NPVs presented in Table 2-1 and Table 2-2, appear to be based on a Federal discount rate of 4.125%, not 4.375%, as stated in the report. • The calculation of the NPVs and AACs in the economic spreadsheet model for the North Jetty are based on a discount rate of 4.125%, not 4.375%, as stated in the report. • The period (actual calendar years) of the annual stream of costs used to calculate the NPVs for each alternative differ between alternatives in the economic spreadsheet models; also, the actual calendar years included in these periods were not stated in the report. • The unit costs for jetty repair and dredging, as presented in the SRB model, are increased over time such that after 50 years, costs will be 15% greater than at present. In accordance with ER 1105-2-100, p. 2-11 (USACE, 2000), when conducting economic analysis, prices should be held constant over the period of analysis. **Presentation of Results** • The NPVs and AACs in the spreadsheets for the North Jetty and South Jetty differ from the results presented in the report. • The term NED, the process of calculating NED benefits, and the method of selecting the NED plan are not explained in Section 2 or Appendix C of the report. • The SRB model uses Monte Carlo simulation to increase the confidence of life cycle estimates and allow for evaluation of variance by producing project cost output, including mean and standard deviation values (Appendix A2, p. A2-49). The risk and uncertainty associated with estimating the stream of annual costs and the resulting NPVs, AACs, and benefit-to-cost (B/C) ratios are not addressed in the economic analysis. • The costs of the NED plan of $250 million in the Executive Summary are presented on a fully funded basis, whereas the costs in the main report are presented as NPVs, resulting in confusion.
Significance – High:
The inability to validate the economic analysis and the assumptions used in the economic spreadsheet model could impact the selection of the NED, or recommended plan.

Recommendations for Resolution:
1. Calculate the NPVs and AACs using the FY10 Federal discount rate of 4.375% for all alternatives; basing the NPVs on the stream of project costs for the 50-year period of analysis. 2. In accordance with ER 1105-2-100, Chapter 2 (USACE, 2000), revise the formulas in the economic spreadsheet models to reflect the same period of analysis for all alternatives. 3. State the years (annual stream of costs) used in calculating the NPV for each alternative and ensure consistency in alternative evaluation. 4. In accordance with ER 1105-2-100, Chapter 2, p. 2-11 (USACE, 2000), revise the repair and dredging costs to reflect the general level of prices prevailing during or immediately preceding the period of planning for the entire period of analysis. 5. Revise Section 2 and Appendix C of the report to include a definition of the term NED, an explanation of the process of calculating NED benefits, and the method of selecting the NED the plan. 6. In accordance with EP 1130-2-500, Appendix B, p. B-9 (USACE, 1996), report the results of all alternatives in a table displaying the mean net benefits and standard errors of each; providing the 90% confidence interval for the mean net benefits (mean+ 1.64x standard error). 7. Present the costs of the NED plan in the Executive Summary and the main report in both a fully funded basis and in NPV.

Literature Cited:

USACE (2000). Planning – Planning Guidance Notebook. Department of the Army, U.S. Army Corps of Engineers, Washington, D.C. Engineer Regulation 1105-2-100. *22* April.

USACE (1996). Project Operations – Partners and Support. Department of the Army, U.S. Army Corps of Engineers, Washington, D.C. Engineer Pamphlet 1130-2-500. 27 December.

Comment 2:
The analysis of the sediment transport process is not comprehensive, and the data and analysis do not support the conclusions concerning large movement of sediment during a breach event.
Basis for Comment:
The report describes large volumes of sediment that will move into the navigation channel after a breach event. However, the Coastal Modeling System (CMS) numerical model results (CHL, 2007; p. 15, Figure 3.2) indicate minimal sediment movement through a jetty breach, even with the model strongly distorted to encourage movement. Similarly, historic breach events at the MCR inlet and region do not support the sediment movement volumes and rates assumed, nor the assumed sudden jetty failure, and the consequent requirement for emergency repairs and dredging. The assumed jetty breach sediment movement is also inconsistent with recent experience with dredged material disposal at the North Jetty. Approximately 400,000 cubic yards were placed at the site each year during 1999-2008, on average, comparable to some jetty breach scenarios. However, the sediment placed at the North Jetty does not appear to have affected navigation. Similarly, the reported "rapid deterioration" of the North Jetty from 1999 to 2004, when 100,000 cubic yards of sediment leaked through the jetty leading to the repairs in 2005, is not consistent with the assumed scenario of a sudden breach event and large sediment movement. Figures A1-252 to A1-254 of jetty breach sediment movement appear to be artist renderings, not products of analysis. The figures are misleading if they are interpreted as model output. Table 3-10 in the main report is presented but not explained, so there is no clear basis for the "Range of Volume Left in Channel" resulting from a breach of the North Jetty. There is no discussion of any hydrodynamic analysis or evaluation of morphologic changes and corresponding sedimentation of the navigation channel. Significant inconsistencies are present in the sediment transport discussion. For example, the documents discuss sediment disposal practices at the shallow water site (SWS), immediately offshore from the tip of the North Jetty. The EA notes, "Active monitoring and evaluation determined that 80% to 95% of the dredged sand annually placed at the SWS moves northward onto Peacock Spit" (dispersed to the north). However, the main report describes how rip currents along the north side of the North Jetty transport sediment towards the tip and then south into the navigation channel. This implies an unrealistic discontinuity in the sediment budget and sediment paths immediately offshore of the jetty tip. The sediment budgets and analysis are not consistent in different parts of the review documents, and seem to vary depending on whether the analysis is centered on dredged material disposal (emphasizing sediment movement onto nearby shores) or jetty stability (emphasizing sediment movement towards the channel). The jetties are described as functioning like "wingdams" preventing sediment movement into the channel. However, it seems more the case that the North Jetty shields the sands of Benson Beach from the dominant southwesterly waves preventing/slowing longshore sediment transport to the north, rather than south into the channel. Also, the process of sediment

movement through a jetty breach is not at all like water through a dam break. The jetties are essentially a pyramid with only a small tip extending above water. What happens below water, with the sediments and foundations, is more central to the long term function and stability of the MCR jetties, navigation channel, and adjacent beaches.

A better analysis of sediment transport is needed because the repair alternatives at present are an ever expanding pile of rock on an ever shrinking foundation of sand. The geological history includes more than 225 million cubic yards of dredging since 1956 from the MCR navigation channel, with most disposed offshore (EPA, 2009). The Southwest Washington Coastal Erosion Study (Gelfenbaum, et al, 2006) concluded, "The carrying capacity of beach sands of Columbia River to the estuary has been reduced by approximately two-thirds over the last century." The missing sediment from the system and ongoing erosion of the shoals that help protect the jetties all point toward a need for a more rigorous investigation of sediment transport and alternatives that could reduce the loss of sediment and subsequent project O&M costs.

Significance – High:

The rehabilitation project will not be successful if ongoing sediment loss continues and the shoals and jetty foundation wash away.

Recommendations for Resolution*:*

1. Eliminate or justify the unrealistic assumption of sudden jetty failure and large volumes of sediment rapidly moving into the navigation channel. Instead, compare alternatives based on life-cycle costs including ordinary jetty repairs and maintenance dredging costs.
2. Provide a real analysis of sediment transport. Include review and reference to data and findings from maintenance dredging records and the studies of the MCR prepared for the multi-agency Southwest Washington Coastal Erosion Study.
3. Describe how implementation of this project will reduce ongoing erosion of the shoals.

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Comment 3:

The underlying assumption that navigational impacts will not occur is not substantiated.

Basis for Comment:

The report clearly explains why navigation benefits were not analyzed. The method used to calculate NED benefits is based on the assumption that navigation will not be affected; the economic analysis is therefore based on a least cost analysis. This assumption, however, is not supported by the analysis presented in the report. A North Jetty breach in the winter is assumed to result in immediate mobilization of sediment that may impact navigation. If this assumption is true, it does not necessarily follow that emergency dredging will successfully occur to enable deep draft vessel access. As stated on p. 3-14 of the main report, under base conditions, during winter months, emergency jetty repairs and emergency dredging may not be possible, potentially resulting in impacts to navigation until the emergency activities are completed. The main report also states (p. 1-48) that operating a hopper dredge at the MCR during winter months has not yet been attempted.

The report does not address the impact of project construction and dredging activities on navigation. For example, the operation of a dredge in the MCR, especially under extreme winter conditions, could have an adverse impact on navigation in the MCR.

The Panel was unable to fully understand the potential impacts on navigation of shoaling resulting from a jetty breach. Since navigation benefits were not evaluated, impacts to the MCR or Lower Columbia River (LCR) channels as a result of shoaling after a jetty breach, in the absence of emergency dredging, is only presented in qualitative terms such as “navigation would be significantly impaired” (p. A2-34). The extent of the impacts are not described (i.e., bar closure, vessels delayed due to having to use tides to access the channel, reduced under-keel clearances, vessel lightloading, etc.). Due to the dismissal of potential navigation impacts, no mitigation is defined.

Significance – High:

Conflicting assumptions concerning impacts to navigation invalidate the logic behind calculating NED benefits using a least cost analysis and impacts the selection of the NED, or recommended, plan.

Recommendations for Resolution:

1. Conduct a transportation cost savings analysis to calculate NED benefits.
2. Include a description of the expected channel depths available after a breach event, and in the absence of emergency dredging, include a description of the portion of the fleet using the channel that will be impacted by the resulting shoaling.

Comment 4:
The SRB model by itself has very limited value for analyzing alternatives and is not a substitute for conventional economic and engineering analysis.
Basis for Comment:
The SRB model results cannot be verified, as it is a custom-made engineering and economics model applicable only to this project and there is no means for the Panel to examine the inner workings of the SRB model and its internal calculations to assess its "adequacy and acceptability". It is not possible to verify model results, or to repeat the application of the SRB model because there is no User's Manual or detailed description of model inputs and how the model was applied for the Mouth of Columbia River project. Furthermore, the model has not been peer reviewed or tested. Without documentation of successful application, the Panel cannot validate the model or have confidence in the results. The SRB model internal calculations and logic are not a commonly applied method for calculating rubble mound structure reliability and damage. The model analyzes more than 600 variables, stacking process upon process, each with wide error bars, resulting in the accumulation of errors. Significant processes do not appear to be included in the model, such as armor rock breakage and deterioration and deep seated slip-circle failures. Figure A2-18a shows model output for jetty cross-section progressive damage. This figure provides one of the few insights into the inner workings of the SRB model. The figure indicates the physics and process of jetty decay are not modeled correctly because the output is not consistent with cross-sections of observed damage. The engineering evaluation does not include much about the physical modeling (i.e., wave tank results). It seems the wave tank model was used to develop the input and equations within the numerical SRB model. It is more conventional to proceed in the opposite sequence, to use a wave tank model to verify a final design concept and verify numerical model predictions. The wave tank model effort was substantial and likely yielded good insights. However, it does not appear that results were used to their fullest potential because the model output and findings were only applied through the SRB model process. The wave tank model results could have been used as part of an independent evaluation, providing an additional line of evidence along with other investigations, data, and findings. The SRB analysis should only be used as one of many tools in the alternatives evaluation rather than a substitute for the preliminary engineering design. Additional engineering analysis and design documentation needs to be provided as part of the preliminary engineering design report. Documentation through the preliminary engineering design process will lead to improved confidence and reliability of SRB analysis.
Significance – High:
The SRB model functions as a "black box" and does not allow an alternatives analysis that is clearly based on sound technical evidence of engineering design performance.

Recommendations for Resolution:

1. Move the SRB model to an appendix, as supplemental information, and assign it a weight of 10% in the evaluation of alternatives. No further work on the SRB model is recommended as part this project.
2. Include a detailed description of the SRB model application allowing verification of model calculations and how the model was applied to the Mouth of Columbia River project.
3. Demonstrate that the model has been peer reviewed and tested.
4. Move the calculations and elements of the study currently within the SRB model (such as rubble-mound damage, slope stability failure, design wave heights and water levels, economic calculations, and much more) out of the SRB model and provide as separate calculations that can be checked and verified.
5. Provide documentation of preliminary engineering analysis and design which would constitute the basis for the SRB analysis. The preliminary engineering analysis should be provided in the report, with details in appendices. Elements that appear missing or inadequate at this level of design include the following:
   - Design criteria and basis of design
   - Structure condition assessment and existing condition survey
   - Subsurface geotechnical investigation
   - Development of jetty repair/rehabilitation alternatives
   - Hydrodynamic analysis (waves, currents, sediment transport) specifically related to the alternatives
   - Determination of stone sizing for alternatives
   - Alternative evaluation
     - Development of evaluation criteria
     - SRB analysis
   - Detailed volume and cost estimate for the alternatives.

Comment 5:
The base condition, as formulated, does not represent the current O&M practice.
Basis for Comment:
The present and future base condition maintenance strategy for the MCR jetties, as currently described in the report, conforms most closely with the fix-as-fails strategy. Under this scenario, jetties will be allowed to deteriorate to the point that just-in-time repairs may not prevent a breach in the jetty, which would result in expensive, winter dredging activities. As the project is currently formulated, the base condition life-cycle costs are the basis for estimating project benefits for all action alternatives. Historical maintenance efforts for MCR jetties are best described by an interim repair strategy. As a result of monitoring and advance repair activities, historically there have been no jetty breaches that have impacted navigation, nor has winter dredging been needed to maintain navigation. EP 1130-2-500, Appendix C, p. C-1 (USACE, 2006) states that for Major Rehabilitation Projects, under the base condition, "maintenance is increased as needed (but within limits) and components or sub-features are repaired on an emergency basis. This essentially represents the current O&M practice." Based on the report, this condition would resemble an interim repair strategy, rather than the fix-as-fails strategy currently described as the base condition.
Significance – High:
Inaccurate formulation of the base condition may increase life cycle costs, and may erroneously escalate project benefits for all action alternatives thus impacting the benefit to cost ratios.
Recommendations for Resolution:
1. Refine the base condition to more closely resemble the current O&M practice, in accordance with EP 1130-2-500, Appendix C (USACE, 1996).

Literature Cited:

USACE (1996). Project Operations – Partners and Support. Department of the Army, U.S. Army Corps of Engineers, Washington, D.C. Engineer Pamphlet 1130-2-500. 27 December.

Comment 6:
The reported analysis and design to mitigate a potential breach of the foreshore dune at the South Jetty root is not adequate.
Basis for Comment:
Potential breaching of the foreshore dune at the South Jetty root, to form a new connection to Trestle Bay, is discussed briefly in a few places, including a proposed cobble berm to mitigate this risk in the main report (Section 3.5.3.3, pp. 3-40 - 3-41, p. 7-1 and elsewhere). Additional analysis is appropriate given the consequences of breaching at this location. It is not clear what analysis has been conducted to evaluate the performance of the proposed dune augmentation. It is not known if the volume of material per linear foot is sufficient to provide the required width of cobble beach for stable conditions upon adjustment after initial placement. Maintenance requirements are not known for this design. Studies by DOGAMI (Allen, 2005) have been conducted on dynamic revetments for shoreline stabilization on the Oregon Coast but do not appear to have been applied. The breaching potential will likely increase with increasing shoreline erosion and loss of sediment from the system. However, potential beneficial use of dredged sediment is not analyzed as part of a design solution for a breach. Long-term erosion trends are assumed and are not adequately addressed in the report. The information provided is inconsistent in this area, with some sections saying the South Jetty dune erosion/augmentation issue will be addressed as part of a separate project, whereas other report sections include South Jetty dune augmentation as part of this project. Foreshore dune breaching has occurred at other coastal inlet navigation jetty structures along the Pacific Coast such as the South Jetty at Grays Harbor, Washington. Beach renourishment with dredged material and jetty structure modification improvements to prevent dune breaching were made with varying levels of success. It is not clear whether these similar project conditions and performance have been evaluated as part of the development and analysis of alternatives at the Columbia River South Jetty location.
Significance – High:
Breaching the dune at the South Jetty root appears to be a substantial risk, with more immediate consequences than breaching of a jetty because of the potential for forming a new tidal inlet with relatively rapid widening and deepening.
Recommendations for Resolution:
1. Either include the South Jetty dune augmentation/stabilization as part of the alternatives, and include costs and preliminary engineering, or state that it is not an element of the proposed work and is part of a separate project. Either way, potential breaching scenarios should be evaluated/modeled and included in the sediment transport and hydraulic analysis. This major investigation is the logical place to add studies of the MCR system (including jetties, navigation channel, estuary, and beaches). 2. Account for long-term shoreline erosion/recession trends in the design.

3. Review other jetty rehabilitation project solutions and performance at coastal inlet navigation facilities such as those conducted at the Grays Harbor South Jetty (Wamsley, 2006).

Literature Cited:

Allen, J. (2005). Cape Lookout shoreline stabilization study: Don't take the cobbles. Cascadia, News from the Oregon Department of Geology and Mineral Industries (DOGAMI). Winter. http://www.oregongeology.com/sub/quarpub/CascadiaWinter2005.pdf

Wamsley, T.V., M.A. Cialone, K. J. Connell, and N.C. Kraus (2006). Breach History and Susceptibility Study, South Jetty, Grays Harbor, Washington. USACE, Coastal and Hydraulics Laboratory. Report ERDC/CHL TR-06-22. September. http://www.dtic.mil/cgi-bin/GetTRDoc?AD=ADA456060&Location=U2&doc=GetTRDoc.pdf

Comment 7:

The basis of design and design environmental criteria are vague, not consistent within the report, and not consistent with conventional coastal engineering design practice.

Basis for Comment:

The document “design_criteria_info.doc” is vague. It discusses “50 year alternatives,” but the term is not defined. It could mean many things, including the following:

1. The project life is 50 years, with complete replacement assumed after 50 years.
2. Design jetty repairs that have the least life-cycle costs over a 50 year period.
3. The economic planning horizon, benefits and costs, are calculated for 50 years.
4. Design to withstand a series of storms over a 50 year period.
5. Design to withstand a single 50 year return period storm event.

Section 3.5.2.1 (Cross Section Intent and Design Philosophy) states, “The repair template must … allow the maximum repair within funding limitations.” This indicates the main design criterion is to provide the most repair possible within a budget limit, rather than design to withstand environmental loads and forces. The “funding limitations” are not stated, yet appear to be behind many of the design and planning decisions. Using funding limitations as a design criterion is not the same as an engineered design that meets environmental loading criteria. The funding limits design criteria are not consistent with the environmental loading design criteria in “design_criteria_info.doc.”

Note that a 50 year project life does not necessarily mean one should apply a 50 year return period event for the design environmental criteria. For example, a petroleum development platform may have only a 35 year project life, but the project may be designed to withstand a 100 year return period storm event or longer. The consequences of jetty failure should be considered in establishing the design criteria. ISO standards are sometimes applied in practice, but do not seem to be included in this work. Additionally, USACE (1995; paragraph 2-4) states rubblemound structures should be designed to successfully withstand the conditions that have a 50% probability of being exceeded during the project’s economic service life. The economic service life needs to first be established as a criterion and then the design storm formulated to meet the acceptable risk level for that service life.

A span of 50 years may be appropriate for an economic planning horizon; however, a 50 year project life or a 50 year return period storm event does not seem reasonable for engineering design considering the importance of navigation through the MCR. The structures should be designed to last indefinitely, as permanent structures, with regular maintenance requirements estimated and included in an economic analysis.

The 50 year criterion may not be consistent with parts of the report that mention a longer period of time. The SRB model discussion in Appendix A2, p. 78 states, “The period of analysis for future condition simulations was 64 years (2006 to 2070) for the North Jetty and Jetty A and 63 years (2007 to 2070) for South Jetty.”

Appendix A2 (p. A2-8) states, "The MCR jetties were constructed to achieve an expected service life of 50-100 years," and concludes that 0.7% per year is the expected maintenance cost based on the 50-100 years service life. The 50-100 years service life, and associated 0.7% figure is used to inform the analysis and to demonstrate a lack of maintenance. However, the original 50-100 years service life, and 0.7% annual expected maintenance cost are arbitrary assumptions. The historic assumed service life and maintenance needs are not supported by the information presented, and largely irrelevant to today's design and maintenance criteria.

The design criteria, if any, from 100 years ago when the jetties were built are not presented and previous maintenance are considered an operational cost. Analysis of past maintenance also may distract from the main problem afflicting the jetties: poor design 100 years ago, not deferred maintenance.

The original builders, working before the development of modern coastal engineering methods, underdesigned the jetties with only 7 ton armor rock, at their angle of repose of 1.25h:1v, or steeper. In addition, they constructed the immense structures on ever shifting sand shoals, locating them where the shoal happened to be at the time of construction, without adequate design features to account for shifting channels and currents.

The starting assumptions and criteria and alternatives are so narrowly constrained that there is questionable value in much of the analysis. The Major Rehabilitation Evaluation study is set up so that the end result is always the same; more rock within the existing jetty footprint. Conventional coastal engineering practice for a project of this scope would include the following:

1. Analysis to determine how much jetty is really needed today to maintain the navigation channel at reasonable cost. The Panel questions whether all 9+ miles of jetty are optimal. There has been no upward trend in maintenance dredging volumes since 1956, despite continued jetty tip recession, which indicates shorter jetty lengths would be equally functional at less cost.

2. Evaluation of alternatives that are not constrained to the original footprint, not built to the maximum crest elevation and authorized length feasible, not constrained only to rock, and discussed or considered beneficial use of dredged material as a design element.

3. Evaluation of durability issues and lessons learned from related projects. For example, the Dover Pier in England has lasted well over 100 years. Similarly, the Humboldt Bay jetties and Crescent City jetties in Northern California have effectively stopped jetty head recession using 40 ton dolos concrete armor units, and the Japanese are building breakwaters with 90 ton dolos concrete armor units.

Significance – High:

The lack of criteria prevents NED analysis and evaluation of whether the structure design meets standards.

Recommendations for Resolution:
1. Establish conventional project criteria including project life, standards of performance and function to be met, and environmental loads and return period events, which are part of conventional coastal engineering design practice. Document in a Preliminary Design Report. 2. Establish Design Environmental Conditions that have a specific return period. 3. If unable to meet the design criteria due to budget limits, state the budget limits as a criterion, and estimate what the equivalent design life or expected performance will be for the compromised design. 4. Expand the starting assumption to allow: a. Beneficial use of dredged material as a component of jetty rehab. b. A design outside the existing jetty footprint c. A design that may allow jetty head recession up to a point when maintenance dredging needs increase. d. A design that can include a partially submerged jetty cross-section. 5. Use a longer return period than 50 years for the design environmental criteria and consider ISO standards. 6. Consult with Dover Pier representatives and other jetty builders to discuss durability issues and lessons learned from their project in order to benefit the MCR project.

Literature Cited:

USACE. (2005). Design of Coastal Revetments, Seawalls, and Bulkheads. Department of the Army, U.S. Army Corps of Engineers. Manual EM 1110-2-1614. June.

Comment 8:
The models and analyses of jetty failure do not include all significant processes.
Basis for Comment:
The SRB and STWAVE models cover many significant processes and variables that affect long-term jetty stability; however, some variables and processes are missing that should be presented in the SRB model and the Major Rehabilitation Evaluation Report: • Armor rock breakage, rounding and wear, which can significantly affect jetty performance, do not appear to be included in the analysis. • Deep seated slip surface failures through the jetty section, a global failure similar to a landslide, also do not appear to be analyzed and may be a significant risk. • Wave height in combination with currents can cause significantly higher sediment transport rates than waves only or currents only. It is not clear if sediment transport analysis, considering both waves and currents acting together, has been done. • Long-term changes in outlet channel morphology do not appear to be analyzed. The process of jetty decay through tidal channel scour appears different at Jetty A than at the North or South Jetties. Tidal channel scour at the tip of Jetty A will not be mitigated by adding spur groins, therefore a different system will need to be designed at Jetty A and accounted for in the jetty performance analysis. The STWAVE model is not sufficient for modeling detailed wave transformations. Important processes such as wave structure interactions, refraction, and diffraction are incorporated in STWAVE using approximate methods. Other models like BOUSS-2D and CGWAVE are readily available and model the physics of these important processes more directly. STWAVE is appropriately applied as a regional wind-wave generation model for regions without a complex bathymetry. However, the Mouth of the Columbia River morphology near the jetties and navigation channel is complex. A phase-resolving wave transformation model such as BOUSS-2D or CGWAVE should be applied at this level of design in addition to STWAVE.
Significance – High:
The analysis of potential jetty failures, waves, currents, and sediment transport is incomplete for this level of design, and may result in significant errors in the evaluation of alternatives. Errors could include underestimating the design wave height, leading to undersized armor rock, excessive maintenance requirements and structure failure.
Recommendations for Resolution:
1. Estimate future repair needs and armor rock characteristics based on past performance of rock at the jetties. This requires a more detailed survey of existing condition, including quantifying existing armor rock size, gradation, and shape. 2. Analyze foundation stability based on measured geotechnical properties. A subsurface geotechnical investigation, including borings and soil testing, is recommended. 3. Provide a design concept for scour protection at Jetty A and check its stability against design environmental criteria, including specific current speed and wave height.

4. Apply models and use analysis methods to investigate sediment transport patterns and jetty foundation erosion under a combination of both waves and currents.
5. Supplement the STWAVE model with a wave transformation model such as BOUSS2D or CGWAVE to help determine design wave heights near the jetties.

Literature Cited:

Demirbilek; Z., and V. Panchang (1998). CGWAVE: A Coastal Surface Water Wave Model of the Mild Slope Equation. USACE Coastal and Hydraulics Laboratory, Report CHL-TR-98-26, 120 pp.

cgwave_man3.pdf (3 MB .pdf)

Nawogu; O. G., and Z. Demirbilek (2001). BOUSS-2D: A Boussinesq Wave Model for Coastal Regions and Harbors - *Report 1: Theoretical Background and User's Manual*. USACE Coastal and Hydraulics Laboratory, Report ERDC/CHL TR-01-25, 92 pp.

BOUSS-2D.pdf (2.2 MB .pdf)

Comment 9:
The alternative selection process may fail to meet the requirements of NEPA Section 1502.14.
Basis for Comment:
The design alternatives presented in the document are limited to the repair and rehabilitation of the jetties within the present configuration. The Panel is concerned about the adequacy of the alternatives analysis and the limited range of alternatives considered. NEPA Section 1502.14 requires a rigorous examination of all reasonable alternatives to any proposal and justification of eliminated design alternatives. The Panel finds that there is little examination of alternative approaches to the principal function of the MCR jetties, which is to secure a consistent navigation channel across the bar at the MCR. As such, the narrow scope of alternatives presented weakens this project. Insufficient information is provided to justify limiting the improvements to the existing footprint. For example, the report does not provide the technical basis for maintaining the 1895 jetty design, length, and orientation to the exclusion of considering other configurations. Considering reasonable alternatives, under NEPA guidance, would allow USACE to use hydrodynamic modeling tools to evaluate alternatives such as the use of weir jetties (Seaburgh, 2002) and other sediment management methods that facilitate bypassing sediment at coastal inlets, as well as low wave and high wave depositional basins in a manner which may reduce long term operation and maintenance costs. The impact of not considering additional alternatives leaves the overall justification of the project less defensible and may lead to questions of the overall merit of the rehabilitation project
Significance – Medium:
Consideration of alternatives beyond rehabilitating the original jetty structures within their existing footprint would comply with NEPA directives, and provide critical information that may reduce long-term costs and improve jetty life and efficacy.
Recommendations for Resolution:
1. Assess, and validate or reject, the technical basis for the initial jetty design, length, and orientation using appropriate physical coastal process models. 2. Assess structural efficacy and cost of alternatives which are not constrained by the existing footprint. 3. Develop modeling efforts for hydrodynamic models and/or sediment transport models that would provide insights into the following areas: a. Thorough analysis of the existing jetty structures focusing on why some areas have survived without repair and others have needed repeated repairs b. Examination of why Jetty A had such a large O&M cost relative to predictions. c. Addition of subsurface berms potentially created through the beneficial use of project dredged material that may reduce wave impact and subsequently reduce wave overtopping and toe scour.

Literature Cited:

Seaburgh, W. C. (2002). Weir Jetties at Coastal Inlets: Part 1, Functional Design Considerations. U.S. Army Corps of Engineers, ERDC/CHL CHETN-IV-53. December.

Comment 10:
A failure analysis for the original structure design and past trends of Operation and Maintenance (O&M) costs has not been provided.
Basis for Comment:
The extent of structure failure or partial failure is well documented and the repairs made to the structure are well documented, as shown in Figures 1-12, 1-15, and 1-16. These figures, however, do not distinguish between areas repaired and areas that are substandard but have not failed and so were not actually repaired. Failure analyses for the groin tips and the runnel formation weakening Jetty A (p. 3-5) are presented, but the report does not include a general failure analysis. A failure analysis would be helpful in determining why one section of jetty failed/degraded whereas another remained intact. This information is needed to derive alternatives that resist both degradation and failure, and result in an informed design of jetty repairs. Maintenance histories (Figures 1-21 through 1-23) show that actual O&M costs have trended significantly above and below the expected O&M costs, based on annual expenditures equivalent to 0.7% of the initial construction costs. Specific causes of actual O&M costs being higher or lower than the assumed 0.7% annual average cost have not been analyzed but can be presumed to be directly related to full or partial failure of portions of the structures. Knowledge of the specific causes of failure combined with the cost of constructing a jetty resistant to these causes taken in consideration of maintaining a jetty less resistant to these causes may be useful in determining or presenting the most cost effective alternative design. A specific presentation of individual jetty failure events would serve to bolster the alternative selection process and the projections of future maintenance costs.
Significance – Medium:
Uncertainty regarding the specific causes of failure and their relationship to trends of past O&M costs creates a functional uncertainty in the corrective measures in the alternatives for repair and rehabilitation.
Recommendations for Resolution:
1. Include an analysis of the causes of failure for each repair event (e.g., Figure 1-15) even if only a statement of "storm intensity" in order to provide assurance that the repairs address the actual causes of previous jetty failures. 2. Relate construction costs of more resistant designs to repair costs of less resistant designs for each causal condition of failure and the associated selected alternative.

Comment 11:

Sea level rise and potential increases in wave height have not been examined sufficiently under different model scenarios.

Basis for Comment:

The issue of climate change, sea level rise, and increased wave action is important to consider in the evaluation of long-term projects (USACE, 2009). There is no discussion in the main report of sea level rise and its impact on this project over the 50+ year project timeline. There is a limited discussion of climate change in Appendix D (p. 5), where the conclusion is that since the projected historical trend of sea level at the project site is estimated to be -0.05 feet in 50 years, sea level rise is not projected to be a significant climate change factor at the project site. Appendix D states the "comprehensive analysis of historical storm events is expected to adequately capture the present deep water contribution of potential wave height variation for this project site. The above approach forms the basis for estimating the potential changes in wave climate that could affect the MCR jetty system." However, this discussion on wave height trends is not compelling. The main report states (p. 1-6), "As the tidal shoals continue to recede (erode), the MCR jetties will be exposed to larger waves and more vigorous currents. To make matters worse, the regional wave climate along the Northwest Pacific Coast has become more severe in the last 10 years. The offshore 100-year wave height has been revised from 41 to 55 feet." (see also Appendix D). The main report states (p. 3-42), "The limit of cross-section resiliency is reached for jetties when the core stone becomes exposed to wave attack." Therefore, this issue may affect jetty erosion and a larger range of wave heights should be included in both the SRB and STWAVE model scenarios.

Wave overtopping is central to the environment deteriorating the existing jetties. As the planning horizon of this project is 50+ years, it seems that a discussion would be useful of sea level rise and modeling potential wave heights and the wave overtopping impacts on the jetties given different rates of recession under a wider range of wave heights. Jetty height and crest elevation are variables that should be modeled given the potential larger wave heights possible under sea level rise. Although the selection of the recommended plan may not change, long-term maintenance costs may be affected, therefore consideration is warranted.

Appendix B states that transient internal hydraulic effects of wave impact may be the most important parameter in the stability of the jetties. However, it is the least certain of all of the parameters. Internal hydraulic pressures in jetties have not been measured. Given this, it seems especially important to consider more extreme wave heights beyond the wave height analyzed, with respect to sea level rise and potential increasing wave height.

Significance – Medium:

The discussion of potential impacts of sea level rise and increased wave action on jetty structures is critical to understanding the potential impacts to the project and in designing a project with lower long-term maintenance costs.

Recommendations for Resolution:
1. Add a separate section to the Major Rehabilitation Evaluation Report that examines climate change, sea level rise, potential wave height changes, and resulting wave overtopping impacts on the jetties given different rates of recession under different model scenarios.

Literature Cited:

USACE (2009). Water Resource Policies and Authorities Incorporating Sea-Level Change Considerations in Civil Works Programs. Department of the Army, U.S. Army Corps of Engineers, Washington, D.C. Engineer Pamphlet EC 1165-2-211. 1 July.

Comment 12:

Construction cost estimates cannot be evaluated because the assumptions and details have not been provided.

Basis for Comment:

A detailed construction cost estimate summary should be provided for the recommended plan, otherwise the basis for the total cost values provided in Section 6.5.9 cannot be reviewed and assessed to determine if they are realistic and complete. The cost estimate information provided in the main report (Section 6.0) and in Appendix E is not sufficient to support the recommended plan:

- Table 6-3 provides a detailed summary of stone volumes for each jetty by construction year, but there is no correlation with construction costs or to the cost estimates provided in Section 6.5.9 or Appendix E.
- Specific cost estimating details are provided in Sections 6.5.7 and 6.5.8, but the assumptions and criteria defining the basis for the cost estimates do not include any summary unit costs for the individual work items.
- Unit costs are provided in Tables A2-9 to A2-11 but pertain to the SRB modeling effort. There is no discussion regarding how they relate to the final project costs presented in Section 6.5.9.
- Appendix E includes budget summary costs for construction, planning/engineering, construction management, and land acquisition. Detailed cost estimates for the Civil Works construction budget numbers are not provided and the basis for the costs cannot be reviewed or verified.
- Costs for the barge offloading and material re-handling area facility installation and maintenance are not described, yet they could be a large direct and indirect cost to the project based on wave exposure (for type and size of barge offload facility structures). The structural requirements (and corresponding construction costs) for an exposed vessel berth will be many orders of magnitude larger than the same berth in protected waters. Stone delivery cost represents a very large percentage of the total cost. Ensuring a cost feasible method of delivery to the jetty structures is critical for development of an accurate cost estimate.

Significance – Medium:

Detailed construction cost estimates need to be provided in order for the cost analysis to be complete and verifiable.

Recommendations for Resolution:

1. Provide a detailed cost breakdown by work item for the Civil Works project item, Breakwater & Seawalls. Provide detailed cost estimates for each major element of work (e.g., mobilization, stone supply and install, site preparation, material re-handling facility installation, maintenance of re-handling facilities, etc.). Give details regarding work item quantity, unit costs, contingency, and escalation.

2. Provide a detailed cost summary within Appendix E, and an additional detailed description of the basis for the costs estimates in Section 6.
3. Conduct an additional investigation of re-handling facility requirements to adequately determine the costs for facility installation and maintenance.

Comment 13:
Potential environmental impacts on sensitive species, upland habitats, and water quality have not been thoroughly discussed or specifically mitigated in the document.
Basis for Comment:
Appendix D and main report (pp. 5-17--5-20) list potential in-water, wetland, and upland impacts. These impacts should be addressed in the mitigation plan. The mitigation plans currently address these three general categories, but do not provide mitigation for potential impacts to specific species, upland habitats and water quality. The mitigation plans are incomplete because the final wetland delineation for the project has not been conducted, and the impact to wetlands and upland habitat is uncertain and therefore not quantified. A vegetation restoration plan is needed to address potential impacts to upland habitats, especially the rare and vulnerable species discussed below. At a minimum, the mitigation plan should state that these plans will be prepared prior to construction activities. Although the extent of the upland impact on this habitat is uncertain, a replanting contingency plan and a clear plan for avoidance are important to include in the mitigation plan. Similarly, potential water quality impacts from spills should be addressed in the mitigation plan with a statement about the spill prevention plan, as discussed below. Section 5.1 (Environmental Effects) of the main report provides details on biological resources, but is missing a vegetation section. Appendix D contains two reports including the Wetland and Waters of the U.S. Delineation Report and The Plant Communities Investigation Report, April 2007, which provides details on the vegetation communities; however, this information is not presented in the main report and therefore the main report lacks a definition of the plant species of concern within the project area. The revised EA states (p. 6) that at least three of these vegetative communities (shorepine-slough sedge, shorepine-Douglas fir, and coast willow-slough sedge) "have been ranked globally and by the State for their rarity and vulnerability to extinction and should be protected from impacts." This information on sensitive species should be integrated into Section 5.1. Furthermore, potential land construction activities as shown on Figure 5-1 of the main report may affect plant communities, including sensitive habitats, warranting a discussion of existing vegetation in the project area. Vegetation impacts that may result from construction are not detailed in the document, and just briefly mentioned in regards to the South Jetty. Mitigation plans should include specific protective measures to avoid potential impacts to these rare and vulnerable species. In general, the main report discusses Endangered Species Act (ESA) species, but does not provide detailed data on specific animal or plant populations. In 2005, critical habitat was designated for all Columbia River steelhead and Columbia River salmon evolutionarily significant units (ESU), with the exception of lower Columbia River coho salmon ESU. Although a wide range of potential impacts are discussed (p. 5-16), ranging from loss of habitat to an increase in perching and in-water habitat for predators that prey on listed species, the mitigation section of the Major Rehabilitation Evaluation Report does not address these impacts. The main report concludes (pp. 5-19 – 5-20) that there will be overall benefits to these species from this project. Additional details would be helpful to ensure that these species suffer no impacts. The Panel realizes that as a specific mitigation plan is developed, this may

likely be incorporated.

Water quality may also be affected over the project duration due to the large volume of container ships, construction dredges, barges, and cruise ships operating in the area, sometimes in adverse extreme weather conditions. For example, there may be a loss of hydraulic fluid or oil spills (p. 3-70). In the discussion of the mitigation plan in Section 5.4 (p. 5-17), the increased risk of pollutant release and spill potential is raised as a potential impact on ecosystem function. A sentence earlier in the document (p. 5-2) states that the Contractor "will provide a spill prevention plan to include measures to minimize the potential for spills and to respond quickly should spills occur." This sentence belongs in Section 5.4 of the main report as well.

Any history of spills in the Mouth of Columbia River area should also be reported in the document. Providing these details will enable a more thorough analysis of environmental impacts and enable additional protective actions to be implemented.

Significance – Medium:

Additional biological resources data and potential impacts to sensitive species, upland communities and water quality is needed to adequately protect the environment and define the mitigation needed to reduce these impacts to less than significant.

Recommendations for Resolution:

1. Incorporate additional information into Section 5 of the report:
   a. A vegetation section defining the sensitive species within project area.
   b. A statement to ensure that stockpiling activities shown in Figures 5.1 – 5.3 of the main report minimize the land impacts to sensitive habitats and wetlands. State whether a survey will be conducted prior to construction activities with sensitive habitats flagged to ensure avoidance.
   c. Provide detailed data on specific animal or plant populations that are listed species
   d. Specific text in the mitigation section for potential impacts to steelhead and salmon.
2. Add the wording from p. 5-2 into Section 5.4 of the mitigation plan regarding the contractor's requirement to prepare a spill prevention plan to address potential water quality impacts. Document any known history of spills in the area.

Comment 14:
Potential impacts to recreational use during project construction, as identified in public comments, are not adequately discussed or mitigated.
Basis for Comment:
The Major Rehabilitation Evaluation Report does not provide detail on the impact of the project construction activities on recreational use, an issue that came up in public comment letters (main report, Section 5.4). The last sentence in Section 5.3 states that there will be no significant impacts on recreation. Appendix C states that there is a growing cruise ship industry and it is unclear how construction activities will affect passenger cruise ship access. On p. C-3 it states that 5/7 day cruise ship tours carry 15,000 passengers annually, and thousands of tour boat passengers take day trips and dinner cruises. These activities generate about $15 to $20 million in revenue annually for local economies. Public access during construction may be an issue. In addition, other recreational uses of the area may be reduced, such as kayaking and hiking. These impacts should be defined, rather than concluding that no recreational or economic impacts to tourism are expected. Omitting this issue may lead to unforeseen consequences for the cruise ship and tourism industries.
Significance – Medium:
Recreational impacts are not adequately presented in the report and subsequently, no mitigation is identified for this potential impact.
Recommendations for Resolution:
1. Add a discussion of the cruise ship industry and other recreational uses at the project site. 2. Examine potential impacts on cruise ships and other recreational activities that may result from the dredging operations and jetty repair operations. 3. Provide potential mitigation options to reduce recreational impacts to less than significant levels. 4. Make a distinction between recreational impacts during construction and after construction.

Comment 15:
There is not sufficient information on the evaluation of barge offloading and material re-handling facilities to ensure these sites can operate as intended and to ensure the construction costs are adequately represented.
Basis for Comment:
Contract-provided barge offloading facilities for the South and North Jetties are described in Sections 6.3.3 and 6.3.4 and shown in Figures 5-1 and 5-3 of the main report. Based on the information presented, it is not clear that these sites have been adequately investigated and are suited for their intended use. The barge offloading and material re-handling facilities at these outer exposed locations should be further investigated to ensure they are economically and operationally feasible. The proposed facilities are referred to as "temporary," but this is questionable if they will be in place for 20 years. The life-cycle costs of the docks and other structures are not trivial and do not seem adequately analyzed. The largest cost and a substantial risk for the recommended plan involves the purchase, transportation, delivery, and offloading of the stone in a very difficult environment over a relatively long time. The USACE-provided sites also need to be operationally feasible in order to use a permitted method of delivering material to the site. Providing contractors with better information on the limitations and usability of these sites at the time of bidding could result in substantial cost savings. There is no discussion in the report of any engineering work performed to evaluate the feasibility of installing structures at these exposed locations, nor any mention of operational feasibility for the size of vessels and wave climate for the periods of construction. These locations are subject to wave heights of more than 15 feet, which will impose very large wave impact loads on fixed structures (dolphins and sheet pile walls), resulting in high risk and cost facilities. USACE intends to permit these sites and provide them to the contractor as the primary point of access. This establishes a certain level of perceived usability to bidders. If they are later determined not to be feasible (i.e., during contract bidding or during construction), it would result in substantial cost and schedule changes. Use of the re-handling facilities will be limited to a "summer" work period (April to October). There is no analysis of sedimentation rate in the report to verify whether the floatation channels will remain open for the summer construction work period. Maintenance dredging estimates for barge offloading facilities are provided in Table 6-1, but it is not clear for what time period (annually or total over the entire duration of the project). Jetty A is listed at 80,000 cubic yards for maintenance dredging. Other options, such as dredging within the Ilwaco channel to the trunk end of Jetty A and developing an offloading facility adjacent to the staging area could be considered.
Significance – Medium:
Insufficient information on the limitations and usability of the offloading and re-handling sites could affect construction cost estimates and project schedule due to operational and physical environment constraints.

Recommendations for Resolution:
1. Conduct a feasibility level engineering analysis and design for the contract-provided offloading and rehandling sites to ensure that selected sites and facilities are feasible and provide reliable estimates of construction cost. The feasibility evaluation should at a minimum include the following: a. Evaluate feasibility of constructing pile supported structures within an extreme hydrodynamic environment. This includes wave/current loads on moored vessels during the construction period and wave/current loads berth structures during extreme winter conditions. b. Evaluate downtime of barges at the proposed sites relative to the wave and current climate during the proposed construction work period. c. Refine the type of structure that is feasible for these locations for inclusion into project permits and cost estimates. 2. Evaluate the need for alternative barge offloading and material re-handling site locations based on the results of the feasibility analysis. 3. Evaluate design concepts for permanent barge/dock facilities, possibly incorporated into the inside face of the jetties near their root. 4. Develop environmental data specific to the proposed offloading site locations for bidders/contractors to use in developing their estimates of downtime and infrastructure requirements at USACE provided rehandling sites. Extreme event offshore wave data and jetty structure design criteria will not be sufficient for contractors to use in evaluating short-term operational and design requirements.

Comment 16:
The requirements, costs, and history associated with emergency dredging compared to scheduled maintenance dredging activities have not been specified.
Basis for Comment:
Dredging is a substantial component of this project and has been historically, yet there is no clear discussion of the role of dredging in the Major Rehabilitation Evaluation Report. Typical annual dredging rates are not presented in the document itself, although Appendix A1 (p. A1-3) states, "Each year, the Portland District dredges 3 to 5 million cubic yards (MCY) of sand at MCR to maintain the 5-mile long deep draft navigation channel." It is unclear if the Portland District dredging is conducted exclusively at MOCR. Analysis of the project area maintenance dredging requirements – past, present, and future – have not been presented. Controlling dredging costs is critical to this project. The EPA publishes a report annually analyzing dredged sediment disposal in the nation. About 4 million cubic yards is dredged at the MCR every year at an annual cost of about $10 million. The fact that maintenance dredging volumes in the project area have not increased (no clear trend) since 1956, despite ongoing jetty tip recession, raises the question of how much jetty is now needed to maintain the MCR navigation channel. However, the main report does not discuss details of the maintenance dredging. Appendix B states the geological history includes 225 million cubic yards of dredging from the MCR navigation channel since 1956. The volumes, history, and fate of these dredged sediment volumes should be described in the main report and are missing from the analysis. The fact that most of this sediment was dumped far offshore and lost to the nearshore may have something to do with the erosion experienced in the area. This large quantity of dredged material warrants discussion and additional consideration of strategies to reduce this volume. The discussion of emergency dredging is also lacking in the main report. The historical downtime for dredging at the dock and jetty repair work during the time period of October to March (peak period for large waves) is not provided. Page 3-70 states, "Given the winter wave conditions that the dredges would be performing in, it is highly likely that damage would occur to the drag arm of the dredge while working." Page A2-65 states that within the SRB model "there is a 0.3 probability that one dredge will lose a drag-arm while performing dredging during winter or a 0.7 probability that one dredge would realize equipment damage," thereby increasing dredging costs. Several places reference the difficulty of dredging in the winter. Conditions may preclude effective dredge use, or the dredge may break and become inoperable, suggesting dredging may be postponed until summer. In terms of dredge operation, p. 1-48 gives the operational limitations of hopper dredges, and admits that operating a hopper dredge at the MRC during winter months has not yet been attempted. Therefore, the inadequate demonstration of equipment effectiveness, lack of documentation of the basis of dredge damage probabilities, and lack of historic utilization increases the risk associated with estimating costs associated with emergency dredging. The document states on p.1-50 that the rate of shoaling within the MCR channel would not be high enough to require emergency dredging; therefore, the increased shoaling volume could be dredged the following summer and would not be considered emergency dredging. The

document never presents operational triggers for when emergency dredging would occur. The main report indicates that there are four dredges capable of working in winter (p. 3-111), but these dredges are not mentioned earlier, when it was presented that only one or two dredges are available in the short term. A discussion of emergency dredging history, success in other areas, and a description of the equipment available is warranted. The analysis considers long-term O&M costs of dredging, but does not explain the criteria used in the calculation estimates. There is no mention of any historic environmental impacts from the dredge operations, such as spills. If spills have occurred, data should be presented.
Significance – Medium:
Additional information on dredging may enable better analysis and lead to a long-term reduction in dredging costs and the development of a contingency plan to successfully avoid navigation impacts.
Recommendations for Resolution:
1. Develop a paragraph on dredging in the main report that specifies clearly what the maintenance dredging program has been, rates, and frequencies, and if they are scheduled or "as needed." Present all the historic maintenance costs, schedules, and frequencies. 2. Provide a detailed history of emergency dredging with success and failures and costs. 3. Add information to specify what rate of shoaling requires emergency dredging compared to scheduling maintenance dredging activities. 4. Present the criteria used in the calculations of dredging O&M costs. 5. Provide any information on historic spills related to dredging operations.

Comment 17:
The current jetty structure condition is not well described, making it difficult to confirm the confidence of the SRB model analysis and selection of a recommended plan.
Basis for Comment:
Although there is a good description of historical failures and repair actions for each jetty, there is no discussion or documentation of current jetty condition or detailed condition assessments of structure and functional condition. A condition assessment of each jetty structure should be conducted through a combination of visual inspection (stone size, gradation, slope defects, stone defects, loss of armor stone, core exposure, etc.) and evaluation and comparison of historical electronic surveying results (single beam, multi-beam, or side scan sonar data). These elements will provide the basis for determining the present condition, assess risk of current condition to failure, and help classify structure along various reaches of each jetty. These data would enable better assessment of vulnerabilities, analyzing why some areas in the jetty have maintained without repair and other areas have needed multiple repairs. A better understanding of these dynamics may reduce O&M costs over the long term. Rubble-mound structures have a tolerance for deterioration before suffering catastrophic failure. A thorough understanding of current and historical structure condition is critical to developing an estimate of the mechanisms causing failure, establishing the timeframe for catastrophic failure, and conducting maintenance/repair work. The SRB model evaluation of alternatives using the base condition depends upon an adequate understanding of current jetty conditions and corresponding impact on estimated future repair and maintenance. The current SRB analysis is based on a “hindcasting” of jetty performance relative to historical performance, but without consideration of the details of condition and causes of failure. The current and historical condition relative to structural and functional rating should be conducted following USACE procedures (USACE, 1998) to establish the baseline conditions for the SRB model analysis. Evaluation of stone source and quality relative to length of service on the structure should be conducted as part of the jetty condition assessment.
Significance – Medium:
A detailed description of the current jetty structure as part of a condition assessment is necessary to understand the accuracy of the SRB model.
Recommendations for Resolution:
1. Conduct a detailed condition assessment of each jetty structure, including visual inspection and historical survey comparison. 2. Compare historical survey data for the validation of interpreted historical conditions and corresponding perceived modes of failure. Incorporate results into the development of baseline conditions for the SRB model. 3. Use a condition rating system such as that outlined in the USACE Manual REMR-OM-24 (USACE, 1998) for evaluation of current condition. Assess both the structural and functional condition of the structures and incorporate the results into the SRB model analysis.

4. Incorporate the results of the condition assessment into Section 1.4, description of project history.
5. Provide an additional description of existing condition in Section 1.4 and 3.3.2 of the main report, including the service life of stone sources used for previous repair and maintenance activities.
6. Based on the results of the condition assessment, the relation between the stone sources reviewed (in Appendix B, Section 5) and the corresponding observed service life of that stone should be discussed and incorporated in the SRB analysis.

Literature Cited:

USACE (1998). Condition and Performance Rating Procedures for Rubble Breakwaters and Jetties. REMR Management Systems—Coastal/Shore Protection System Devices. Technical Report REMR-OM-24, U.S. Army Corps of Engineers, Washington, D.C.

Comment 18:
The mechanisms causing jetty head scour have not been sufficiently analyzed to allow selection of the appropriate jetty head repair measure.
Basis for Comment:
Causes of jetty head scour have not been sufficiently investigated. Tidal shoal and outlet channel geomorphic processes should be further evaluated and analyzed to ensure that proper jetty head repair measures are selected. The mechanisms causing the "scour holes" and undermining of the jetty in the vicinity of the jetty tips (North Jetty and Jetty A) have not been sufficiently analyzed for selection of the jetty head repair measure. Figure A1-32 indicates a progressive erosion of ebb tidal shoals in the vicinity of the North Jetty (between Stations 60 and 90) undermining the south toe of the structure. The report understates the situation when it notes (Appendix A1, p. 28), "If the jetty foundation washes away, jetty reconstruction is problematic." A solid understanding of the environment and bathymetry changes is essential for development of a reliable design alternative. Spur groins installed along the south slope of the North Jetty will assist in addressing scour generated by localized currents, but will not provide protection from overall MCR tidal shoal and channel morphological changes. Continued ebb shoal erosion and potential tidal channel movement could undermine the head of the proposed offshore spur groins (located near Stations 90 and 70). It seems likely that scour holes are related to the observed jetty tip recession. The 100 foot deep scour hole at the end of Jetty A is particularly alarming from a structural design perspective. Equally alarming is the discussion of "Vertical scour along the toe of the MCR jetties has exceeded 10 meters in some reaches" (Appendix A2, p. A2-11). If there really is, or was, a more than 30 foot high underwater scarp in places along the toe of the jetties, then more investigation is warranted. Figures showing typical sections often do not extend to the toe of slope, and show details that aren't feasible, such as rock limits ending in a small angle without an engineered toe. (See Appendix A1, Figure A1-258). Strategies to deal with scour, especially at the jetty tips appear undeveloped. Design features could include scour blankets, launched toes, or a program of regular fill using dredged material.
Significance – Medium:
Inadequate evaluation of the geomorphic processes responsible for the deterioration at the jetty tips (North Jetty and Jetty A) could lead to an incorrect approach to rehabilitation of those areas of damaged structures.

Recommendations for Resolution:

1. Conduct a more detailed evaluation of historical geomorphic changes in the outlet channel and shoals in order to evaluate tidal shoal erosion and tidal channel migration. Comparative analysis of historical bathymetric surveys would be helpful in developing a better understanding of historical trends and associated correlation with jetty structure historical damage, failure, and repair activities. Additionally, use historical geomorphic change analysis and hydrodynamic analysis to estimate long- term changes and impacts to the North Jetty and Jetty A to formulate jetty head rehabilitation alternatives and development of design criteria.
2. Do not limit the jetty repair preliminary designs to the footprint of the authorized jetties. Evaluate scour protection alternatives extending past the jetty tips.
3. Draft plans, profiles, and sections at this level of design using suitable software, such as AutoCAD® or MicroStation®. Microsoft Excel® is not an adequate substitute for drafting software.
4. Draft the jetty design typical sections to scale and extend past the scour holes and navigation channel.
5. Conduct a subsurface geotechnical investigation to obtain the geological properties needed to verify or design an adequate foundation.

Comment 19:
Risk thresholds for selected alternatives are not clearly defined.
Basis for Comment:
Risk thresholds are used in repair frequency predictions as triggers for maintenance response and subsequently in maintenance cost predictions. The frequency of reaching degradation thresholds is predicted by risk thresholds. Combining degradation thresholds with repair costs (minor vs. major) can also be used to determine the threshold for triggering maintenance actions, balancing multiple small repairs against the cost of a single major repair. The Major Rehabilitation Evaluation Report includes extensive discussions of risks related to different portions of the project; however, while this discussion of risk is extensive, defined thresholds are not presented in the document. It is to be expected that the risk (probability) of surpassing thresholds may vary among alternatives in both configuration (number and placement of spurs, jetty length) and in cross sections considered. The risk associated with each alternative considered should be assessed based on materials, cross sections, supporting geological features, currents, and storms. It is also proper procedure to examine how the risk of one design component may be altered by the inclusion or exclusion of a second design component.
Significance – Medium:
Undefined risk thresholds may serve to undermine the logic of the cost and maintenance predictions and, to a lesser extent, the alternatives selected.
Recommendations for Resolution:
1. Define risk thresholds for alternatives, including source of risk and effect of exceeding the threshold.

Comment 20:
It is not clear how uncertainty and derived risk analyses were considered in the structure and application of the model.
Basis for Comment:
Project life-cycle cost analyses should consider the risk of construction cycle and operational cycle downtime, which does not appear to be included. However, risks cannot be evaluated without understanding the level of uncertainty associated with the SRB model result. The uncertainty associated with actual future conditions, which may deviate from the modeled future conditions, is not apparent. The SRB model includes 600 variables (Section 9, p. A2-91) each of which has a data set which can be expected to reflect an associated variance. Depending on the calculation stream, these variances, applied geometrically, will lead to accumulated statistical errors and uncertainties. These cumulative internal variances can be expected to result in high uncertainty in the output of the SRB model, which should be considered in the evaluation of alternatives.
Significance – Medium:
Potentially wide error bars (uncertainty) may compromise life-cycle maintenance and repair schedules.
Recommendations for Resolution:
1. Quantify and explain the uncertainty (i.e., error bars) associated with each variable when analyzing processes that involve a chain of events. 2. Identify, analyze, and define errors that may accumulate to assess model reliability.

Comment 21:

The model output parameters and wave height components are not clearly explained and supported.

Basis for Comment:

The meaning of the following SRB model output parameters is not clear:

- Functional Reliability
- Structural Reliability
- Probability of Unsatisfactory Structure Performance.

For example, the main report (Section 3.6.1, p. 3-43) includes the following: "Functional reliability is the likelihood that a structure will satisfactorily perform its intended function within a given time interval. Functional reliability is derived by combining structural reliability metrics with metrics that describe the present structure cross-section configuration." One difficulty is that the understanding of "Functional Reliability" requires first understanding "structural reliability metrics", (which are not to be confused with "metrics that describe the present cross-section configuration"). However, the "structural reliability metrics" are not clearly defined either. A word search of Appendix A2 for the term "Structural Reliability" does not reveal a set of equations for calculating the parameter or a clear explanation.

Similarly, much of the SRB model includes terminology and variables that are hard to understand. For example, Table A2-12, Jetty Maintenance Thresholds, (p. A-60) consists of numbers and parameters not connected to anything that has a physical meaning. Conventional calculations and metrics such as volumes, areas, and depths are parameters with physical meaning that would improve the understanding of the SRB model. Understanding the SRB model outputs would be improved with graphics that are connected to parameters with physical meaning.

The wave height component of the SRB model is not supported by standard coastal engineering practice. Progressive jetty damage in the SRB model is based on a stochastic time series of wave heights, which is derived from "An ensemble of 52 storm events … recorded at NDBC buoys… during 1998 to 2008." It is unclear why only 10 years of buoy data were used when a longer record of more than 17 years with gaps removed is available (Appendix A1, pp. 34 and 37). It is also not certain that extreme wave height events were properly included in the SRB model process. It is common industry practice to test a coastal engineering design using a specific design environmental criterion, such as the 100 year return period wave height.

Significance – Medium:

The model parameters that compare alternatives lack a physical meaning, such as a volume of rock or depth of scour. It is therefore difficult to verify, calculate, or evaluate whether the parameters used or model results are reasonable.

Recommendations for Resolution:
1. Explain and demonstrate how the model output parameters relate to physical performance measures, with graphics or figures. 2. Measure jetty damage and performance with conventional calculations, and commonly applied metrics, for example: a. Volume of sediment entering the navigation channel, or dredge volume, b. Depth or volume of scour at the jetty toe c. Volume or area of armor rock displaced from the jetty. 3. Test the design against a specific storm event, such as the 100 year return period event. 4. Calculate the return period of extreme events using the complete record of measured offshore wave data.

Comment 22:
The culvert installation details, as well as potential impacts, need further clarification.
Basis for Comment:
The Major Rehabilitation Evaluation Report states that the existing culvert has increased scour and adversely affected the North Jetty, and that it will be relocated. There are a few sentences in the main report and in Appendix D that mention the culvert, but there is not enough information provided in the main report to determine if there will be any potential impacts from the new discharge location. The table at the end of Appendix D provides the most detail anywhere in this report regarding the culvert relocation. On p. 6-6 in the main report there is a sentence stating work will begin in 2014 to install a culvert to divert overland flow to another area that will not impact the North Jetty root stability. While this sounds like a reasonable approach to protect the North Jetty, more information is needed to clarify the impact such as the source of the water, an assessment of the water quality, and an estimate of the flow rate involved. Without knowing the exact new location, it is not possible to assess the potential environmental impact of relocating this water flow.
Significance – Medium:
More detailed information on the new location of the culvert as well as water quality, flow rates, and source of the water is necessary to determine the environmental impact of the relocation.
Recommendations for Resolution:
1. Add one paragraph in the main report that addresses the culvert relocation. 2. Present any available data on the water quality, flow rates, and water source of water discharged through the culvert. 3. Provide the specific location planned for new culvert.

Comment 23:
The various base years cited in the report and the difference between project life and period of analysis require additional explanation.
Basis for Comment:
The terms “project life” and “period of analysis” are not defined or differentiated, and the project base year varies throughout the report: • In the economic spreadsheet models, the NPVs are calculated for differing periods of analysis (2009-2070 for South Jetty, 2008-2070 for Jetty A, and 2008-2070, 2008-2057 and 2008-2069 for the North Jetty); whereas the AACs are based on a 50 year period of analysis. • The period of analysis extends 50 years beyond the base year of 2011 when discussing sea level rise (pp. A1-38 and A2-68). • The period of analysis for future condition simulations is 64 years (2006 to 2970) for the North Jetty and Jetty A and 63 years (2007 to 2070) for the South Jetty (p. A2-78). • The AAC is calculated using an amortization factor applied to the present year cost stream from the NPV implementation year (2006/2007) to 2069 (p. A2-51). • The base year of the economic analysis is not identified in Section 2 or Appendix C, but is stated as 2014 elsewhere in the report (pp. ES-3 and A2-78). • Within the SRB model, the base year is stated as 2011 when discussing sea level rise (pp. A1-38 and A2-68). • Within the SRB model, the base year for NPV cost discounting is 2006 for the North Jetty and Jetty A, and 2007 for the South Jetty (p. A2-51).
Significance – Low:
Inconsistencies in terminology and periods of analysis can lead to misunderstanding of findings and results.
Recommendations for Resolution:
1. Define and differentiate between the terms “project life” and “period of analysis.” 2. Revise the report to eliminate inconsistencies between the varying periods of analysis. 3. Use a consistent base year throughout the analysis, and revise the report to reflect consistency. 4. Revise Section 2 and Appendix C of the report to state the year that is considered to be the base year, the length of the period of analysis, and the calendar years that are included in the period of analysis. 5. Provide definitions of all terms in a Glossary.

Comment 24:
Cargo tonnage and vessel trip statistics presented throughout the report are inconsistent.
Basis for Comment:
Data presented throughout the report have inconsistencies that should be corrected. The following are examples of inconsistencies in values for cargo tonnages, vessel trips, and value of cargo: • Page ES-1 – cargo on the MCR is 45 million (M) tons and 3,500 vessel crossings based on 2008 Waterborne Commerce Statistics Center data. These data are not cited in the body of the report. • Page 1-2 – cargo on the MCR is 40 M tons worth $17 billion, with 12,000 commercial vessels navigating the MCR annually. • Pages 2-1 and C-1 – cargo on the MCR is 40 M tons valued at $17 billion based on a 2009 Pacific Northwest Waterways Association (PNWA) factsheet cited in Appendix C. • Pages 1-4 and C-4 – cargo on the MCR is 32 M tons in 2003 and projected at 43 M tons in 2020 based on 2005 Center for Economic Development and Research (CEDER) data, cited as a footnote in Appendix C. • Page C-5, Table C-1 – 5,364 total vessel trips on the MCR based on 2005 Waterborne Commerce Statistics Center data. • Page A1-3 – cargo on the MCR is 48 M tons worth $16 billion, with 12,000 commercial vessels navigating the MCR annually. The cargo and vessel trip statistics presented in the report appear to include all traffic on the MCR and Lower Columbia River (LCR). The report assumes all traffic accessing the MCR is dependent on the MCR jetties. The without-project condition channel depths are not adequately described. The cargo and vessel trips that would be impacted by the jetties, that is, the portion of the fleet transiting the MCR that would be restricted by the without-project condition channel depths, is not described.
Significance – Low:
Consistent cargo and vessel trip data for the MCR are needed in order to develop an understanding of the significance of the jetties.
Recommendations for Resolution:
1. Describe the cargo tonnages, vessel trips, and value of cargo consistently throughout the report, or supply an explanation of the differences and why various data sources were used. 2. Describe the portion of the fleet accessing the MCR that is dependent on the jetties (i.e., what are the without-project condition channel depths and what portion of the fleet transiting the MCR would be restricted by the without-project condition channel depths).

Comment 25:
Terminology related to jetty rehabilitation and failure is defined inconsistently or vaguely in some places.
Basis for Comment:
Inconsistencies in terminology can make understanding the project difficult. Commonly used terms in the document, such as "failure," are not clearly and qualitatively defined. Phrases such as "close to failure" appear frequently, in a qualitative sense, but without an understanding of how much jetty damage, if any, constitutes a "failure." Another example is in the SRB model where "fix-as-fails" repairs are described as, "To defer jetty maintenance for as long as possible, the jetty is maintained close to the margin of functional loss." The concept makes sense but how the model deals with terms like "as long as possible" and "close to the margin of functional loss" is unclear. Other phrases, such as "scheduled repair" and "rehabilitation" seem to be inconsistent as well. For example, "scheduled repair" includes "head capping" in the executive summary of the main report, but does not include "head capping" in some alternatives analyzed by the SRB model.
Significance – Low:
Without clear, consistent definitions of terminology, it is difficult to understand exactly what is being proposed or analyzed and can lead to misinterpretations.
Recommendations for Resolution:
1. Add a Definitions list or Glossary to the document.

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APPENDIX B

Final Charge to the Independent External Peer Review Panel
as
Developed by USACE and Submitted to the Panel on December 28, 2010

on the

Mouth of Columbia River IEPR

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CHARGE FOR PEER REVIEW

Members of this IEPR Panel are asked to determine whether the technical approach and scientific rationale presented in the Columbia River at the Mouth, Oregon and Washington Major Rehabilitation Evaluation Report are credible and whether the conclusions are valid. The Panel is asked to determine whether the technical work is adequate, competently performed, properly documented, satisfies established quality requirements, and yields scientifically credible conclusions. The Panel is being asked to provide feedback on the economic, engineering, environmental, geomorphology, and plan formulation. The panel members are not being asked whether they would have conducted the work in a similar manner.

Specific questions for the Panel (by report section or Appendix) are included in the general charge guidance, which is provided below.

General Charge Guidance

Please answer the scientific and technical questions listed below and conduct a broad overview of the Mouth of the Columbia River ER. Please focus on your areas of expertise and technical knowledge. Even though there are some sections with no questions associated with them, that does not mean that you cannot comment on them. Please feel free to make any relevant and appropriate comment on any of the sections and appendices you were asked to review. In addition, please note the following guidance. Note that the Panel will be asked to provide an overall statement related to 2 and 3 below per USACE guidance (EC 1165-2-209; Appendix D).

1. Your response to the charge questions should not be limited to a “yes” or “no.” Please provide complete answers to fully explain your response.
2. Assess the adequacy and acceptability of the economic and environmental assumptions and projections, project evaluation data, and any biological opinions of the project study.
3. Assess the adequacy and acceptability of the economic analyses, environmental analyses, engineering analyses, formulation of alternative plans, methods for integrating risk and uncertainty, and models used in evaluation of economic or environmental impacts of the proposed project.
4. If appropriate, offer opinions as to whether there are sufficient analyses upon which to base a recommendation.
5. Identify, explain, and comment upon assumptions that underlie all the analyses, as well as evaluate the soundness of models, surveys, investigations, and methods.
6. Evaluate whether the interpretations of analysis and the conclusions based on analysis are reasonable
7. Please focus the review on assumptions, data, methods, and models.

Please **do not** make recommendations on whether a particular alternative should be implemented, or whether you would have conducted the work in a similar manner. Also please **do not** comment on or make recommendations on policy issues and decision making.

Comments should be provided based on your professional judgment, **not** the legality of the document.

1. If desired, panel members can contact one another. However, panel members **should not** contact anyone who is or was involved in the project, prepared the subject documents, or was part of the USACE Independent Technical Review.
2. Please contact the Battelle Deputy Project Manager (Richard Uhler, uhlerr@battelle.org) or Project Manager (Karen Johnson-Young, johnson-youngk@battelle.org) for requests or additional information.
3. In case of media contact, notify the Battelle Project Manager immediately.
4. Your name will appear as one of the panel members in the peer review. Your comments will be included in the Final IEPR Report, but will remain anonymous.

Please submit your comments in electronic form to Richard Uhler, uhlerr@battelle.org, no later than January 31, 2011, 5 pm EST.

Independent External Peer Review
Columbia River at the Mouth, Oregon and Washington
Major Rehabilitation Evaluation Report

Final Charge Questions

GENERAL QUESTIONS

1. To what extent has it been shown that the project is technically sound, environmentally acceptable, and economically justified?

2. Are the assumptions that underlie the economic, engineering, and environmental analyses sound?

3. Are the economic, engineering, and environmental methods, models, and analyses used adequate and acceptable?

4. In general terms, are the planning methods sound?

5. Are the interpretations of analysis and conclusions based on the analysis reasonable?

MAIN REPORT

SECTION 1.0 -- INTRODUCTION

6. Is the project's purpose and scope complete and understandable?

7. What other information, if any, should be included in this section?

8. Has adequate public, stakeholder, and agency involvement occurred to determine all issues of interest and to ensure that the issues have been adequately addressed to the satisfaction of those interested parties?

9. Comment on the extent to which the existing conditions are clearly and adequately described.

10. Comment on whether the information presented supports the problem identified under the base condition.

SECTION 2.0 -- ECONOMIC CONSIDERATIONS

11. Has the base condition, without-project condition and summary of costs and benefits been adequately described, analyzed, and explained?

12. Does the National Economic Development (NED) Plan contrast to the base condition?

13. Is it clearly explained why navigation benefits were not analyzed?

SECTION 3.0 -- ENGINEERING CONSIDERATIONS

14. Is the description of functional and structural reliability clear and reasonable?

15. Was the Stochastic Risk-Based Life Cycle Simulation (SRB) model used in an appropriate manner? Is the description of how the model functions, the relative influence of model parameters and model calibration process clear and logical?

16. Comment on the repair and rehabilitation alternatives. Is the description of the different plans clear and distinct?

17. Comment on the engineering features for alternatives. Do the plan descriptions clearly indicate which features are incorporated into the various plans?

18. Comment on the evaluation of engineering features. Is the scope, function and analysis of the engineering features clearly described?

19. Comment on the general alternative development approach. Does the alternative evaluation presented follow USACE guidance?

20. Comment on the engineering evaluation of alternatives. Are the plans adequately evaluated based upon their engineering merit?

21. Has the sediment analysis been adequately performed and documented to support the movement of material that occurs during a breach event?

22. Has the analysis been adequately performed and documented to support reductions in channel maintenance dredging?

23. Does the analysis adopt adequate risk thresholds for different alternatives and are such thresholds uniformly consistent?

24. Are potential life safety issues accurately and adequately described under existing, future without project, and future with project conditions?

25. Has the rationale for head capping locations at each jetty been adequately explained?

26. Has the basis for the number and location of spur groins been adequately explained?

SECTION 4.0 -- ASSESSMENT OF ALTERNATIVES

27. Does plan selection reflect a full range of design alternatives?

28. Are the problems and opportunities appropriately defined and addressed in this study?

29. Are there any other constraints or objectives that should be considered as part of the project that would be important to reaching the projects final goals?

30. Do the alternatives adhere to the USACE Plan Formulation Criteria? Do they appropriately address the needs and objectives of the project? What additional information, if any, should be discussed?

31. Comment on the completeness of the project-specific criteria used in the comparison of alternatives.

32. Was the NED Plan appropriately identified and selected?

SECTION 5.0 -- ENVIRONMENTAL CONSIDERATIONS

33. Comment on the completeness of the environmental documentation. Have all National Environmental Policy Act (NEPA) requirements been satisfied?

34. Have the water resources in the project area been accurately described?

35. Comment on the thoroughness and accuracy of the marine and estuarine resource information presented.

36. Comment on the overall discussion of environmental effects due to the project.

37. Comment on the adequacy of available information used to characterize wetland resources within the study area.

38. Comment on whether the special status species and resource areas in the project area have been accurately described.

39. Comment on the adequacy of the environmental and without-project condition summaries in terms of data quality, timeliness of the data, and breadth of information covered.

SECTION 6.0 – CONSTRUCTION AND COST ESTIMATE

40. Comment on the overall adequacy and reasonableness of the detailed cost estimates.

41. Comment on the extent to which the cost summary is complete and consistent with the detailed analyses shown in this section.

42. Is the construction schedule adequate for completion of the recommended activities?

SECTION 7.0 – RECOMMENDATIONS

No questions.

SECTION 8.0 – REFERENCES

No questions.

APPENDICES

Appendix A1 – Coastal Engineering

43. Does Appendix A1 describe the coastal engineering history and challenges specific to the Mouth of the Columbia River?

44. Does Appendix A1 contain adequate information to assess coastal engineering at the Mouth of the Columbia River?

Appendix A2 – Reliability Analysis, Event Tree Formulation and Life-cycle Simulation

General Questions

45. Is the purpose of the model clearly defined?

46. Is the model diagram easily understood?

47. Does the model follow a logical programming path?

48. Does the model adequately capture and evaluate all of the relevant variables?

49. Can the model as described achieve the stated purpose?

50. Does the model accurately describe (model) repair activities and sequences? Is it modeling the repair activities similarly to how the repairs will be sequenced and performed?

Technical Quality

51. Comment on the overall technical quality of the model.

52. Is the model a realistic representation of the actual system?

53. Are the analytical requirements of the model properly identified?

54. Does the model address and properly incorporate the analytical requirements?

55. Are the assumptions clearly identified, valid, and do they support the analytical requirements?

56. Comment on the ability of the model to calculate benefits for total project life.

57. Has the design wave height of 55 feet been appropriately calculated and documented?

58. Have the waves generated by the model been validated against observed wave data?

Usability

59. Comment on the model's usability.

60. Are the model results easily understood?

61. Do the model results support the project objectives?

62. Is user documentation available and complete?

63. Is the model transparent and does it allow for easy verification of calculations and outputs?

Appendix B – Geotechnical Studies

64. Does the background information adequately describe the geologic history and conditions at the Mouth of the Columbia River and surrounding area?

65. Are all of the site specific and distinct geological features relevant to the project described and appropriately addressed in the engineering design?

66. Were risk and uncertainty sufficiently considered?

Appendix C – Economic Analysis

67. Comment on the assumptions and forecast methods used to calculate project benefits.

68. Comment on the reasonableness of the scenarios used to calculate benefits.

69. Comment on the method used to calculate the National Economic Development (NED) benefits.

70. Comment on the assumptions used in the calculation of present value of benefits.

71. Comment on the extent to which the NED benefits summary is consistent with and justified in the economic analysis.

Appendix D – Environmental Documentation

72. Comment on the ability of the proposed mitigation plans to address adverse impacts from the project.

73. Are the conclusions regarding the type and projected magnitude of adverse impacts to resources within the study area reasonable?

74. Comment on the appropriateness and comprehensiveness of the identified mitigation projects considered for addressing predicted impacts arising from the project.

Appendix E – M-CACES Cost Estimate for Recommended Plan

75. Comment on the overall adequacy and reasonableness of the detailed cost estimates.

76. Discuss the appropriateness of the explicit or implicit assumptions that are included in the cost estimates and whether assumptions are adequately addressed.

77. Comment on the extent to which the cost summary is complete and consistent with the detailed analyses provided in the study report.

Appendix F – Project Management Plan

No questions.

Appendix G – Schedule of Fully Funded Project Costs

No questions.

FINAL OVERVIEW QUESTION

78. What is the most important concern you have with the document or its appendices that was not covered in your answers to the questions above?

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October 4, 2011

U.S. Army Corps of Engineers, Portland District
Attn: Mark Brodesser
PO Box 2946
Portland, OR 97208-2946

Subj: Review and Recommendations for Life-Cycle Simulation Model for the Jetties at the Mouth of the Columbia River, Oregon and Washington
Contract No. W912PL-08-D-0016; Task Order No. DT03

Dear Mr. Brodesser:

The purpose of this letter is to provide the results of an assessment of the Stochastic Reliability Based lifecycle simulation model (SRB) which evaluates maintenance strategies for the rubble mound jetties located at the Mouth of the Columbia River (MCR). Moffatt & Nichol (M&N) is under contract with the U.S. Army Corps of Engineers (USACE), Portland District, to prepare this review and provide recommendations for proceeding towards meeting the requirements of an approved planning model as defined by *EC 1105-2-412 - Assuring Quality of Planning Models*.

BACKGROUND

The SRB model is a computer simulation MATLAB® code that stochastically evaluates the environmental loading affecting each of the MCR jetties, and relates structural response (cross-section evolution) of each jetty to functional performance. The structure response is evaluated in terms of cross-section area change (loss) over time due to jetty degradation. Jetty repairs are activated within the SRB model after the jetty cross-section is reduced below a specified threshold value. Jetty repairs are calculated in terms of the tonnage of armor stone required to re-establish the jetty cross section to its standard dimensions. Life-cycle costs estimated by the SRB model include jetty repair and incremental dredging attributed to jetty degradation and loss of function. Because life-cycle costs are estimated using stochastic methods, their realization can be considered probabilistic. Although reliability is also calculated within the SRB model, reliability is not used to simulate structure response and related consequences (life-cycle cost). Reliability is modeled as a function of repair and maintenance, and is used as a supplemental metric to inform on overall jetty performance.

As part of the USACE review process, the model underwent an Independent External Peer Review (IEPR) and was subject to Headquarters (HQUSACE) review for approval of use. The IEPR panel had four highly critical comments regarding the SRB model; subsequently, the panel did not approve the model for one-time use.

The M&N approach towards assessing the model is based on a tiered approach as follows:

- Assessment of the critical IEPR comments for possible resolution;
- Review overall modeling approach to verify inclusion of all critical mechanisms;
- Review formulation of the critical mechanisms;
- Review model documentation for adequacy in describing mechanism formulations;
- Review implementation of the mechanism formulation in the MATLAB® code;
- Review calibration/validation of processes incorporated in the model; and
- Preliminary review of MATLAB® code for efficiency and transparency.

This evaluation focuses solely on the model approach for the North Jetty as it is assumed the overall approach will be similar for the South Jetty and Jetty A. Also, there has been some modification of the North Jetty model to address ATR Comments so it presumably represents the latest and best formulation.

The results of our assessment of the model and our conclusions and recommendations are described in the following sections of this letter. The evaluation of the IEPR comments is discussed first since appropriate resolution of these comments is critical for model approval. The remainder of the report deals with the assessments of the overall approach, the MATLAB® code, and the model documentation. The conclusions and recommendations are in the last section.

EVALUATION OF IEPR COMMENTS

There are four significant comments from the IEPR that require resolution if the model is to be accepted as an authorized planning model. Each of these comments is addressed in this section.

Comment # 2: The analysis of the sediment transport process is not comprehensive, and the data and analysis do not support the conclusions concerning large movement of sediment during a breach event.

This comment addresses the sediment transport into the navigation channel as a result of a breach in the Jetties. The breakwater has breached in the past which has allowed sediment transport into the navigation channels, but the quantities and mechanisms have not been well documented. The disagreement between the Coastal Modeling System (CMS) Model Study is also of concern, although clearly the CMS model evaluation utilized a time scale inconsistent with the actual processes. The CMS model simulated the breach over a period of 6.5 days whereas the time frame for the observed shoaling related to the breach occurrence was on the order of months. This time frame difference would explain the difference in shoaling magnitude.

The recommendation from the IEPR that a more thorough investigation of the shoaling processes be incorporated is likely inconsistent with the time frame for the model implementation. After evaluation of the costs associated with the breach occurrences, a more appropriate approach may be to incorporate the emergency repair to the Jetty and disregard the dredging costs associated with the breach. This approach would satisfy the bulk of the IEPR comment. If the breach is considered in a planning scenario, some reasonable cost could be incorporated in the planning outside of the model framework.

Comment # 4: The SRB model by itself has very limited value for analyzing alternatives and is not a substitute for conventional economic and engineering analysis.

This IEPR comment is a blanket statement which leaves very little room for a response. However, it appears that there is a clear misunderstanding about what the model does and how it performs. The primary response to this comment would be to provide more transparency in the model formulations and how these formulations are appropriate for the MCR jetties. The formulations need to be validated to illustrate confidence in the predictive capability of the model based on historical jetty maintenance experiences.

It should also be emphasized that the model should be considered as a comparison tool and that it does not make the final decision. The IEPR review seemed to believe the model concluded with a decision which is incorrect. Engineering and economic judgment is still required once the model evaluation of alternatives is completed.

The portion of the comment related to armor rock breakage and slip circle failure is beyond the scope of the model and the comment should be considered invalid. The model is based on the assumption that the bulk of the damage is related to coastal processes and that these processes are included in the model with additional damage sources accounted for in the selection of the damage function calibration factor. This comment can also be addressed similar to the response to Comment #8 below.

Comment # 7: The basis of design and design environmental criteria are vague, not consistent within the report, and not consistent with conventional coastal engineering design practice.

The resolution to this comment is to clarify that the model is for a 50-year planning horizon and that all design criteria should be based on 100-year return interval. All other references to various 50-year periods should be clarified within the documentation.

Comment # 8: The models and analyses of jetty failure do not include all significant processes.

This comment suggests that additional geotechnical data should be gathered in the vicinity of the jetties, specifically boring data. Based on discussions with the Portland District personnel, we understand the generally feeling that there is adequate geotechnical data for the design of the jetties. This comment is best addressed by documenting and explaining the extent of the geotechnical data that has been assembled for past maintenance efforts. It can also be pointed out that the predominant processes impacting the stability of the jetties is related to the coastal processes more than geotechnical issues based on historical experience with the jetties.

To a great extent, the soil properties related to scour are addressed in the model based on calibration against historical observations and this implicitly considers this facet of the geotechnical factors.

ASSESSMENT OF MODEL APPROACH

Model approach was reviewed with a general purpose to identify fundamental issues and discrepancies in the model. The main comments are provided below.

1. The model calculations and most of governing input parameters were defined with a hard coded jetty segment size of 100 ft. It is understood, that the segment length was selected as a typical length of repairs and damage. Greater flexibility in the model application and calibration could be achieved if the internal segment size for calculations is made adjustable.

2. The present approach defines one year as overall time step in the model and calculates damage to each segment cumulatively based on the number of storms in each year. It would be more logically correct to iterate over a sequence of storms in each year and then calculate damage to the jetty segments in each storm. That would allow more flexibility to evaluate damage on any different time step and, if needed, on a storm-by-storm basis.

3. The number of storms is limited to 52 historically observed storms, for which measured storm parameters are applied. The selected set of storms represents the general population of storms in the area sufficiently well. However, use of preselected storms and water levels in Monte Carlo simulations may impose some limitation in the analysis. During the storms which have a potential to damage the jetties wave heights at the structures are limited by depth. Therefore, wave direction (which governs distribution of wave heights along the jetties) and more importantly water level are the main parameters which control the level of damage and distribution of damage along the structure. The model presently utilizes only three water levels for each storm, while more variability could be added to water levels in the MC simulations. Additionally, it would be advantageous to provide a guidance on how to define a set of synthetic storm conditions which represent the population of storms in the area where detailed observations of the storms is not available.

4. The wave parameters for segment damage function were extracted from STWAVE model output. It is expected that the wave parameters vary along each segment of the jetty and for every segment a single set of parameters (wave height, period, etc) was identified. A description of how to select these values from the STWAVE results would be beneficial.

5. Tidal currents, river floods and storms cause significant morphological changes around the jetties such as scour, channel migration, and shoal evolution. These changes were approximated in the model by historic trends. It would be advantageous to include the possibility to modify these trends as a part of “what if” alternative simulations. For example, what if scour at the toe of the North jetty expanded and resulted in additional damages.

6. The deterministic and random variables should be clearly defined in the model. The random variables are defined in the beginning of each MC simulation. The deterministic are either preset or calculated using formulas based on other variables.

7. Formulas for static (toe scour and slope failure) and dynamic (wave breaking and overtopping) effects on jetty damage needs to be verified. These formulas define the governing procedure of each jetty's response to a storm. Accuracy of these formulations is crucial. Most formulas from accepted procedures deal with prediction of damage to a breakwater from a single storm under the assumption that the breakwater keeps the initial profile shape. If the jetty sustains damage from one storm to another, the profile will adjust by stone displacements. Currently, the model accumulates damage from multiple storms in one year without considering adjustment of the structure between the storms. It is assumed that the second storm will have the same damage as the first one, which may lead to overestimation of the total damage.

8. The model utilizes a simplified parameterization of the cross-section profile of the jetty. The cross-section is divided at −5 ft MLLW into top and bottom layers. The top layer is affected by dynamic damage, and the bottom layer is affected by static damage. Since damage is calculated as loss of area, additional assumptions were applied to the slopes, top width and jetty height to match the remaining area. It is clear that the resulting profile is only an approximation of the actual damaged profile. A clear explanation of the process of profile adjustment would help in understanding how stone volumes in the top and bottom layers are calculated, as well as reused and lost stone.

9. Approximation of jetty damage from a storm is the key element of the entire model. The damage functions were defined from lab tests for selected conditions, such as normal profile, damaged profile, etc. They represent relationships between wave heights and lost cross-section areas as A = f(H). The damage functions were calibrated in the model by using shift in wave height as $A = f(H - H_{shift})$, which essentially moves the threshold when damage begins. It was identified that each damage function could have its own shift parameter, but only if that function was utilized in the calculations. It is possible that damage functions for a new configuration of the jetty may be slightly different, which make it difficult to select the appropriate shifts for forecast conditions under new alternatives.

10. Shoreline erosion/accretion is approximated in the model from the historic trend which is a reasonable approximation. Additional flexibility in the model could be achieved by allowing easy modifications to these trends or specifications of new ones based on the jetty repair alternatives. For example, if an alternative can cause acceleration in shoreline erosion/accretion. It is also very conservative to assume that <u>all</u> eroded sediments are transported into the navigation channel.

11. Two independent components, financial and structural, should not be combined into one MC simulation. It would be better to separate them into two MC analyses by making

structural components (storms, damages, and repairs) completely independent of financial components (price for repairs and dredging). This should answer the question—what if the storm sequence is the same, but the strategy on the repairs changes, would the jetty reliability be the same? Then results of these MC simulations can be recalculated with variable prices. This second simulation would tell if the prices change, will this affect an earlier decision about the repair strategy?

COMMENTS ABOUT MATLAB® CODE

The comments about the model code are given below.

1. The simulation folder contains many files of different types, including Excel spreadsheets, text files, and MATLAB® binary files. There is no distinct difference between the names of input and output files or perhaps folders to isolate input and output files in different locations.

2. The main input file is called *AA_XLS_new.mat*, where AA is the jetty name. The variables in this file were derived by a preprocessing script from Excel files. There are many variables in the file but no descriptions. Some references can be found by referencing the preprocessing script, but without MATLAB®, there is no easy way to modify the file or check the content.

3. The main model script is called *event_tree_NNN.m*, where NNN is name of the jetty and alternative. The file consists of more than 7300 lines. About 2000 lines are dedicated to plotting and output. This is a very large file to edit and navigate, considering the fact that most modifications to model control variables should be done in that file. Additionally, there are four subroutines which are stored in separate files. None of the scripts include online help or detailed description of the input/output parameters. Some subroutines have more than 20 input variables. The input/output and variable handling is not done in a structured manner.

4. Many variable names reflect the name of the jetty that the routine was developed for. This practice creates unnecessary difficulties for comparing between different versions of the code. For example, it would be difficult to compare codes between NJ and SJ to verify if the two routines work similar.

5. The routines create too many variables which are stored in the same workspace. Some structuring of the variables could potentially help in review of model results.

6. There are too many hard-coded coefficients in the scripts. Many of them are not placed in the same part of the code and are spread throughout the code. The hard-coded coefficients are mixed with process control parameters. This creates difficulties in identification of parameters which can be changed to modify the way MC simulations are performed.

7. There are many parameters which define particular events, for example, *Repair_Crest_el_1939* or *Crest_El_2006*. These variables probably have very little information for forecast mode. Therefore, it is clearly a question if hindcast and forecast modes can be separated into different subroutines, while forcing functions remain the same.

8. The alternatives are implemented within the same main code. The selection is done by setting a single variable *fut* in the beginning of the code. It is not transparent how additional alternatives can be added or existing ones modified. There are numerous IF statements, which seem to depend on the value of *fut*.

9. Some graphical output is created for a jetty segment selected before the MC simulation. There is probably a way to create plots for another segment without the need to rerun simulations, however it is not obvious. Graphical output could be completely separated from the main routine to allow more flexibility in creation of figures without the need to rerun a simulation. This is especially important, since MC simulations give stochastic (variable) results.

COMMENTS ABOUT DOCUMENTATION AND USER'S MANUAL

The *Model Documentation Report* provided a general description of the model background and principal algorithms. Sufficient details were given on the basic model organization, principles of operation, and main input and output. A part of the report named *Model Operation Guide* included some information on the calibration process, model setup, selection of alternatives (repair strategies), and model inputs and outputs. This part was found to be rather brief and in most cases only indicated general locations (a script name or data file) where modifications can be done to allow the user to change inputs into the model. Explanation of the model calibration was not complete. In particular, specific details about how the values of calibration parameters were used in the forecast mode were not included.

Most of input parameters (damage function, STWAVE model output, jetty configurations) were defined in a series of Excel files. However, most of the parameters in these files were self explanatory, and it would be difficult to make significant changes to the model inputs without modifications to the main code of the model. For example, the damage functions were defined by hard-coded variables with fixed sizes. Any changes to the damage function array size would require modification in the corresponding Excel file, preparation script, and the main code. A detailed description of how would be accomplished is not provided.

CONCLUSIONS AND RECOMMENDATIONS

Our overall recommendation is to retain the existing model and make improvements to satisfy planning model approval requirements. The basic premise of the model is sound and a great deal of effort has gone into formulating the important processes impacting the jetties and the maintenance procedures available for jetty repair.

The recommendation to retain the existing model is based on several considerations. The first consideration is the requirement to complete the evaluation of maintenance plan alternatives and recommend the most appropriate plan within the next few months. Several years have gone into the development of this model. Knowing that objectives for the model evolved over this time period, it should not take as long to develop a model from scratch. However, we do estimate that model development from scratch would require at least a year or two including model approval for use in the evaluation of planning alternatives. This time frame does not meet the requirements of the Portland District schedule.

The second consideration for retaining the existing model with improvements is the engineering cost associated with development from scratch. While we have not worked up a detailed cost estimate for a scope of this magnitude, the fee for M&N to do this work would likely be approximately $400,000. Portland District personnel as well as review personnel would also be participating in this project requiring additional engineering costs. Working with the existing model and making the recommended modifications will be significantly less, likely less than half of this budget.

Improvements are required to meet the requirements for an authorized planning model. Specifically, the following improvements should be implemented:

1. Modularize the model code using the existing approaches where they are appropriate. Specifically, separate parts of the code related to the following:

    - Setup of global variables
    - Setup of MC simulation
    - Specification of alternatives
    - Calculation of damage functions
    - Geometry adjustment after damage
    - Creation of output and plotting

2. Validate independent modules based on available literature and previous experience with the MCR jetties. Alternative formulations of the damage functions used in the model should be provided for comparison of model results with alternative published analytical formulations.

3. Calibration results for the model need to be clearly documented. To accomplish this, the calibration process and parameters must be clearly documented within the model and in the model output and reporting. Additional performance metrics can also be extracted from the model results and clearly presented. This will help improve the transparency of the model for those not directly involved with setting up and running the model.

4. During the process of modularizing the existing model, the structure should be changed to allow a single model code capable of evaluating alternatives for all three jetties.

5. Improvements are required in the user interface to allow the user to easily review all input and output parameters. Existing hard-coded parameters should be removed from the model code to provide greater transparency.

6. A well-documented user's manual needs to be prepared to allow qualified modelers to apply the model to evaluate alternatives. The majority of this effort would be improvements to the *Model Operation Guide*.

7. The economic and structural analyses should be separated into independent routines. The economic analysis calculations would be based on the output from structural simulations with an interface between the two models. This approach also permits the use of different economic analysis approaches for a single structural simulation.

8. Additional metrics for evaluating alternatives can be output from the model to assist in the economic evaluation of the alternatives. These include structural and functional reliabilities, stone volumes which were lost, placed, or moved, and others. A facility can be created to easily calculate and output new metrics as needed. These additional metrics will add to the transparency of the model results and go a long way towards gaining approval for the model as an authorized planning model.

9. The shoaling related to jetty breaching should be eliminated while the repair requirements to the jetty section should be retained for the breaching. This recommendation is based on IEPR comments suggesting that it will be difficult to get a professional consensus regarding the appropriate shoaling volume and distribution. As this shoaling volume is relatively small compared to the morphological changes related to jetty tip retreat, the impact to costs in the alternative analysis is relatively minor.

There are two additional issues which are fundamental to an appropriate modeling approach. The first issue is the morphological assessment within the model related to recession of the jetty tips. Decisions regarding future maintenance of the jetties needs to address whether the current location should be retained as the optimal location or whether the tips should be allowed to recede further. The current approach for morphological impacts as implemented within the model does not address this decision. A much more sophisticated morphological modeling approach is required to address this issue. However, given the available time to evaluate the jetty maintenance alternatives and the high likelihood that whatever approach is used will extend controversy of the model applicability, we do not recommend development of a more detailed morphological model at this point. However, this component could be included at a later date when scheduling or application requirements permit.

The second fundamental issue that should be addressed further is the damage functions currently used in the model. The damage functions are fundamental to the model results and therefore their application in the model should be accurate and transparent. An analysis should be performed in order to define the possibility of a clearer approximation for the damage functions derived from physical model results. The calibration process for the shift parameter in the damage functions will also be reviewed with an attempt to improve the calibration process. This task may or may not result in a better damage function specification or calibration parameter selection; however, it will become a part of code modulation and restructuring task and would permit comparison of alternative damage function approaches.

Given the recommended tasks above for model improvements and realizing that time is of the essence in getting the model approved for this application, we estimate that the work to accomplish these tasks would require approximately 3.5 months. If work begins immediately, the project would be completed by approximately mid-January 2012. This work would include getting approval for model use, simulating the currently identified maintenance alternatives, and assistance in preparing the alternatives assessment report.

It has been a pleasure to be involved with this challenging project. We hope to continue to be of assistance with moving this model forward and making it a useful tool for evaluating maintenance strategy alternatives. Please do not hesitate to contact me if you have any questions or concerns regarding our assessment of the model and the potential for application to the MCR jetty maintenance planning.

Sincerely,

MOFFATT & NICHOL

David H. Dykstra

David H. Dykstra
Project Scientist

STATEMENT OF WORK FOR
MODIFICATION No. 2

CONTRACT NO. W912PL-08-D-0016, MOFFATT & NICHOL
TASK ORDER NO. DT03, LIFE-CYCLE SIMULATION MODEL SUPPORT FOR THE JETTIES AT THE MOUTH OF THE COLUMBIA RIVER, OREGON AND WASHINGTON

1. BACKGROUND. During Phase 1 of the task order, the AE team assessed the current SRB model architecture, code, and documentation; the three outstanding IEPR comments and Assuring Quality of Planning Models (EC 1105-2-412), and made a recommendation on the most efficient approach to obtain model approval. The AE team was asked to provide details on how to achieve model approval and respond to open IEPR comments by either:

(1) Improve and revise existing model architecture and code;
or
(2) Start over with entirely new planning model

The AE team's recommendation is to improve and revise the existing model code. The team identified nine specific recommendations to improve the model. Those recommendations will be used as the first nine tasks for this modification. Additional tasks will be identified for technical writing, plan formulation and Report Editing.

2. OBJECTIVES. This modification of the task order is for phase II.

During Phase 2 the CENWP's product delivery team will work collaboratively with the AE team to develop the following:

- A fully documented model which has been validated and verified, with input and output files, and a user's manual – meeting the requirement of EC 1105-2-412.
- Clearly defined design criteria and basis for design.
- A range of alternatives leading to a least-cost plan.

The AE Team members under this task order shall possess the following skill sets:

- MATLAB programmer with 5 years experience.
- Senior coastal engineer with 20 years experience in the design of coastal structures.
- Economist with 10 years USACE plan formulation experience (Phase 2).

3. MANDATORY SERVICES TO BE PROVIDED.

a. <u>Task 1: Modularize the model code</u> The model code architecture will be modified utilizing the existing modeling approaches where they are appropriate, and separating the parts of the code related to the following:

- Setup of global variables

- Setup of Monte Carlo simulation
- Specification of alternatives
- Calculation of damage functions
- Geometry adjustment after damage
- Creation of output and plotting

b. Task 2: Validate Independent modules The independent modules that are established in Task 1 will be validated for functionality and accuracy utilizing available literature and previous experience with the MCR jetties. Alternative formulations of the damage function used in the model will be developed by the AE team for comparison of model results with alternative published analytical formulations.

c. Task 3: Document Calibration Results The AE team will calibrate the revised model clearly documenting the calibration process and the parameters used in the model and in the model output and reporting. Additional performance metrics will also be extracted from the model results and clearly presented when feasible. The goal of documenting the calibration process and parameters used is to provide transparency of the model functions for reviewers not directly involved with setting up and running the model.

d. Task 4: Develop Single Model Code for all Three Jetties During the process of modularizing the existing model code, the structure will be changed to allow a single model code capable of evaluating all three jetties.

e. Task 5: Improve User Interface. Develop a user interface that will permit the user to easily review all input and output parameters. Existing hard-coded parameters will be removed from within the model code to provide greater transparency of how individual parameters affect model output.

f. Task 6: Prepare Users Manual. A well documented user's manual will be prepared in order to allow qualified modelers to apply the model to evaluate alternatives. The majority of this effort will be improvements to the existing Model Operation Guide.

g. Task 7: Separate the Economic and Structural Analysis. The economic and structural analysis will be separated into two independent routines. The economic analysis calculations will be based on the output from the structural simulations with an interface between the two models. This approach will permit the use of different economic analysis approaches for a single structural simulation.

h. Task 8: Provide the Capacity to Output Additional Metrics from Model. Create a facility to calculate and output additional metrics as needed. New metrics may include structural and functional reliability, stone volumes which were lost, placed or moved and others not yet identified. Additional metrics will be used to enhance the transparency of the model results with the intent of facilitating model approval.

i. Task 9: Remove Breach Shoaling. The in-channel shoaling volumes and required additional dredging will be removed from within the model. Retain the damage repair requirements to the jetty section and track as a breach in order to distinguish from a repair volume related to general damage. Tracking the damage as a breach will enable the model to indicate at what point a breach is probable and it will help inform maintenance strategy and repair cost.

j. Task 10: Utilize Improved Model. Assist USACE Product Development Team with the evaluation of alternatives utilizing the improved SRB model. The alternatives should remain the same or similar to the previously used alternatives, however, the base condition will require to be altered to represent the changed site conditions that will occur as a result of the North Jetty Major Maintenance Report (NJ MMR) that was written after the MCR Major Rehabilitation Report and has been submitted for the FY 2012 budget. Provide an economist that will assist the USACE PDT with plan formulation, evaluation of the alternatives and performing the economic analysis.

k. Task 11: Incorporate New Data and Streamline Report. Assist USACE Project Development team with the incorporation of results from the new model runs into the existing Major Rehabilitation Report. During and prior to the process of incorporating the new model data the AE team will review the report and with PDT concurrence make modifications that increase the readability of the report. The goal of the modifications shall be to retain the existing information while shaping the report into a more concise document.

4. MANDATORY SUBMITTALS TO BE PROVIDED. Under this modification, the Contractor shall provide the following:

> **a. Submittal 1 Model code and Documentation** user's manual, revised A1 and A2 appendices reflecting model code changes and validation and verification files.
>
> **b. Submittal 2 Revised Major Rehab Report.** Provide the text and technical writing services to revise the existing Major Rehabilitation report as follows; describe the basis of design and engineering criteria used for plan formulation incorporating modifications to the alternatives, justification for head-capping and spur groin locations and selection of alternative.

5. SCHEDULE. All services required under this task order modification shall be completed no later than 20 January 2012. It is anticipated that the Notice to Proceed (NTP) for this modification will be issued by Oct 14, 2011.

6. ONLY WHEN AUTHORIZED (OWA) SERVICES. The following OWA tasks will be negotiated and funded at time of award. The Contractor shall not perform any OWA services without specific written direction from the Contracting Officer's Representative.

a. <u>Additional Meetings</u>. Establish two (2) units of additional OWA meetings. Each unit shall be for three (3) people for two (2) days. Costs shall include travel and per-diem to Portland, Oregon.

DEPARTMENT OF THE ARMY
CORPS OF ENGINEERS, PORTLAND DISTRICT
PO BOX 2946
PORTLAND OR 97208-2946

REPLY TO
ATTENTION OF

AUG 07 2009

Planning, Programs and Project
Management Division

Bernard Moseby
National Deep Draft Navigation Planning Center of Expertise
Mobile District, USACE
PO Box 2288
Mobile, AL 36628-0001

Dear Mr. Moseby:

The purpose of this letter is to inform you that Portland District is submitting to the National Deep Draft Navigation Planning Center of Expertise (DDNPCX) a reliability model of the jetty system at the Mouth of the Columbia River (MCR). Portland District requests that the Center conduct the approval process of this model per EC1105-2-407.

This computer model is to be used in the Major Rehabilitation Study of the jetties at the Mouth of the Columbia River (MCR). The model is written in Matlab and is actually three separate models, one for each of the jetties there; North Jetty, South Jetty, and Jetty "A". The model and supporting files have been placed on the USACE public FTP location: ftp://ftp.usace.army.mil/pub/nwp/MCR_SRB_review/

These files will be available for ten days on the FTP site. The files will need to be re-posted if you do not download them within this timeframe.

NWP Points of Contact are as follows:

Rod Moritz 503-808-4864, Technical expert;
Jason Magalen, 503-808-4832, Technical assistant;
Tom Hackett, 503-808-4769, Planning POC;
Brian Shenk, 503-808-4221, Economics POC.

Because of the size and complexity of the model, we are recommending that the model reviewer or reviewers communicate periodically with key NWP personnel during the review process. We would like to work with you once the review team is developed to establish an appropriate way to check in on comments, and maintain the review schedule. If you would like, we are available to conduct a kick off meeting with the review team to introduce and explain the model.

Please provide the reviewers names, and the review and approval schedule. Tom Hackett of my staff is managing the review process for the District and he will be in contact with you during the review period. You may contact him at (503) 808-4769 or email at thomas.w.hackett@usace.army.mil.

Sincerely,

for Christine McBurden

Laura Hicks
Chief, Project Management & Planning Branch

CENAE-EP-HG 24 August 2010

MEMORANDUM FOR: Mr. Bernard E. Moseby, CESAM-PD-FE, Chief, Economic Analysis and Deputy Director, Deep Draft Navigation Planning Center of Expertise

SUBJECT: Review and Certification Letter for the Mouth of the Columbia River (MCR) Stochastic Reliability Based (SRB) Lifecycle Model for the MCR Major Rehabilitation Report

The following is the background information on the review process for the certification of the MCR SRB Lifecycle Model:

1. In October 2009, a request was made by the NWP PM to the ATR team leader to assist in obtaining model certification of the Mouth of the Columbia (MCR) Stochastic Reliability Based (SRB) model. This process was conducted using current USACE planning guidance and coordinated through the Deep Draft Navigation PCX to request from USACE Headquarters an "approved for use" status of the MCR SRB model.

2. A technical review of the MCR SRB model was initiated in November 2009 and has continued to date utilizing both part of the ATR team (Mr. Robert C. Patev, Team Leader and Mr. Wally Brassfield, ATR cost team member) and Mr. John Winkelman, a Coastal Regional Technical Specialist (RTS), from North Atlantic Division (NAD). Since the MCR SRB model was developed using the MATLAB language/software, Mr. Winkelman was an important part of this team due to his knowledge of the software, his technical position as a coastal engineer/planner Regional Technical Specialist with the HSDR PCX, and his past work experience in SPD on West Coast coastal navigation projects.

3. The review was begun in November 2009 by Mr. Patev and Mr. Winkelman and included a visit to CENAE by Mr. Hans Moritz, who is the developer of the MCR SRB model. The meeting lasted approximately two days and included a detailed presentation of the model code, model development assumptions, variable and model input descriptions, a discussion of the model output, and a lengthy discussion of model philosophy. Questions or comments generated prior to and during the meeting were documented and addressed as part of the Dr. Checks review process. Twenty three comments were generated and submitted into Dr. Checks in January 2010. Questions and comments were related to model coding, model variables and model constant value selection, model assumptions, and limited coastal engineering issues. Each issue and question was answered and/or addressed satisfactorily.

4. Following this meeting and installation of the MCR SRB MATLAB code at NAE, a number of variables and their ranges were defined to investigate model performance, sensitivity, and stability of the code. This was performed in terms of engineering reliability aspects of the program only. During this phase of the review, Mr. Moritz provided the review team with a list of key variables and constants within the code for validation. Many of these variables were discussed further during a number of

email/phone exchanges during this phase. After these communications and detailed examination of the code, the values selected in the model for engineering parameters were determined to be reasonable and based upon a sound engineering decision process. When these values were changed in the model, noticeable changes to the model output were recognized, but the model did not produce any unreasonable results in terms of engineering reliability.

5. The values for costs included in the MCR SRB model were reviewed and modified by Mr. Brassfield in July 2010. However, the validation of the methods and mathematical calculation for the estimation of the economic consequences produced by the model has not been reviewed by any team member since this was outside of their areas of expertise.

The following limitations, review assumptions and technical recommendations were drawn by the review team during their review:

1. With a model of this size and complexity it is difficult to determine if all of the code is error proof or if the model is providing the exact correct answer. However, based on the review, as described, the model, from a coastal analysis/performance stand point does appear to be reasonable and is a reasonable tool for determining the future, relative performance of various maintenance schemes for the MCR jetties discussed in the MRR. As with any model of this complexity, and for a system of this complexity, the precise numbers and resulting values are likely not absolutely correct but instead are reasonable and relatively correct between alternatives.

2. This model and code has only been reviewed as to what was included in the code installed at NAE in 2009. This review was limited only to the aspects of the engineering reliability and not the actual consequence determination in the program. The cost inputs have been reviewed by the ATR cost team member but the application of the economics to the outputs has not been validated as part of this review. In addition, any additional changes or modifications of the code should be reviewed by the ATR team to determine the validation of those modifications to the code and the replication of the results with previous versions of the code.

3. The MCR SRB model was developed to perform an integrated analysis of both engineering reliability and consequence assessment. Typically, major rehabilitation models are developed separately into stand alone models for engineering reliability and economic consequences. If the schedule permits, I would strongly recommend that the SRB process and results be validated with a simpler model using hazard functions from the SRB reliability curves and the development of consequences using a traditional economic simulation model.

4. During the Independent External Peer Review (IEPR), it is important to provide the additional documentation and explanations discussed in my previous comments. Also, the face to face meeting for explaining the model is essential due to the complexity of the model. This is a model that is trying to meet a difficult USACE planning objective that covers an immensely complicated coastal engineering project and forecasts an uncertain

future. It should also be made clear what the purpose of the model is, and that this is a project specific model that has been developed, honed, and calibrated for this specific project area. The numerous factors and variables, etc. within this model, to a great extent, are project specific and are not to be used in a generalized model for other USACE projects.

5. Based on the information presented above, I recommend that the MCR SRB lifecycle model be certified as is and a request be sent to USACE Headquarters as "approved for use" for the MCR Major Rehabilitation Report only.

If there are any questions regarding this memorandum, please do not hesitate to contact me at your earliest convenience.

Robert C. Patev
ATR Team Leader
NAD Navigation RTS

CESAM-PD-FE

18 January 2011

MEMORANDUM FOR COMMANDER, South Atlantic Division, ATTN: WILBERT V. PAYNES, (CESAD-PDS-P)

SUBJECT: Model Certification – Approval for Use, Columbia River at the Mouth, Oregon and Washington, Major Rehabilitation of the Jetty System at the Mouth of the Columbia River, Stochastic Reliability-Based (SRB) Model

1. References:

a. EC 1165-2-209, Civil Works Review Policy, 31 January 2010

b. EC 1105-2-412, "Assuring Quality of Planning Models" dated 20 July 2009,

c. EC 1105-2-407, "Planning Models Improvement Program: Model Certification" dated 31 May 2005.

d. Memorandum, CECW-CP, 30 March 2007, Subject: Peer Review Process

e. Supplemental information for the "Peer Review Process" Memo, dated March 2007

2. In accordance with EC 1165-2-209, "Civil Works Review Policy" Model Certification – Approval for Use, the Major rehabilitation of the Jetty System at the Mouth of the Columbia River, Stochastic Reliability-Based (SRB) Model, has been coordinated with and executed through the Deep Draft Navigation Planning Center of Expertise (DDN-PCX).

3. The review was a Level I review - for highly complex models used in decision-making where there could be a high risk of making an incorrect investment decision.

4. The review was performed by Robert C. Patev, CENAE-EP-WG, Team Leader and John Winkelman, CENAE-EP-WM, New England District, Corps of Engineers. The Model Assessment Criteria documentation that supports a recommendation of 'Approval for Use' for the SRB Model is enclosed. The Deep Draft Center is requesting coordination of the enclosed certification package through the Planning CoP Leader for processing, review and recommendation.

4. The Deep Draft Navigation Planning Center of Expertise (DDN-PCX) point of contact is Bernard Moseby, CESAM-PD-FE, (251)-694-3884.

FOR THE COMMANDER:

Encls

BERNARD E. MOSEBY
Technical Director, DDN-PCX

Model Approval Plan
(Supplemental)

Stochastic Reliability Based
MATLAB model
MCR jetties

Mouth of the Columbia River
Major Rehabilitation Report

CENWP

1. Purpose

The purpose of this Model Approval Plan is to outline the review process and requirements necessary to assure the quality of the Stochastic Reliability Based MATLAB model for the MCR jetties (SRB), as submitted from the CENWP to the DDPCX in support of the Approval for Single Use of the model in the Mouth of the Columbia River, Major Rehabilitation Report (MCR MRR). This review plan is based on the requirements contained in *EC 1105-2-412 Assuring Quality of Planning Models* and the *Standard Operating Procedures for the Processing of Planning Model Certification/Approval Actions,* which complements Engineering Circular 1105-2-412 (EC) and provides a guideline for implementation of the EC. The MCR SRB model has been in development since 2005, significantly pre-dating the EC, therefore the model is in the latter stages of the review/approval process. This plan is intended to capture what has already been done and describe how the PDT intends to complete the model approval process.

2. Reference and Guidance

2.1. Engineering Circular 1105-2-412, Assuring Quality of Planning Models, 31 March 2011.
2.2. Budget Engineer Circular (EC) 11-2-199, dated 31 March 10
2.3. Standard Operating Procedures for the Processing of Planning Model Certification/Approval Actions dated 16 November 2010

3. Background

Stochastic Reliability Based (SRB) model developed for the Mouth of the Columbia River (MCR) evaluates the expected reliability of different alternative cross-sections of the three existing jetties. The wave climate and damage function currently used in the model are specific to the MCR. EC 1105-2-412, Assuring Quality of Planning Models makes a distinction between model certification and model approval based upon the origin of the model and the extent of the model's intended use; Section 5. c stipulates that models that have been developed by the corps (or outside entities) and are viewed by the vertical team as single-use or study specific models require model approval. Models which will be used over a wider range of conditions and locations require certification. At this time the PDT recommends that the MCR SRB model be considered a Regional/Local Model as defined EC 1105-2-412 section 5. a. (2) and that it be reviewed for approval, not certification due to it being specific to the MCR jetties in its current form.

The MCR SRB model has been developed over several years and has been subjected to an Agency Technical Review (ATR). After incorporating comments the model was reviewed during the Independent Engineering Peer Review (IEPR) of the MCR Major Rehab Study (Attachment 1). The MCR SRB model has not received approval for use from HQUSACE and two IEPR comments that were specific to the model have not been resolved. In order to address the IEPR team's unresolved comments CENWP solicited the assistance of the firm Moffat and Nichol via a two phase task order to review the model, associated documentation and engineering regulations and identify specific changes that need to be made in the model code and assist CENWP in making those changes. Phase I of the task order produced a letter report (Attachment 2) that evaluates the functionality of the MCR SRB model and identified nine specific improvements to the model code that address the outstanding concerns regarding the model. All nine of the recommendations were adopted by the PDT and two additional tasks related to including the updated model and the results into the MCR Major Rehabilitation Report (MRR) were incorporated into the task order modification for phase II (Attachment 3).

3.1 Previous Reviews

A review plan for the MCR Major Rehabilitation Report was last revised in September 2010 and submitted to the DDPCX for consideration. The review plan described the series of reviews for the different elements required for the report.
This Review Plan (RP) outlined the reviews as required by EC 1105-2-410. The RP supplements the Project Management Plan (PMP) and identified three levels of peer review: District Quality Control (DQC), Agency Technical Review (ATR), and Independent External Peer Review (IEPR) based on the scale, impacts, and cost of this project.
All decision documents and their supporting analyses have undergone DQC, ATR and IEPR, to "ensure the quality and credibility of the government's scientific information", in accordance with EC 1105-2-410 and the quality management procedures of the responsible command. The Circular addresses review of the decision document as it pertains to both approaches and planning coordination with the appropriate Center. The Circular also requires that DrChecks be used to document all ATR and IEPR comments, responses, and associated resolutions accomplished. These requirements have been met for the multiple components of the MCR MRR and the comments and responses are attached to this model review plan for consideration.

The types of technical reviews that were conducted are provided below.

3.1 a District Quality Control (DQC).

DQC is the review of basic science and engineering work products focused on fulfilling the project quality requirements defined in the Program Management Plan (PMP). It was managed in the home district and may be conducted by staff in the home district as long as they are not doing the work involved in the study, including contracted work that is being reviewed. Basic quality control tools include a Quality Management Plan providing for seamless review, quality checks and reviews, supervisory reviews, Project Delivery Team (PDT) reviews, etc. Additionally, the PDT is responsible for a complete reading of the report to assure the overall integrity of the report, technical appendices and the recommendations before approval by the District Commander. It is expected that the MSC/District quality management plans address the conduct and documentation of this fundamental level of review. DQC is not covered by this Review Plan. The MCR MRR was assigned a separate DQC review team to present an unbiased opinion of the technical merits of the report. The DQC team was led by the Deputy Chief of Engineering and Construction and the review resulted in XXXX comments and responses which had a dramatic improvement on the report.

3.1 b Agency Technical Review (ATR).

ATR (which replaces the level of review formerly known as Independent Technical Review) was an in-depth review, managed within USACE, and conducted by a qualified team outside of the home district that was not involved in the day-to-day production of a project/product. The purpose of this review was to ensure the proper application of clearly established criteria, regulations, laws, codes, principles and professional practices. The ATR team reviewed the various work products and assures that all the parts fit together in a coherent whole. The ATR team was comprised of senior USACE personnel, the ATR team roster is attached. To assure independence, the leader of the ATR team was chosen from outside the home MSC.

3.1 c Independent External Peer Review (IEPR).

This is the most independent level of review, and is applied in cases that meet certain criteria where the risk and magnitude of the proposed project are such that a critical examination by a qualified team outside of USACE is warranted. The criteria for application of IEPR include, but are not limited to (1) the total project cost exceeds $45 million; (2) there is a significant threat to human life; (3) it is requested by a State Governor of an affected state; (4) it is requested by the head of a Federal or state agency charged with reviewing the project if he/she determines the project is likely to have a significant adverse impact on resources under the jurisdiction of his/her agency after implementation of proposed mitigation (the Chief has the discretion to add IEPR under this circumstance); (5) there is significant public dispute regarding the size, nature, effects of the project; (6) there is significant public dispute regarding the economic or environmental cost or benefit of the project; (7) cases where information is based on novel methods, presents complex challenges for interpretation, contains precedent-setting methods or models, or presents conclusions that are likely to change prevailing practices; or (8) any other circumstance where the Chief of Engineers determines IEPR is warranted. IEPR may be appropriate for feasibility studies; reevaluation studies; reports or project studies requiring a Chiefs Report, authorization by Congress, or an EIS; and large programmatic efforts and their component projects. It was determined that MCR MRR warranted an IEPR. The IEPR was managed by Bechtel, an eligible outside organization. The scope of review addressed all the underlying planning, engineering, including safety assurance, economics, and environmental analyses performed, not just one aspect of the project. A review of the attached charge questions given to the IEPR team indicates that the MATLAB model received a comprehensive review by qualified programmers and ocean engineers. The IEPR charge questions and comments and responses are attached. Three of the IEPR comments resulted in comments and responses dialogues where the IEPR team and the PDT were unable to reach concurrence.

3.2 Post IEPR Activity

In an effort to resolve the non-concur items identified in the IEPR, CENWP engaged the services of Moffatt & Nichol and together with the PDT has outlined a path forward to resolve the open IEPR comments by improving the model code, allowing for the transparency, compliance with current technology and corps policy, documentation, practicality with data inputs and outputs and clearly identifying the use and limitations of the model consistent with EC 1105-2-412. Following is a list of the steps contained in EC 1105-2-412 and the actions that the PDT has either taken or propose to take to satisfy those steps:

Step 1: Proponent Identifies model to be used for a national, regional or local application and PCX determines the need for certification or approval.

Response: The proponent is CENWP, and we have identified the model as Regional/Local model developed by USACE with assistance from a non-corps entity (Moffat & Nichol) as a study specific model, therefore the PDT believes model approval not certification is required.

Step 2: Proponent submits model and documentation to the appropriate PCX.

Response: PDT has forwarded the model code, ATR and IEPR comments to the DDPCX. DDPCX determined that the model was not approvable via memo indicating that the PDT should resolve outstanding IEPR comments prior to approval. PDT has engaged an expert modeling team from a qualified AE firm. Updated model and documentation will be sent to DDPCX for review and approval.

Step 3: PCX determines appropriate level of review utilizing the criteria outlined in EC. PCX has final approval on level of review.

Response: The MCR SRB model development predates the EC, so a formal review level was never assigned. It is assumed by the PDT that the model will require a level 1 or level 2 review.

Step 4: PCX establishes a review team, team leader and defines the anticipated charge scope of review. The review charge and scope should guide the product reviewers and direct them to key issues, assumptions, routines and aspects for review. A team selected from the roster of qualified reviewers maintained by the appropriate PCX, including external and internal reviewers, will conduct Level 1 and Level 2 reviews. Level 3 and Level 4 reviews may be conducted by Corps internal experts, but the review team, as deemed appropriate by the PCX, could include external individuals as well. Protocol and procedures for the model review process will be specified in the PCX standard operating procedures (SOP) and will reflect prevailing industry practices.

Response: The MCR PDT worked with the PCX (if it wasn't DDPCX then list who please) to conduct the model ATR and the overall MCR Major Rehabilitation Report (MCR MRR) IEPR, which included an extensive number of PCX recommended questions regarding the model, modeling process and interpretation of the results into the MCR MRR. The results of both reviews have been received by the DDPCX. Outstanding comments from the IEPR are being resolved as previously described and it is the belief of the PDT that the resolution of the comments shall conclude the review process and provide the DDPCX with the information and documentation required to render approval.

Step 5: The PCX develops a certification plan to include to include the information from steps 1-4, defining the scope of the review. The certification plan (and accompanying model documentation materials) is submitted to CECW-P for approval. Written approval from CECW-P must be received by the PCX prior to proceeding with the certification review.

Response: The MCR PDT has been pursuing an overall Major Rehabilitation Report approval process, of which the model approval is a component. The MCR PDT engaged the vertical team as well as the relevant PCX(s) to develop a review and approval plan early in the development stages of the project. The review plan included DQC, ATR (model specific and report) prior to conducting an IEPR. The PDT would like the DDPCX to give consideration to the previously conducted reviews, the changes generated from the reviews and the future actions described in this plan. If there are additional steps required that has not been completed or proposed in this plan please identify and the PDT will include them prior to submission for approval.

Step 6: Once the PCX has received approval to proceed, the PCX will hold an initial meeting to begin the certification process to assure that all participants understand the nature of the effort, as well as to discuss any particular technical or administrative issues that will be important in the review. The meeting (which can be held by teleconference) will include representatives of the PCX, the model proponent and the review team. CECW-P will be notified of the meeting and invited to attend.

Response: The goal of the project's proponent, CENWP, is to complete the revised MCR MRR in time for submission in the FY 14 budget request. In order to accomplish this goal the PDT requests that the PCX forward the review plan to CECW-P as soon as possible and schedule the teleconference to assure that the actions proposed by the PDT are consistent with the requirements for model approval.

Step 7: In fulfilling it's role, the review team will provide to the PCX a consolidated documentation of review comments and recommendations. The review should adhere to the review charge and scope provided by the PCX. The PCX will strive for consensus, but one or more reviewers may not concur with the views of the majority. Matters of disagreement should be addressed forthrightly in the report. As a final recourse, a reviewer may choose to prepare a brief dissent describing the issues of contention and arguments in support of the minority view. To encourage reviewers to express their views freely, the review comments are treated as panel responses and are given to proponents with identifiers removed.

Response: This process was conducted during the rigorous IEPR conducted from November 2010 through March 2011. The review team was comprised of external experts and the review was conducted according to the process described in EC 1165-2-209 and supplemental implementation guidance. The charge questions were developed with the assistance of the PCX and are attached to this plan as appendix D. A review of the charge questions will demonstrate that the IEPR team was directed to review the model carefully and render a professional opinion on the quality and to make recommendations on how to overcome deficiencies noted. The PDT is currently pursuing their recommendations.

Step 8: Review comments are provided to the PCX within 90 days after submittal of the model for review to the review team. (Ninety days is the estimated maximum time for review of models in level 1. For models in other categories, the review time will be adjusted accordingly, and is expected to be less than 90 days.) The PCX then assesses whether the review team fulfilled the charge and scope provided. When the PCX determines that the review charge and scope have been met, the comments are provided to the proponent for review and response, and a checkpoint meeting is scheduled to discuss the review comments and issues for response. The checkpoint meeting will be held with the same parties as the initial meeting in Step 6, above.

Response: The IEPR process is in the final stage, resolution of outstanding comments. The charge questions provided and agreed upon by PCX and PDT were the basis of the IEPR.

Step 9: Feedback from the proponent, within 30 days after receipt of the comments, is transferred through the PCX back to the review team until all comments are either resolved or all parties reach an agreement on outstanding issues. The PCX will strive to resolve all comments, but not all comments may be resolved. CECW-P in consultation with the HQ Model Certification Panel, the proponent and the PCX will have the final decision on comment resolution and product certification/approval. The final decision on model certification/approval should be made within 90 days after initial submittal of review comments to the proponent. (In cases where substantial revisions are made to the model, this time period may be longer).

Response: The project is currently at this stage. The outstanding comments are being resolved by streamlining the model, increasing transparency and reconfiguring the model code into modules in order to track interim results. The SRB model will be reconfigured in order to provide the ability to utilize an input files that generate discrete output results. This process will increase the ability of the PDT to evaluate alternatives quickly and efficiently.

Step 10: The PCX will furnish Headquarters Planning Community of Practice Leader the documentation of the review, model documentation, and a recommendation for or against certification/approval. CECW-P, in consultation with the Model Certification HQ Panel, will make the determination to certify/approve or not certify/approve the model. Upon certification/approval, CECW-P will issue a certification/approval memorandum and (for certified models) instruct the PCX to add the model to the National toolbox of certified models.

Response: The documentation has been submitted. Additional documentation describing the changes made and actions taken, along with the model code will be re-submitted as soon as it is available.

4. Documentation Provided by Proponent

Notification to DDPCX from CENWP-P	Attachment 4
MCR SRB Model Certification Memo	Attachment 5
Deep Draft PCX Approval for Use	Attachment 6

4.1. Model Technical Documentation

- **Calibration Results Documentation**

Moffat and Nichol, working with the PDT is currently reviewing the model calibration and will produce a calibration report with the PDT. Document will be available when received and approved. (see task 3 MCR MN SOW MOD2 attachment 3).

4.2. Model User Documentation

- The PDT and Moffat and Nichol are currently reviewing the model operations and establishing code that will allow the model to accept and produce input/output files. Upon completion of this task the Model User Guide will be updated and forwarded.

4.3. Model Support Literature

-

4.4. Model QA/QC Documentation/Activities

- Notification to DDPCX from CENWP-P Attachment 4
- MCR SRB Model Certification Memo Attachment 5
- Deep Draft PCX Approval for Use Attachment 6

5. Type/Scope of Review

Per EC-1105-2-412, 31 March 2011, the PCX recommended an Extensive Review. The model is currently undergoing an extensive review and the PDT recommends continuing, but not re-initiating, this process

The following language defines the scope of the review and will be provided to the model reviewers:

5.1. Preliminary charge for reviewers of the MCR Stochastic Reliability Based Model

The initial charge given to the ATR review and IEPR review team is shown below. In addition to the underlying theory, conceptualization, and computational aspects of the model, reviewers are asked to comment on aspects of the model that potentially affect its usability and reliability as a potential producer of information to be used to influence planning decisions.

While the specific review questions included below were intended to prompt the reviewer for information specific to the efforts to Approve for Single Use, the reviewers were encouraged to offer comments believed relevant and appropriate to any elements of the technical quality and usability of the model, Major Rehab Report and appendices as documented in the provided review materials. Accordingly, please provide responses to the sought scientific and technical topics listed below and perform a broad review of the focusing on your areas of expertise, experience, and technical knowledge. Listed below are the model review charge questions.

IEPR Charge Questions relevant to the Model Provided by PDT

1. Is the purpose of the model clearly defined?

2. Is the model diagram easily understood.

3. Does the model follow a logical programming path.

4. Is the model free from programming errors that would alter the model results significantly enough to skew the plan selection?

5. Does the model adequately capture and evaluate all of the relevant variables.

6. Can the model described achieve the stated purpose?

7. Does the model accurately describe (model) repair activities and sequences? Is it modeling the repair activities similarly to how the repairs will be sequenced and performed.

Technical Quality

8. Comment on the overall technical quality of the model.

9. Is the model based on well-established contemporary theory?
    a. Is the available science applied correctly?
    b. Are the models empirically supported?

10. Is the model a realistic representation of the actual system?

11. Are the analytical requirements of the model properly identified?

12. Does the model address and properly incorporate the analytical requirements?

13. Are the assumptions clearly identified, valid, and do they support the analytical requirements?

14. Are the formulas used in the model mathematically correct and are the model computations appropriate and done correctly?

15. Comment on the ability of the model to address risk and uncertainty.

16. Comment on the ability of the modes to calculate benefits for total project life.

17. Does the model adequately assess the full range of costs associated with the three jetties?

18. Will the model be useful in capturing and quantifying the full extent of benefits expected to be obtained from anticipated repairs?

System Quality

19. Has the model been sufficiently tested and validated, or do critical errors still exist?

Usability

20. Comment on the models' usability.

21. Comment on the availability of the data required by the model.

22. How easily are model results understood?

23. Comment on how useful model results are for supporting project objectives.

24. Is user documentation available, user friendly, and complete?

25. Is the model transparent and does it allow for easy verification of calculations and outputs?

OTHER GENERAL QUESTIONS

26. Can the model be adapted to other geographic regions?
    a. If so, how much can the model be modified before they need to be reviewed again?

27. Is it clear where the model's geographic boundaries fall?

28. Is the approach to the development and use of the model described clearly enough to allow the approach to be repeated and obtain the same or similar results?
    a. If not, why?
    b. If not, what needs to be done to make the approach repeatable?

29. Comment on the ability of the model to calculate benefits for total project life.

30. Is the application of the model defensible?

31. Comment on whether there are any resolution issues with the model (i.e., size of the area that can effectively be evaluated).
    a. At what scale (e.g. acres, hundreds of acres) can the models be effectively applied?

32. Comment on whether all of the most important variables are included in the model.
    a. Are variables that are both stressors and drivers included in the model?
    b. Should additional variables be included?
    c. Are some of the variables more sensitive than others?

33. To what extent is best professional judgment used in the model?

34. To what extent is the model developed specifically for the MCR Jetties?

35. Are error checks built into the model?

36. Are USACE policies and procedures related to the model clearly identified?

37. Does the model properly incorporate USACE policies and accepted procedures?

38. Is sea level change addressed by the model?
    a. If yes, is it internal to the model or does it need to be addressed externally?

5.2 Follow-On review charge.

The reviewers will not be charged with initiating a new review of the product in its entirety. The reviewers are charged with reviewing the IEPR comments and responses, and the PDT's subsequent actions, edits and changes in order to confirm that the PDT has adequately addressed the IEPR panel's questions. Follow-up questions made by the reviewers will also be addressed by the PDT until the reviewers, and the PDC, are satisfied that all outstanding issues have been resolved.

6. DNN-PCX Summary.

The DDN-PCX will provide a summary of review findings, which will include a summary of comments, and a strategy for implementing any necessary actions to remedy any additional or remaining deficiencies. The DDN-PCX will close-out the review when it determines identified issues have been resolved to its satisfaction.

Battelle
The Business of Innovation

Final Independent External Peer Review Report Columbia River at the Mouth, Oregon and Washington Major Rehabilitation Evaluation Report

Prepared by
Battelle Memorial Institute

Prepared for
Department of the Army
U.S. Army Corps of Engineers
Deep Draft Navigation Planning Center of Expertise
Mobile District

Contract No. W912HQ-10-D-0002
Task Order: 0007

March 9, 2011

Final Independent External Peer Review Report
Columbia River at the Mouth, Oregon and Washington
Major Rehabilitation Evaluation Report

by

Battelle
505 King Avenue
Columbus, OH 43201

for

Department of the Army
U.S. Army Corps of Engineers
Deep Draft Navigation Planning Center of Expertise
Mobile District

March 9, 2011

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FINAL
INDEPENDENT EXTERNAL PEER REVIEW REPORT
for the

Columbia River at the Mouth, Oregon and Washington
Major Rehabilitation Evaluation Report

EXECUTIVE SUMMARY

Project Background and Purpose

The Mouth of the Columbia River (MCR) navigation project is located at the confluence of the Columbia River with the Pacific Ocean on the border between Washington and Oregon. Navigation is maintained by three primary navigation structures, North Jetty, South Jetty, and Jetty A. The North Jetty and Jetty A are located in Pacific County, Washington, near Ilwaco and Long Beach on the Long Beach Peninsula. The North Jetty was completed in 1917. Jetty A, positioned on the south side of the North Jetty, was constructed in 1939 to a length of 1.1 miles. Jetty A was constructed to direct river and tidal currents away from the North Jetty foundation. The South Jetty is located in Clatsop County, Oregon near Warrenton/Hammond and Astoria. The initial 4.5-mile section of the South Jetty was completed in 1895, with a 2.4-mile extension completed in 1913. Jetty construction realigned the ocean entrance to the Columbia River, established a consistent navigation channel that was 40 feet below MLLW across the bar, and significantly improved navigation through the MCR. Improvements made from 1930 to 1942 (including addition of Jetty A and Sand Island pile dikes) produced the present entrance configuration. Each year, ocean-going vessels on the Columbia River carry about 40 million tons of cargo with an estimated value of $17 billion on an annual basis. More than 12,000 commercial vessels and 100,000 recreational/charter vessels navigate through the MCR annually.

Prior to improvement in 1885, the tidal channels through the MCR shifted north and south between Fort Stevens and Cape Disappointment, a distance of about 5.5 miles. The controlling depth of dominant channel through the ebb tidal delta varied between 18 to 25 feet deep below MLLW. The ebb and flood tidal deltas at MCR entrance were distributed over a large area immediately seaward and upstream of the river mouth. Ships often had difficulty traversing the Columbia River bar, the area in which the flow of the estuary rushes headlong into towering ocean waves. On many occasions, outbound ships had to wait a month or more until bar conditions were favorable for crossing. To make navigating through the MCR even worse, sailing ships had to approach either of the two natural channels abeam to the wind and waves. The natural channels often shifted widely within the course of several tidal cycles. At best, crossing the bar was dangerous. At worst, it was not possible. Offshore of the MCR lies the vast expanse of the northeast Pacific Ocean. Inshore of the MCR lies the Columbia River and estuary, the coastal outlet for a drainage basin of 250,000 square miles.

Despite intermittent repair and partial rehabilitation efforts, all of the MCR jetties are currently in an unacceptably deteriorated condition. This project was undertaken to address problems related to the structural stability of the MCR jetty system in order to extend the functional life of the jetties and maintain deep-draft navigation.

Independent External Peer Review Process

USACE is conducting an Independent External Peer Review (IEPR) of the Columbia River at the Mouth, Oregon and Washington Major Rehabilitation Evaluation Report (hereinafter Mouth of Columbia River IEPR). Battelle, as a 501(c)(3) non-profit science and technology organization with experience in establishing and administering peer review panels for USACE, was engaged to coordinate the IEPR of the Mouth of Columbia River Major Rehabilitation Evaluation Report. Independent, objective peer review is regarded as a critical element in ensuring the reliability of scientific analyses. The IEPR was external to the agency and conducted following USACE and Office of Management and Budget (OMB) guidance described in USACE (2010), USACE (2007), and OMB (2004). This final report describes the IEPR process, describes the panel members and their selection, and summarizes the Final Panel Comments of the IEPR Panel (the Panel).

Five panel members were selected for the IEPR from more than 28 identified candidates. Based on the technical content of the Mouth of Columbia River Major Rehabilitation Evaluation Report and the overall scope of the project, the final panel members were selected for their technical expertise in the following key areas: design and construction engineering (coastal engineering), plan formulation, biology NEPA, hydrology and hydraulics engineering/coastal engineering, geomorphology, and economics. USACE was given the list of candidate panel members, but Battelle made the final selection of the Panel.

The Panel received electronic versions of the Mouth of Columbia River IEPR documents, totaling more than 1,000 pages, along with a charge that solicited comments on specific sections of the documents to be reviewed. The charge was prepared by USACE according to guidance provided in USACE (2010) and OMB (2004). Charge questions were provided by USACE and included in the draft and final Work Plans.

The USACE Project Delivery Team briefed the Panel and Battelle during a kick-off meeting held via teleconference prior to the start of the review. In addition to this initial teleconference, a second teleconference with USACE, the Panel, and Battelle was conducted halfway through the review period to provide the Panel an opportunity to ask questions of USACE and clarify uncertainties. The Panel produced more than 500 individual comments in response to the 78 charge questions.

IEPR panel members reviewed the Mouth of Columbia River IEPR documents individually. The panel members then met via teleconference with Battelle to review key technical comments, discuss charge questions for which there were conflicting responses, and reach agreement on the Final Panel Comments to be provided to USACE. Each Final Panel Comment was documented using a four-part format consisting of: (1) a comment statement; (2) the basis for the comment; (3) the significance of the comment (high, medium, or low); and (4) recommendations on how to resolve the comment. Overall, 25 Final Panel Comments were developed. Of these, 8 were identified as having high significance, 14 had medium significance, and 3 had low significance.

Results of the Independent External Peer Review

The panel members agreed among one another on their "assessment of the adequacy and acceptability of the economic, engineering, and environmental methods, models, and analyses used" (USACE, 2010; p. D-4) in the Mouth of Columbia River IEPR document. Of primary significance, and as discussed in several of the Final Panel Comments, the Panel has serious concern with the SRB model and the potentially over-emphasized role it played in the evaluation of alternatives, engineering design, and economic analyses. Table ES-1 lists the Final Panel Comments statements by level of significance. The full text of the Final Panel Comments is presented in Appendix A of this report. The following statements summarize the Panel's findings.

Plan Formulation Rationale: From a planning perspective, the Major Rehabilitation Evaluation Report is well done and in compliance with all of the typical formulation steps; however, it was never clearly explained that the scope of work was limited to the repair and rehabilitation within the present configuration, nor why it was limited in this manner. Undefined risk thresholds may serve to undermine the logic of the cost and maintenance predictions and, to a lesser extent, the alternatives selected. The Panel agreed that the SRB model is not a substitute for conventional engineering and economic analyses and should not be a stand-alone analysis for selecting a recommended plan.

Economics: The Panel identified three major issues in the economic analysis: (1) inconsistencies in the Major Rehabilitation Evaluation Report and economic spreadsheet models; (2) the assumption that navigation would not be impacted; and (3) the formulation of the base condition. Inconsistencies in the report and economic spreadsheet models pertaining to the calculation of NPVs and AACs prevented the Panel from validating the economic analysis. Based on the assumption that navigation will not be impacted, a least cost analysis was used in lieu of a transportation cost savings analysis to calculate NED benefits. Conflicting assumptions concerning the ability to maintain navigation invalidate the logic behind calculating NED benefits using a least cost analysis. As the project is currently formulated, the base condition maintenance strategy for the MCR jetties conforms most closely with the fix-as-fails strategy, while the base condition life-cycle costs are the basis for estimating project benefits for all action alternatives. Inaccurate formulation of the base condition may increase life cycle costs, and may erroneously escalate project benefits. Each of these issues could impact the selection of the NED plan, which was selected as the recommended plan.

Engineering: There are serious technical difficulties with the Major Rehabilitation Evaluation Report and analyses. The report lacks a set of design criteria, including project life, standards of performance to be met, and environmental conditions with return period events. All are part of conventional coastal engineering design practice. The SRB model cannot be verified and does not include important processes. Major questions remain that have not been adequately investigated for this level of study, including subsurface geotechnical properties, feasibility of proposed barge offloading/material re-handling facilities, and the long term stability of the jetty foundations assuming continued erosion and loss of nearshore sediment. The report indicates that large volumes of sediment will move into the navigation channel after a breach event. However, the data and analysis do not support this conclusion. Additionally, is no clear discussion of the role of maintenance or emergency dredging, especially under extreme winter conditions. Detailed construction cost estimates also need to be provided in order for the cost analysis to be complete and verifiable. Although there is a good description of historical failures and repair actions for each jetty, there is no discussion or documentation of current jetty condition or detailed condition assessments of structure and functional condition.

Environmental: There is no discussion in the main report of sea level rise and potential wave height increases and its impact on this project over the 50+ year project timeline, given that the regional wave climate has been documented as more severe in the last 10 years. This has potential impacts to the project and in designing a project with lower long-term maintenance costs. Potential environmental impacts on sensitive species, upland habitats, and water quality as well as potential impacts to recreational use during project construction are not comprehensive nor adequately described in the mitigation plan. Finally, the alternatives are limited to armoring the existing configuration of the jetties and may not satisfy NEPA directive for alternative analysis.

Table ES-1. Overview of 25 Final Panel Comments Identified by the Mouth of Columbia River IEPR Panel

Significance – High	
1	The economic analysis used to select the National Economic Development (NED) plan cannot be validated, nor can it be determined if assumptions were applied correctly in the economic spreadsheet models.
2	The analysis of the sediment transport process is not comprehensive, and the data and analysis do not support the conclusions concerning large movement of sediment during a breach event.
3	The underlying assumption that navigational impacts will not occur is not substantiated.
4	The SRB model by itself has very limited value for analyzing alternatives and is not a substitute for conventional economic and engineering analysis.
5	The base condition, as formulated, does not represent the current O&M practice.
6	The reported analysis and design to mitigate a potential breach of the foreshore dune at the South Jetty root is not adequate.
7	The basis of design and design environmental criteria are vague, not consistent within the report, and not consistent with conventional coastal engineering design practice.
8	The models and analyses of jetty failure do not include all significant processes.
Significance – Medium	
9	The alternative selection process may fail to meet the requirements of NEPA Section 1502.14.
10	A failure analysis for the original structure design and past trends of Operation and Maintenance (O&M) costs has not been provided.
11	Sea level rise and potential increases in wave height have not been examined sufficiently under different model scenarios.

Table ES–1. Overview of 25 Final Panel Comments Identified by the Mouth of Columbia River IEPR Panel, continued

Significance – Medium	
12	Construction cost estimates cannot be evaluated because the assumptions and details have not been provided.
13	Potential environmental impacts on sensitive species, upland habitats, and water quality have not been thoroughly discussed or specifically mitigated in the document.
14	Potential impacts to recreational use during project construction, as identified in public comments, are not adequately discussed or mitigated.
15	There is not sufficient information on the evaluation of barge offloading and material re-handling facilities to ensure these sites can operate as intended and to ensure the construction costs are adequately represented.
16	The requirements, costs, and history associated with emergency dredging compared to scheduled maintenance dredging activities have not been specified.
17	The current jetty structure condition is not well described, making it difficult to confirm the confidence of the SRB model analysis and selection of a recommended plan.
18	The mechanisms causing jetty head scour have not been sufficiently analyzed to allow selection of the appropriate jetty head repair measure.
19	Risk thresholds for selected alternatives are not clearly defined.
20	It is not clear how uncertainty and derived risk analyses were considered in the structure and application of the model.
21	The model output parameters and wave height components are not clearly explained and supported.
22	The culvert installation details, as well as potential impacts, need further clarification.
Significance – Low	
23	The various base years cited in the report and the difference between project life and period of analysis require additional explanation.
24	Cargo tonnage and vessel trip statistics presented throughout the report are inconsistent.
25	Terminology related to jetty rehabilitation and failure is defined inconsistently or vaguely in some places.

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LIST OF ACRONYMS

AAC	Average annual cost
ATR	Agency Technical Review
CEDER	Center for Economic Development and Research
CE/ICA	Cost effectiveness/incremental cost analysis
CHL	Coastal and Hydraulic Laboratory
CMS	Coastal Modeling System
COI	Conflict of Interest
DEC	Design Environmental Conditions
DrChecks	Design Review and Checking System
EA	Environmental Assessment
EFH	Essential Fish Habitat
ESA	Endangered Species Act
ESU	Evolutionary significant unit
IEPR	Independent External Peer Review
LCR	Lower Columbia River
MCR	Mouth of Columbia River
MLLW	Mean lower low water
NED	National Economic Development
NEPA	National Environmental Policy Act
NPV	Net present value
NTP	Notice to Proceed
O&M	Operation and Maintenance
OMB	Office of Management and Budget
PNWA	Pacific Northwest Waterways Association
SWS	Shallow water site
USACE	United States Army Corps of Engineers
USEPA	United States Environmental Protection Agency
WRDA	Water Resources Development Act

1. INTRODUCTION

The Mouth of the Columbia River (MCR) navigation project is located at the confluence of the Columbia River with the Pacific Ocean, on the border between Washington and Oregon. Navigation is enabled by three primary navigation structures, North Jetty, South Jetty, and Jetty A, plus maintenance dredging of about 4 million cubic yards per year from the entrance channel. The North Jetty and Jetty A are located in Pacific County, Washington, near Ilwaco and Long Beach on the Long Beach Peninsula. The North Jetty was completed in 1917. Jetty A, positioned on the south side of the North Jetty, was constructed in 1939 to a length of 1.1 miles. Jetty A was constructed to direct river and tidal currents away from the North Jetty foundation. The South Jetty is located in Clatsop County, Oregon near Warrenton/Hammond and Astoria. The initial 4.5-mile section of the South Jetty was completed in 1895, with a 2.4-mile extension completed in 1913. Jetty construction realigned the ocean entrance to the Columbia River, established a consistent navigation channel that was 40 feet below mean lower low water (MLLW) across the bar, and significantly improved navigation through the MCR. Improvements made from 1930 to 1942 (including addition of Jetty A and Sand Island pile dikes) produced the present entrance configuration.

Prior to improvement in 1885, the tidal channels through the MCR shifted north and south between Fort Stevens and Cape Disappointment, a distance of about 5.5 miles. The controlling depth of dominant channel through the ebb tidal delta varied between 18 to 25 feet deep below MLLW. The ebb and flood tidal deltas at MCR entrance were distributed over a large area immediately seaward and upstream of the river mouth. Ships often had difficulty traversing the Columbia River bar, the area in which the flow of the estuary rushes headlong into towering ocean waves. On many occasions, outbound ships had to wait a month or more until bar conditions were favorable for crossing. To make navigating through the MCR even worse, sailing ships had to approach either of the two natural channels abeam to the wind and waves. The natural channels often shifted widely within the course of several tidal cycles. At best, crossing the bar was dangerous. At worst, it was not possible. Offshore of the MCR lies the vast expanse of the northeast Pacific Ocean. Inshore of the MCR lies the Columbia River and estuary, the coastal outlet for a drainage basin of 250,000 square miles.

The objective of the work described here was to conduct an Independent External Peer Review (IEPR) of the Mouth of Columbia River Major Rehabilitation Evaluation Report in accordance with procedures described in the Department of the Army, U.S. Army Corps of Engineers (USACE) Engineer Circular *Civil Works Review Policy* (EC No. 1165-2-209) (USACE, 2010), USACE CECW-CP memorandum *Peer Review Process* (USACE, 2007), and Office of Management and Budget (OMB) bulletin *Final Information Quality Bulletin for Peer Review* (OMB, 2004). Battelle, as a 501(c)(3) non-profit science and technology organization with experience in establishing and administering peer review panels, was engaged to coordinate the IEPR of the Mouth of Columbia River Major Rehabilitation Evaluation Report. Independent, objective peer review is regarded as a critical element in ensuring the reliability of scientific analyses.

This final report details the IEPR process, describes the IEPR panel members and their selection, and summarizes the Final Panel Comments of the IEPR Panel on the existing environmental, economic, and engineering analyses contained in the Mouth of Columbia River Major Rehabilitation Evaluation Report. The full text of the Final Panel Comments is presented in Appendix A.

2. PURPOSE OF THE IEPR

To ensure that USACE documents are supported by the best scientific and technical information, USACE has implemented a peer review process that uses IEPR to complement the Agency Technical Review (ATR), as described in USACE (2010) and USACE (2007).

In general, the purpose of peer review is to strengthen the quality and credibility of the USACE decision documents in support of its Civil Works program. IEPR provides an independent assessment of the economic, plan formulation, engineering, and environmental analysis of the project study. In particular, the IEPR addresses the technical soundness of the project study's assumptions, methods, analyses, and calculations and identifies the need for additional data or analyses to make a good decision regarding implementation of alternatives and recommendations.

In this case, the IEPR of the Mouth of Columbia River Major Rehabilitation Evaluation Report was conducted and managed using contract support from Battelle, which is an Outside Eligible Organization under Section 501(c)(3) of the U.S. Internal Revenue Code with experience conducting IEPRs for USACE.

3. METHODS

This section describes the method followed in selecting the members for the IEPR Panel (the Panel) and in planning and conducting the IEPR. The IEPR was conducted following procedures described by USACE (2010) and in accordance with USACE (2007) and OMB (2004) guidance. Supplemental guidance on evaluation for conflicts of interest (COIs) was obtained from the *Policy on Committee Composition and Balance and Conflicts of Interest for Committees Used in the Development of Reports* (The National Academies, 2003).

3.1 Planning and Schedule

After receiving the notice to proceed (NTP), Battelle held a kick-off meeting with USACE to review the preliminary/suggested schedule, discuss the IEPR process, and address any questions regarding the scope (e.g., clarify expertise areas needed for panel members). Any revisions to the schedule were submitted as part of the final Work Plan.

Table 1 defines the schedule followed in executing the IEPR. Due dates for milestones and deliverables are based on the NTP date of December 6, 2010. Note that the work items listed in Task 7 occur after the submission of this report. Battelle will enter the 25 Final Panel Comments developed by the Panel into USACE's Design Review and Checking System (DrChecks), a Web-based software system for documenting and sharing comments on reports and design documents, so that USACE can review and respond to them. USACE will provide responses (Evaluator Responses) to the Final Panel Comments, and the Panel will respond (BackCheck Responses) to the Evaluator Responses. All USACE and Panel responses will be documented by Battelle.

Table 1. Mouth of Columbia River IEPR Schedule

TASK	ACTION	DUE DATE
1	**NTP**	12/6/2010
	Review documents available	12/7/2010
	[a]Battelle submits draft Work Plan	12/15/2010
	USACE provides comments on draft Work Plan	12/20/2010
	[a]Battelle submits final Work Plan	12/28/2010
2	Battelle requests input from USACE on the conflict of interest (COI) questionnaire	12/8/2010
	USACE provides comments on COI questionnaire	12/9/2010
	[a]Battelle submits list of selected panel members	12/16/2010
	USACE provides comments on selected panel members	12/17/2010
	Battelle completes subcontracts for panel members	1/5/2011
3	[a]Battelle receives final charge from USACE (to be included in Work Plan)	12/10/2010
4	USACE/Battelle kick-off meeting	12/13/2010
	Battelle sends review documents to IEPR Panel	1/6/2011
	USACE/Battelle/Panel kick-off meeting	1/7/2011
	Battelle convenes mid-review teleconference for panel to ask clarifying questions of USACE	1/19/2011
5	Panel members complete their individual reviews	1/31/2011
	Battelle convenes panel review teleconference with IEPR Panel	2/10-2/11/2011
	Panel members provide draft Final Panel Comments to Battelle	2/21/2011
6	[a]Battelle submits Final IEPR Report to USACE	3/9/2011
7[b]	Battelle inputs Final Panel Comments to DrChecks; Battelle provides Final Panel Comment response template to USACE	3/10/2011
	Battelle convenes teleconference with USACE to review the requirements of the Evaluator Response process.	3/11/2011
	USACE provides draft Evaluator Responses and clarifying questions to Battelle	3/16/2011
	Battelle convenes teleconference between Battelle, Panel, and USACE to discuss Final Panel Comments, draft responses, and clarifying questions	3/23/2011
	USACE inputs final Evaluator Responses in DrChecks	3/30/2011
	Battelle inputs the Panel's BackCheck Responses in DrChecks	4/7/2011
	[a]Battelle submits pdf printout of DrChecks project file	4/8/2011
	Project Closeout	6/13/2011

[a] Deliverable

[b] Task 7 occurs after the submission of this report.

3.2 Identification and Selection of IEPR Panel Members

The candidates for the Panel were evaluated based on their technical expertise in the following key areas: design and construction engineering (coastal engineering), plan formulation, biology/ National Environmental Policy Act (NEPA), hydrology and hydraulics engineering/coastal engineering, geomorphology, and economics. These areas correspond to the technical content of the Mouth of Columbia River IEPR and overall scope of the Columbia River at the Mouth, Oregon and Washington Major Rehabilitation Evaluation Report project.

To identify candidate panel members, Battelle reviewed the credentials of the experts in Battelle's Peer Reviewer Database, sought recommendations from colleagues, contacted former panel members, and conducted targeted Internet searches. Battelle initially identified more than 28 candidates for the Panel, evaluated their technical expertise, and inquired about potential COIs. Of these, Battelle chose seven of the most qualified candidates and confirmed their interest and availability. Of the seven candidates, five were proposed for the final Panel and two were proposed as backup reviewers. Information about the candidate panel members, including brief biographical information, highest level of education attained, and years of experience, was provided to USACE for feedback. Battelle made the final selection of panel members according to the selection criteria described in the Work Plan.

The five proposed primary reviewers constituted the final Panel. The remaining candidates were not proposed for a variety of reasons, including lack of availability, disclosed COIs, or lack of the precise technical expertise required.

The candidates were screened for the following potential exclusion criteria or COIs.[1] These COI questions were intended to serve as a means of disclosure and to better characterize a candidate's employment history and background. Providing a positive response to a COI screening question did not automatically preclude a candidate from serving on the Panel. For example, participation in previous USACE technical peer review committees and other technical review panel experience was included as a COI screening question. A positive response to this question could be considered a benefit.

- Involvement by you or your firm[2] in the Major Rehabilitation of the Jetty System at the Mouth of the Columbia River, Major Rehabilitation Evaluation Report and technical appendices.
- Involvement by you or your firm[2] in any work related to deep draft navigation studies on the Columbia River.

[1] Battelle evaluated whether scientists in universities and consulting firms that are receiving USACE-funding have sufficient independence from USACE to be appropriate peer reviewers. See OMB (2004, p. 18), "….when a scientist is awarded a government research grant through an investigator-initiated, peer-reviewed competition, there generally should be no question as to that scientist's ability to offer independent scientific advice to the agency on other projects. This contrasts, for example, to a situation in which a scientist has a consulting or contractual arrangement with the agency or office sponsoring a peer review. Likewise, when the agency and a researcher work together (e.g., through a cooperative agreement) to design or implement a study, there is less independence from the agency. Furthermore, if a scientist has repeatedly served as a reviewer for the same agency, some may question whether that scientist is sufficiently independent from the agency to be employed as a peer reviewer on agency-sponsored projects."

- Involvement by you or your firm[2] in projects related to the Major Rehabilitation of the Jetty System at the Mouth of the Columbia River, Major Rehabilitation Evaluation Report and technical appendices.
- Involvement by you or your firm[2] in the conceptual or actual design, construction, or O&M of any projects related to the Major Rehabilitation of the Jetty System at the Mouth of the Columbia River, Major Rehabilitation Evaluation Report and technical appendices.
- Current employment by the U.S. Army Corps of Engineers (USACE).
- Involvement with paid or unpaid expert testimony related to the Major Rehabilitation of the Jetty System at the Mouth of the Columbia River, Major Rehabilitation Evaluation Report and technical appendices.
- Current or previous employment or affiliation with members of any of the following cooperating Federal, State, County, local and regional agencies, environmental organizations, and interested groups: National Marine Fisheries Service, U.S. Fish and Wildlife Service, U.S. Geological Survey, Washington Department of Ecology, Oregon Department of Environmental Quality, Oregon Department of Land Conservation and Development, or Portland State University (for pay or pro bono).
- Past, current or future interests or involvements (financial or otherwise) by you, your spouse or children related to the mouth of the Columbia River.
- Current personal involvement with other USACE projects, including whether involvement was to author any manuals or guidance documents for USACE. If yes, provide titles of documents or description of project, dates, and location (USACE district, division, Headquarters, ERDC, etc.), and position/role. Please highlight and discuss in greater detail any projects that are specifically with the Portland District.
- Current firm[2] involvement with other USACE projects, specifically those projects/contracts that are with the Portland District. If yes, provide title/description, dates, and location (USACE district, division, Headquarters, ERDC, etc.), and position/role.
- Any previous employment by the USACE as a direct employee or contractor (either as an individual or through your firm[2]) within the last 10 years, notably if those projects/contracts are with the Portland District. If yes, provide title/description, dates employed, and place of employment (district, division, Headquarters, ERDC, etc.), and position/role.
- Previous experience conducting technical peer reviews. If yes, please highlight and discuss any technical reviews concerning deep draft navigation or coastal engineering, and include the client/agency and duration of review (approximate dates).
- Pending, current or future financial interests in contracts/awards from USACE related to the Major Rehabilitation of the Jetty System at the Mouth of the Columbia River, Major Rehabilitation Evaluation Report and technical appendices.
- A significant portion (i.e., greater than 50%) of personal or firm[2] revenues within the last 3 years came from USACE contracts.
- Any publicly documented statement (including, for example, advocating for or discouraging against) related to Major Rehabilitation of the Jetty System at the Mouth of the Columbia River, Major Rehabilitation Evaluation Report and technical appendices.

- Participation in relevant prior Federal studies relevant to this project, including:
  - U.S. Army Corps of Engineers. 1983. Columbia River at the Mouth Navigation Channel Improvement, Final Environmental Impact Statement, Oregon-Washington. Portland, Oregon.
  - Earth Sciences Associates and Geo Recon International. 1985. Geologic and Seismic Investigation of Columbia River Mouth Study Area, Report for U.S. Army Corps of Engineers, Portland District, Portland, Oregon.
  - Northwest Geophysical Associates, Inc. 1996. 1996 Columbia River Offshore Disposal Site Study, Sidescan Sonar Investigation, Report for U.S. Army Corps of Engineers, Portland District, Portland, Oregon.
  - U.S. Army Corps of Engineers. 1999. Integrated Feasibility Report for Channel Improvements and Environmental Impact Statement, Columbia and Lower Willamette River Federal Navigation Channel. Portland, Oregon.
  - NMFS. 2004. Endangered Species Act Section 7 Formal Consultation and Magnuson-Stevens Fishery and Conservation Management Act Essential Fish Habitat Consultation for the Columbia River North and South Jetties Rehabilitation, Columbia River Basin, Clatsop County, Oregon.
  - USACE. 2005. Interim Repair Decision Document for North and South Jetties at the Mouth of the Columbia River, Oregon and Washington. U.S. Army Corps of Engineers-Portland District, Portland, Oregon.
  - Global Remote Sensing. 2005. Mouth of the Columbia River Offshore Disposal Site Study, Multibeam Investigations, Report for U.S. Army Corps of Engineers, Portland District, Portland, Oregon.
  - Tetra Tech, Inc. April 2007. Wetland and Waters of the U.S. Delineation Revised Final Report: North Jetty, Mouth of the Columbia River, Pacific County, Washington. Prepared for U.S. Army Corps of Engineers, Portland, Oregon.
  - Tetra Tech, Inc. April 2007. Clatsop Spit Plant Communities Investigation and Mapping, Final Report: South Jetty, Mouth of the Columbia River, Clatsop County, Oregon. Prepared for U.S. Army Corps of Engineers, Portland, Oregon.
  - Ward, D. L., Melby, J.A., Myrick, G.B., and Henderson, W.G. 2007. Physical Model Study of Jetties at the Mouth of the Columbia River, Oregon and Washington. ERDC/CHL TR-07-XX. U.S. Army Corps of Engineers. Engineer Research and Development Center-Coastal and Hydraulics Laboratory. Vicksburg, Mississippi.
  - Demirbilik, Z., Lin, L, and Nwogu, O.G. 2008. Wave Modeling for Jetty Rehabilitation at the Mouth of the Columbia River, Oregon and Washington. ERDC/CHL TR-08-3. U.S. Army Corps of Engineers. Engineer Research and Development Center-Coastal and Hydraulics Laboratory. Vicksburg, Mississippi.
  - Moritz, H.R. and Moritz, H. P. 2009. Stochastic Risk-Based Life Cycle Simulation of Century Old Jetties at the Mouth of the Columbia River, USA. International Conference on Coasts, Marine Structures, and Breakwaters 2009. Proceedings of the Institution of Civil Engineers. Presented in Edinburgh, Scotland, September 2009.
- Participation in prior non-Federal studies relevant to this project.

- Is there any past, present or future activity, relationship or interest (financial or otherwise) that could make it appear that you would be unable to provide unbiased services on this project? If so, please describe:

In selecting the final members of the Panel from the list of candidates, Battelle chose experts who best fit the expertise areas and had no COIs. The five final reviewers were either affiliated with academic institutions or consulting companies or were independent engineering consultants. Battelle established subcontracts with the panel members when they indicated their willingness to participate and confirmed the absence of COIs through a signed COI form. USACE was given the list of candidate panel members, but Battelle made the final selections of the Panel. Section 4 of this report provides names and biographical information on the panel members.

Prior to beginning their review and within 2 days of their subcontracts being finalized, all members of the Panel attended a kick-off meeting via teleconference planned and facilitated by Battelle in order to review the IEPR process, the schedule, communication procedures, and other pertinent information for the Panel.

3.3 Preparation of the Charge and Conduct of the IEPR

Shortly after Battelle received NTP, USACE provided the following documents and reference materials. The documents and files in bold font were provided for review and the other documents were provided for reference or supplemental information only.

- **Columbia River at the Mouth, Oregon and Washington Major Rehabilitation Evaluation Report**
  - **Appendix A1: Coastal Engineering**
  - **Appendix A2: Reliability Analysis, Event Tree Formulation and Life-Cycle Simulation**
  - **Appendix B: Geotechnical**
  - **Appendix C: Economics**
  - **Appendix D: Environmental Documentation**
  - **Appendix E: M-CACES Cost Estimate for Recommended Plan**
  - Appendix F: Project Management Plan
  - Appendix G: Schedule of Fully Funded Project Costs
- USACE guidance *Civil Works Review Policy* (EC 1165-2-209) dated January 31, 2010
- CECW-CP Memorandum dated March 31, 2007
- Office of Management and Budget's *Final Information Quality Bulletin for Peer Review* released December 16, 2004.

In addition, throughout the review period, USACE provided additional documents at the request of panel members. These additional documents were provided as supplemental information only and were not part of the official review:

- Jetty Rehab, Mouth of the Columbia River, USGS Draft v01 Appendix Figures, Edwin Elias and Guy Gelfenbaum 2007
- Jetty Rehab, Mouth of the Columbia River, USGS Draft v02, Edwin Elias and Guy Gelfenbaum 2007

- Analysis of Jetty Rehabilitation at the Mouth of the Columbia River, Washington/Oregon, USA Part: 2 Regional Circulation, Sediment Transport, and Morphology Change June 2007 ERDC/CHL Kenneth J. Connell and Julie Dean Rosati
- 2009 MCR Jetty inspection reports and supporting documentation
- Summary of the Jetty heads and the physical model
- Model Documentation Report
- Additional documentation on design criteria
- Appendix b geotechnical studies (as listed in the file name)
- Exhibit M Economic Analysis of the Columbia River Channel Improvement Project, Final Supplemental Integrated Feasibility Report and Environmental Impact Statement
- Economic spreadsheet models for each jetty
- Three AVIs and videos showing the velocity vectors at the MCR
- a summary of the Jetty heads and the physical model
- Mouth of the Columbia River North Jetty, South Jetty, and Jetty A Rehabilitation Template Examples
- Documentation sent to USACE Headquarters to obtain model approval for use.

Charge questions were provided by USACE and included in the draft and final Work Plans. In addition to a list of 78 charge questions/discussion points, the final charge included general guidance for the Panel on the conduct of the peer review (provided in Appendix B of this final report).

Battelle planned and facilitated a final kick-off meeting via teleconference during which USACE presented project details to the Panel. Before the meeting, the IEPR Panel received an electronic version of the Mouth of Columbia River IEPR documents and the final charge. A full list of the documents reviewed by the Panel is provided in Appendix B of this report. The Panel was instructed to address the charge questions/discussion points within a comment-response form provided by Battelle.

3.4 Review of Individual Comments

Prior to completion of the review of the Mouth of Columbia River IEPR documents, a teleconference with USACE, the Panel, and Battelle was held halfway through the review period to provide the Panel an opportunity to ask questions of USACE regarding uncertainties requiring clarification. At the end of the review period, the Panel produced approximately 500 individual comments in response to the charge questions/discussion points. Battelle reviewed the comments to identify overall recurring themes, areas of potential conflict, and other overall impressions. As a result of the review, Battelle summarized the 500 comments into a preliminary list of 44 overall comments and discussion points. Each panel member's individual comments were shared with the full Panel in a merged individual comments table.

3.5 IEPR Panel Teleconference

Due to the number of comments and the complexity of the issues, Battelle facilitated two 3-hour teleconferences with the Panel so that the panel members, many of whom are from diverse scientific backgrounds, could exchange technical information. The main goal of the teleconferences was to identify which issues should be carried forward as Final Panel Comments in the IEPR report and decide which panel member would serve as the lead author for the development of each Final Panel Comment. This information exchange ensured that the Final IEPR Report would accurately represent the Panel's assessment of the project, including any conflicting opinions. The Panel engaged in a thorough discussion of the overall positive and negative comments, added any missing issues of high-level importance to the findings, and merged any related individual comments. In addition, Battelle confirmed each Final Panel Comment's level of significance to the Panel.

The Panel also discussed responses to seven specific charge questions where there appeared to be disagreement among panel members. The conflicting comments were resolved based on the professional judgment of the Panel, and each comment was either incorporated into a Final Panel Comment, determined to be consistent with other Final Panel Comments already developed, or determined to be a non-significant issue.

At the end of these discussions, the Panel identified 30 initial comments and discussion points that should be brought forward as Final Panel Comments.

3.6 Preparation of Final Panel Comments

Following the teleconference, Battelle prepared a summary memorandum for the Panel documenting each Final Panel Comment (organized by level of significance). The memorandum provided the following detailed guidance on the approach and format to be used to develop the Final Panel Comments for the Mouth of Columbia River IEPR:

- Lead Responsibility: For each Final Panel Comment, one Panel member was identified as the lead author responsible for coordinating the development of the Final Panel Comment and submitting it to Battelle. Battelle modified lead assignments at the direction of the Panel. To assist each lead in the development of the Final Panel Comments, Battelle distributed the merged individual comments table, a summary detailing each draft final comment statement, an example Final Panel Comment following the four-part structure described below, and templates for the preparation of each Final Panel Comment.
- Directive to the Lead: Each lead was encouraged to communicate directly with other IEPR panel members as needed and to contribute to a particular Final Panel Comment. If a significant comment was identified that was not covered by one of the original Final Panel Comments, the appropriate lead was instructed to draft a new Final Panel Comment.
- Format for Final Panel Comments: Each Final Panel Comment was presented as part of a four-part structure:
    1. Comment Statement (succinct summary statement of concern)
    2. Basis for Comment (details regarding the concern)
    3. Significance (high, medium, low; see description below)
    4. Recommendation(s) for Resolution (see description below).
- Criteria for Significance: The following were used as criteria for assigning a significance level to each Final Panel Comment:

1. High: Describes a fundamental problem with the project that could affect the recommendation, success, or justification of the project. Comments rated as high indicate that the Panel analyzed or assessed the methods, models, and/or analyses and determined that there is a "showstopper" issue.
2. Medium: Affects the completeness of the report in describing the project, but will not affect the recommendation or justification of the project. Comments rated as medium indicate that the Panel does not have sufficient information to analyze or assess the methods, models, or analyses.
3. Low**:** Affects the understanding or accuracy of the project as described in the report, but will not affect the recommendation or justification of the project. Comments rated as low indicate that the Panel identified information (tables, figures, equations, discussions) that was mislabeled or incorrect or data or report sections that were not clearly described or presented.

- Guidance for Developing Recommendation: The recommendation section was to include specific actions that USACE should consider to resolve the Final Panel Comment (e.g., suggestions on how and where to incorporate data into the analysis, how and where to address insufficiencies, areas where additional documentation is needed).

Battelle reviewed and edited the Final Panel Comments for clarity, consistency with the comment statement, and adherence to guidance on the Panel's overall charge, which included ensuring that there were no comments regarding either the appropriateness of the selected alternative or USACE policy. At the end of this process, 25 Final Panel Comments were prepared and assembled; four of the original 30 comments were merged with other existing Final Panel Comments and one was deleted because it did not meet the criteria for significance for Final Panel Comments. There was no direct communication between the Panel and USACE during the preparation of the Final Panel Comments; however, Battelle sent working drafts of the Final Panel Comments to USACE as a means to help them get a head start in providing responses to the Panel comments. Battelle informed USACE that these working drafts could be revised, merged, deleted, or new comments created prior to the submittal of the Final IEPR Report. The Final Panel Comments are presented in Appendix A of this report.

4. PANEL DESCRIPTION

Candidates for the Panel were identified using Battelle's Peer Reviewer Database, targeted Internet searches using key words (e.g., technical area, geographic region), searches of websites of universities or other compiled expert sites, and referrals. Battelle prepared a draft list of primary and backup candidate panel members (who were screened for availability, technical background, and COIs), and provided it to USACE for feedback. Battelle made the final selection of panel members.

An overview of the credentials of the final five primary members of the Panel and their qualifications in relation to the technical evaluation criteria is presented in Table 2. More detailed biographical information regarding each panel member and his or her area of technical expertise is presented in the text that follows the table.

Table 2. Mouth of Columbia River IEPR Panel: Technical Criteria and Areas of Expertise

	Phillips	Cuba	Rein	Sultan	Maher	Sultan
Civil Design/Construction [Coastal Engineering] (one expert needed)	**X**					
Minimum 10 years experience in civil design/construction and coastal engineering	X			X		X
Familiar with large, complex Civil Works projects with high public and interagency interests	X			X		X
Experience performing coastal engineering design and construction management for coastal projects	X			X		X
Familiar with similar projects across the United States and related coastal engineering	X			X		X
Experience in computer modeling including Matlab experience in coastal engineering	X			X		X
Familiar with construction industry and practices used in coastal construction in the Pacific Northwest	X			X		X
Degree in civil engineering	X			X		X
Plan Formulation (one expert needed)		**X**				
Minimum 10 years experience in the plan formulation process		X		X		X
Familiar with large, complex Civil Works projects with high public and interagency interests		X		X		X
Familiar with evaluation of alternative plans for coastal projects		X		X		X
Familiar with USACE standards and procedures		X		X		X
Degree in planning or a related field		See waiver*				
Biology NEPA (one expert needed)			**X**			
Minimum 10 years experience in biology		X	X			
Familiar with large, complex Civil Works projects with high public and interagency interests		X	X			
Particular knowledge of ecosystem restoration		X	X			
Familiar with all NEPA requirements		X	X			
Minimum of an M.S. degree in Biology		X	X			
Hydrology and Hydraulics Engineering/Coastal				**X**		

	Phillips	Cuba	Rein	Sultan	Maher	Sultan
Engineering (one expert needed)						
Minimum 10 years experience in hydrology and hydraulics engineering				X		X
Familiar with large, complex Civil Works projects with high public and interagency interests				X		X
Experience with sediment transport and engineering analyses related to design to include a variety of materials and cross-sections				X		X
Familiar with standard USACE hydrologic and hydraulic computer models used in jetty design				X		X
Minimum of an M.S. degree in civil engineering or hydrology and hydraulics				X		X
Registered professional engineer				X		X
Economics (one expert needed)					**X**	
Minimum 10 years experience in economics				X	X	X
Familiar with large, complex Civil Works projects with high public and interagency interests				X	X	X
Able to evaluate the appropriateness of cost effectiveness and incremental cost analysis (CE/ICA), as applied to USACE projects				X	X	X
Experience with National Economic Development (NED) analysis procedures, particularly as they relate to jetty construction projects					X	
Degree in economics or related field				X	X	X
Geomorphology (one expert needed)						**X**
Minimum 10 years experience in geomorphology				X		X
Familiar with large, complex Civil Works projects with high public and interagency interests				X		X
Experience with geological analyses related to project design to include a variety of materials and cross-sections used in jetty design				X		X
Minimum M.S. degree in civil engineering or geology				X		X
Registered professional engineer				X		X

* Dr. Tom Cuba has 28 years of experience in planning and biology/ecology. Dr. Cuba does not have his degree in planning or a related field. He has his Ph.D. in marine science/ecology. Battelle believes that his planning experience is commensurate with a degree in planning.

Shane Phillips, P.E.

Role: This panel member was chosen primarily for his coastal engineering design and construction management for coastal projects experience and expertise.
Affiliation: Coast and Harbor Engineering, Inc.

Shane Phillips, **P.E.,** a principal civil engineer at Coast and Harbor Engineering, Inc. in Edmonds, Washington, has 17 years of experience in marine and coastal engineering. He earned his B.S. in civil engineering in 1993 from Washington State University and is a registered professional engineer in Washington, California, Texas, Louisiana, and Florida. His specific engineering experience includes the feasibility evaluation, preliminary design, and final design of geotechnical, structural, and civil components of coastal and marine construction projects.

Mr. Phillips has applied his coastal engineering design expertise to a variety of coastal shore protection projects along the Pacific Northwest coast and has served as both on-site resident engineer and project manager on coastal construction projects including jetty, revetments, levees, dredging, and boating facilities. He served as project and design engineer for the North Jetty Beachfront Properties Coastal Erosion project in Ocean Shores, Washington, which involved the design and construction of a 1,000 foot long rock revetment structure.

Mr. Phillips has managed and executed feasibility studies, planning studies, and engineering of coastal and marine construction projects for port facilities, marinas, boating facilities, ferry terminals, marine terminals, navigation channels, and shoreline properties. He was Project Engineer for preliminary and final engineering design phase on the Willapa Bay, Washington SR-105 Emergency Stabilization Project consisting of a 1,400 foot long rock groin, 1,200 foot long submerged rock jetty and 1,100 feet of beach nourishment.

Coastal design experience includes the layout and design of floating breakwaters, groins, piers, bulkheads, beach nourishment, shoreline stabilization, dredging, water quality improvement, and nearshore restoration. Structural design experience includes the evaluation and engineering design of marine terminals, piers, bulkheads, retaining walls, breakwaters, and marinas using concrete, steel, and timber materials. Mr. Phillips has reviewed/verified computer modeling preparation and calibration and regularly works with engineering programs including AutoCad 2010, PCSTBLE, ACES, Surfer, SMS, Matlab, and Land Development.

Tom Cuba, Ph.D.

Role: This panel member was chosen primarily for his experience and expertise in the coastal plan formulation process.
Affiliation: Delta Seven, Inc.

Thomas R. Cuba, Ph.D., CEP, President and Chief Scientist at Delta Seven, Inc., serves as a Research Scientist at Stillwater Research Group, and is a research adjunct professor at the University of South Florida. He earned his Ph.D. in marine ecology from the University of South Florida in 1984. Dr. Cuba has 28 years of planning experience, which includes developing management plans for a variety of Florida watersheds and aquatic preserves, working on waterfront infrastructure feasibility plans, and designing wetland, pond, and seagrass restoration plans. Dr.Cuba’s six-year service as a Naval Intelligence Officer included plan formulation responsibilities, and he has been involved in civil and governmental plan formulation of engineered ecological restoration projects since 1984. Additionally, he conducted comprehensive conservation and public works plan formulation for Pinellas County, Florida and subsequently worked to enact these plans through public projects and codification in county ordinances.

Dr. Cuba has served as project manager and chief scientist on several watershed-based management and restoration projects (all of which included construction elements) and, for many of these, he acted as chair of the multi-stakeholder board. Dr. Cuba has assessed alternatives in beach nourishment and the placement of jetties and groins during his work with Pinellas County and in private practice. He is familiar with USACE plan formulation standards and procedures and has served on four USACE IEPR panels in the recent past as plan formulator (Clear Creek, C-111, Tamiami Trail, and LCA6).

Felicia Orah Rein, Ph.D.

Role: This panel member was chosen primarily for her biology/NEPA experience and expertise.
Affiliation: Watershed Solutions, Inc. and Florida Atlantic University

Felicia Orah Rein, Ph.D., is president and senior scientist at Watershed Solutions, Inc., an environmental consulting and restoration services firm specializing in environmental restoration, environmental assessments and impact analyses, ecological monitoring, water resource management, and reduction of sediment transport and erosion. She is also an affiliate professor at Florida Atlantic University. She earned her Ph.D. in ecosystem science/restoration ecology from the University of California at Santa Cruz in 2000 and has more than 20 years of experience managing and implementing large-scale multidisciplinary restoration ecology and resource protection projects.

Dr. Rein has extensive experience with large complex Civil Works projects with high public visibility, including assessment of environmental impacts of the New York/New Jersey Harbor deepening project for which she provided expertise in dredged material beneficial uses and source reduction and conducted vegetation and wetland mapping on coastal sites. Her NEPA expertise has involved collaboration with the National Marine Fisheries Service, California Department of Fish and Game, California State Water Resource Control Board, and U.S. Fish and Wildlife Service. She has a strong knowledge of ecosystem restoration, having worked on projects such as the Far Rockaway, Averne site park and housing development projects. Her role included wetland restoration areas and focused on water quality and vegetation impacts. Dr. Rein has prepared numerous Phase I (NEPA) environmental site assessments and is familiar with all NEPA requirements. As a senior project manager, she has provided scientific expertise on environmental documents according to NEPA guidelines and worked closely with local, state, and Federal government, as well as lawyers, environmentalists, and community groups on complex water rights assessments. She has experience in wetland ecology of urban regions, having worked in the initial phases of the fast-tracked wetland restoration projects in the NY/NJ region, including the hydrologic restoration of Liberty State Park and others.

She has conducted technical peer reviews, quality assurance/quality control (QA/QC) reviews, and acted as an expert consultant in environmental damage disputes for engineering and consulting firms. Dr. Rein is a member of Sigma Xi National Scientific Research Society.

Nels Sultan, P.E., Ph.D.

Role: This panel member was chosen to serve in a **dual role** for his hydrology and hydraulic engineering and geomorphology experience and expertise.
Affiliation: PND Engineers, Inc.

Nels Sultan, P.E., Ph.D., a coastal engineer at PND Engineers, Inc. in Seattle, Washington, has more than 20 years of experience specializing in the analysis and design of waterfront projects, including coastal geomorphology, coastal numerical models, and wave tank physical models. He earned his Ph.D. in ocean engineering from Texas A&M University in 1995. He is a registered professional civil engineer in Washington and Alaska and is a former officer in the Naval Reserve, Civil Engineering Construction Corps.

Dr. Sultan has worked on all aspects of design engineering for ports, harbors, shore protection, dredging, and other coastal and marine facilities projects. His extensive project experience includes preparing plans, specifications, and cost estimates through final design and construction (using a variety of materials including rock, geocontainers, stone masonry, and concrete), in addition to analyzing wave conditions, coastal processes, and sediment transport. Dr. Sultan’s experience includes serving as the ocean engineer on the South Jetty Permeability project in Grays Harbor, Washington, where the jetty is subject to erosion of sediment at its landward end and has been completely severed from the mainland on occasion. Dr. Sultan analyzed aerial photographs, wind, wave, and tide conditions in order to determine whether the south jetty was permeable to sediment transport and contributing to erosion problems.

He served as project manager and coastal engineer for the Skagway Small Boat Harbor Dredging and Entrance Surge Control project in Alaska and led design and construction support services for a new 290 foot long, curved, partially penetrating vertical breakwater that provided surge control at the harbor entrance. Also for this project, Dr. Sultan prepared a wind and wave study for breakwater alternatives and provided computer modeling, using both desktop and CGWAVE modeling of wave transmission, wave diffraction, and reflected waves to evaluate waves at the adjacent ferry terminal floating dock and the shoreline north of the planned wave barrier. He also served as the ocean engineer for the Willapa Bay, WA SR-105 Stabilization Project Monitoring Program, which involved beach nourishment, an underwater dike, and a multi-purpose rock groin.

Dr. Sultan is a member of the Association of Coastal Engineers, American Society of Civil Engineers and the American Geophysical Union.

Daniel Maher, M.S.
Role: This panel member was chosen primarily for his experience and expertise in economics.
Affiliation: G.E.C., Inc.

Daniel Maher, M.S., is a senior economist and project manager at G.E.C., Inc. with 22 years of experience conducting large water resource/public works planning studies. He received his M.S. in agricultural economics from Louisiana State University in 1988. Mr. Maher has served as a project manager or economist on numerous regional economic impact, navigation, water supply, recreation, flood control, and ecosystem restoration projects. Mr. Maher has developed benefits and costs for National Economic Development (NED) analyses of large water resource planning efforts and navigation projects, which involved using methodologies estimating project benefits of coastal construction projects based on transportation savings. For example, Mr. Maher was the economist and project manager responsible for estimating NED benefits associated with increasing the current authorized depth of the federal central harbor and navigation channels to the Tenth Avenue Marine Terminal in San Diego, California. The primary benefits of deepening the harbor were the reduction in vessel operating costs by allowing deeper draft vessels to traverse the channel fully loaded, and the reduction or elimination of vessel tidal delays. Additionally, he was responsible for estimating the NED benefits and assessing the operational and environmental impacts resulting from the removal of several underwater natural obstructions in San Francisco Bay. These underwater pinnacles are considered a major hazard to navigation in the bay, especially regarding deep-draft oil tankers. The economic feasibility of removing these pinnacles was based on quantifiable transportation savings resulting from reduced bay transit distances of oil tankers and container vessels that frequent the ports on the bay.
Mr. Maher has also been responsible for cost effectiveness/incremental cost analysis (CE/ICA) for several USACE ecosystem restoration projects including Canonsburg Lake Ecosystem Restoration Project (Pittsburg District); Licking River Watershed and Dillon Lake Ecosystem Restoration Project (Huntington District); and Big Sunflower Ecosystem Restoration Feasibility Study (Vicksburg District). For each of these projects Mr. Maher worked with biologists and ecologists to define appropriate metrics for measuring environmental benefits and converting benefits to an average annual basis for each alternative considered. He also reviewed construction and operations and maintenance costs associated with each alternative, and conducted cost effective analysis and incremental cost analysis using IWR-PLAN. Mr. Maher has experience with numerous economic computer programs, including IMPLAN Economic Impact Software, IWR-Planning Suite, and IWR-MAIN Water Use Forecast System.

5. SUMMARY OF FINAL PANEL COMMENTS

The panel members agreed among one another on their "assessment of the adequacy and acceptability of the economic, engineering, and environmental methods, models, and analyses used" (USACE, 2010; p. D-4) in the Mouth of Columbia River IEPR. Table 3 lists the 25 Final Panel Comment statements by level of significance. The full text of the Final Panel Comments is presented in Appendix A. Of primary significance, and as discussed in several of the Final Panel Comments, the Panel has serious concern with the SRB model and the potentially over-emphasized role it played in the evaluation of alternatives, engineering design, and economic analyses. The following statements summarize the Panel's findings.

Plan Formulation Rationale: From a planning perspective, the Major Rehabilitation Evaluation Report is well done and in compliance with all of the typical formulation steps; however, it was never clearly explained that the scope of work was limited to the repair and rehabilitation within the present configuration, nor why it was limited in this manner. Undefined risk thresholds may serve to undermine the logic of the cost and maintenance predictions and, to a lesser extent, the alternatives selected. The Panel agreed that the SRB model is not a substitute for conventional engineering and economic analyses and should not be a stand-alone analysis for selecting a recommended plan.

Economics: The Panel identified three major issues in the economic analysis: (1) inconsistencies in the Major Rehabilitation Evaluation Report and economic spreadsheet models; (2) the assumption that navigation would not be impacted; and (3) the formulation of the base condition. Inconsistencies in the report and economic spreadsheet models pertaining to the calculation of NPVs and AACs prevented the Panel from validating the economic analysis. Based on the assumption that navigation will not be impacted, a least cost analysis was used in lieu of a transportation cost savings analysis to calculate NED benefits. Conflicting assumptions concerning the ability to maintain navigation invalidate the logic behind calculating NED benefits using a least cost analysis. As the project is currently formulated, the base condition maintenance strategy for the MCR jetties conforms most closely with the fix-as-fails strategy, while the base condition life-cycle costs are the basis for estimating project benefits for all action alternatives. Inaccurate formulation of the base condition may increase life cycle costs, and may erroneously escalate project benefits. Each of these issues could impact the selection of the NED plan, which was selected as the recommended plan.

Engineering: There are serious technical difficulties with the Major Rehabilitation Evaluation Report and analyses. The report lacks a set of design criteria, including project life, standards of performance to be met, and environmental conditions with return period events. All are part of conventional coastal engineering design practice. The SRB model cannot be verified and does not include important processes. Major questions remain that have not been adequately investigated for this level of study, including subsurface geotechnical properties, feasibility of proposed barge offloading/material re-handling facilities, and the long term stability of the jetty foundations assuming continued erosion and loss of nearshore sediment. The report indicates that large volumes of sediment will move into the navigation channel after a breach event. However, the data and analysis do not support this conclusion. Additionally, is no clear discussion of the role of maintenance or emergency dredging, especially under extreme winter conditions. Detailed construction cost estimates also need to be provided in order for the cost analysis to be complete and verifiable. Although there is a good description of historical failures and repair actions for each jetty, there is no discussion or documentation of current jetty condition or detailed condition assessments of structure and functional condition.

Environmental: There is no discussion in the main report of sea level rise and potential wave height increases and its impact on this project over the 50+ year project timeline, given that the regional wave climate has been documented as more severe in the last 10 years. This has potential impacts to the project and in designing a project with lower long-term maintenance costs. Potential environmental impacts on sensitive species, upland habitats, and water quality as well as potential impacts to recreational use during project construction are not comprehensive nor adequately described in the mitigation plan. Finally, the alternatives are limited to armoring the existing configuration of the jetties and may not satisfy NEPA directive for alternative analysis.

Table 3. Overview of 25 Final Panel Comments Identified by the Mouth of Columbia River IEPR Panel

Significance – High	
1	The economic analysis used to select the National Economic Development (NED) plan cannot be validated, nor can it be determined if assumptions were applied correctly in the economic spreadsheet models.
2	The analysis of the sediment transport process is not comprehensive, and the data and analysis do not support the conclusions concerning large movement of sediment during a breach event.
3	The underlying assumption that navigational impacts will not occur is not substantiated.
4	The SRB model by itself has very limited value for analyzing alternatives and is not a substitute for conventional economic and engineering analysis.
5	The base condition, as formulated, does not represent the current O&M practice.
6	The reported analysis and design to mitigate a potential breach of the foreshore dune at the South Jetty root is not adequate.
7	The basis of design and design environmental criteria are vague, not consistent within the report, and not consistent with conventional coastal engineering design practice.
8	The models and analyses of jetty failure do not include all significant processes.
Significance – Medium	
9	The alternative selection process may fail to meet the requirements of NEPA Section 1502.14.
10	A failure analysis for the original structure design and past trends of Operation and Maintenance (O&M) costs has not been provided.
11	Sea level rise and potential increases in wave height have not been examined sufficiently under different model scenarios.
12	Construction cost estimates cannot be evaluated because the assumptions and details have not been provided.
13	Potential environmental impacts on sensitive species, upland habitats, and water quality have not been thoroughly discussed or specifically mitigated in the document.
14	Potential impacts to recreational use during project construction, as identified in public comments, are not adequately discussed or mitigated.
15	There is not sufficient information on the evaluation of barge offloading and material re-handling facilities to ensure these sites can operate as intended and to ensure the construction costs are adequately represented.

Table 3. Overview of 25 Final Panel Comments Identified by the Mouth of Columbia River IEPR Panel, continued

Significance – Medium	
16	The requirements, costs, and history associated with emergency dredging compared to scheduled maintenance dredging activities have not been specified.
17	The current jetty structure condition is not well described, making it difficult to confirm the confidence of the SRB model analysis and selection of a recommended plan.
18	The mechanisms causing jetty head scour have not been sufficiently analyzed to allow selection of the appropriate jetty head repair measure.
19	Risk thresholds for selected alternatives are not clearly defined.
20	It is not clear how uncertainty and derived risk analyses were considered in the structure and application of the model.
21	The model output parameters and wave height components are not clearly explained and supported.
22	The culvert installation details, as well as potential impacts, need further clarification.
Significance – Low	
23	The various base years cited in the report and the difference between project life and period of analysis require additional explanation.
24	Cargo tonnage and vessel trip statistics presented throughout the report are inconsistent.
25	Terminology related to jetty rehabilitation and failure is defined inconsistently or vaguely in some places.

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APPENDIX A

Final Panel Comments

on the

Mouth of Columbia River IEPR

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Comment 1:
The economic analysis used to select the National Economic Development (NED) plan cannot be validated, nor can it be determined if assumptions were applied correctly in the economic spreadsheet models.
Basis for Comment:
Economics is the key consideration in evaluating the NED plan, which was selected as the recommended plan. Several issues were identified in the review documents and the economic spreadsheet models that could significantly change the outcome of the economic analysis and the selection of the recommended plan. These issues primarily pertain to the calculation of net present values (NPVs) and Average Annual Costs (AACs), and the presentation of the economic analysis results. **Calculation of NPVs and AACs** • The AACs, based on the NPVs presented in Table 2-1 and Table 2-2, appear to be based on a Federal discount rate of 4.125%, not 4.375%, as stated in the report. • The calculation of the NPVs and AACs in the economic spreadsheet model for the North Jetty are based on a discount rate of 4.125%, not 4.375%, as stated in the report. • The period (actual calendar years) of the annual stream of costs used to calculate the NPVs for each alternative differ between alternatives in the economic spreadsheet models; also, the actual calendar years included in these periods were not stated in the report. • The unit costs for jetty repair and dredging, as presented in the SRB model, are increased over time such that after 50 years, costs will be 15% greater than at present. In accordance with ER 1105-2-100, p. 2-11 (USACE, 2000), when conducting economic analysis, prices should be held constant over the period of analysis. **Presentation of Results** • The NPVs and AACs in the spreadsheets for the North Jetty and South Jetty differ from the results presented in the report. • The term NED, the process of calculating NED benefits, and the method of selecting the NED plan are not explained in Section 2 or Appendix C of the report. • The SRB model uses Monte Carlo simulation to increase the confidence of life cycle estimates and allow for evaluation of variance by producing project cost output, including mean and standard deviation values (Appendix A2, p. A2-49). The risk and uncertainty associated with estimating the stream of annual costs and the resulting NPVs, AACs, and benefit-to-cost (B/C) ratios are not addressed in the economic analysis. • The costs of the NED plan of $250 million in the Executive Summary are presented on a fully funded basis, whereas the costs in the main report are presented as NPVs, resulting in confusion.
Significance – High:
The inability to validate the economic analysis and the assumptions used in the economic spreadsheet model could impact the selection of the NED, or recommended plan.

Recommendations for Resolution:
1. Calculate the NPVs and AACs using the FY10 Federal discount rate of 4.375% for all alternatives; basing the NPVs on the stream of project costs for the 50-year period of analysis. 2. In accordance with ER 1105-2-100, Chapter 2 (USACE, 2000), revise the formulas in the economic spreadsheet models to reflect the same period of analysis for all alternatives. 3. State the years (annual stream of costs) used in calculating the NPV for each alternative and ensure consistency in alternative evaluation. 4. In accordance with ER 1105-2-100, Chapter 2, p. 2-11 (USACE, 2000), revise the repair and dredging costs to reflect the general level of prices prevailing during or immediately preceding the period of planning for the entire period of analysis. 5. Revise Section 2 and Appendix C of the report to include a definition of the term NED, an explanation of the process of calculating NED benefits, and the method of selecting the NED the plan. 6. In accordance with EP 1130-2-500, Appendix B, p. B-9 (USACE, 1996), report the results of all alternatives in a table displaying the mean net benefits and standard errors of each; providing the 90% confidence interval for the mean net benefits (mean+ 1.64x standard error). 7. Present the costs of the NED plan in the Executive Summary and the main report in both a fully funded basis and in NPV.

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Comment 2:

The analysis of the sediment transport process is not comprehensive, and the data and analysis do not support the conclusions concerning large movement of sediment during a breach event.

Basis for Comment:

The report describes large volumes of sediment that will move into the navigation channel after a breach event. However, the Coastal Modeling System (CMS) numerical model results (CHL, 2007; p. 15, Figure 3.2) indicate minimal sediment movement through a jetty breach, even with the model strongly distorted to encourage movement. Similarly, historic breach events at the MCR inlet and region do not support the sediment movement volumes and rates assumed, nor the assumed sudden jetty failure, and the consequent requirement for emergency repairs and dredging.

The assumed jetty breach sediment movement is also inconsistent with recent experience with dredged material disposal at the North Jetty. Approximately 400,000 cubic yards were placed at the site each year during 1999-2008, on average, comparable to some jetty breach scenarios. However, the sediment placed at the North Jetty does not appear to have affected navigation. Similarly, the reported "rapid deterioration" of the North Jetty from 1999 to 2004, when 100,000 cubic yards of sediment leaked through the jetty leading to the repairs in 2005, is not consistent with the assumed scenario of a sudden breach event and large sediment movement.

Figures A1-252 to A1-254 of jetty breach sediment movement appear to be artist renderings, not products of analysis. The figures are misleading if they are interpreted as model output. Table 3-10 in the main report is presented but not explained, so there is no clear basis for the "Range of Volume Left in Channel" resulting from a breach of the North Jetty. There is no discussion of any hydrodynamic analysis or evaluation of morphologic changes and corresponding sedimentation of the navigation channel.

Significant inconsistencies are present in the sediment transport discussion. For example, the documents discuss sediment disposal practices at the shallow water site (SWS), immediately offshore from the tip of the North Jetty. The EA notes, "Active monitoring and evaluation determined that 80% to 95% of the dredged sand annually placed at the SWS moves northward onto Peacock Spit" (dispersed to the north). However, the main report describes how rip currents along the north side of the North Jetty transport sediment towards the tip and then south into the navigation channel. This implies an unrealistic discontinuity in the sediment budget and sediment paths immediately offshore of the jetty tip. The sediment budgets and analysis are not consistent in different parts of the review documents, and seem to vary depending on whether the analysis is centered on dredged material disposal (emphasizing sediment movement onto nearby shores) or jetty stability (emphasizing sediment movement towards the channel).

The jetties are described as functioning like "wingdams" preventing sediment movement into the channel. However, it seems more the case that the North Jetty shields the sands of Benson Beach from the dominant southwesterly waves preventing/slowing longshore sediment transport to the north, rather than south into the channel. Also, the process of sediment movement through a jetty breach is not at all like water through a dam break. The jetties are essentially a pyramid with only a small tip extending above water. What happens below water, with the sediments and foundations, is more central to the long term function and stability of the MCR jetties, navigation channel, and adjacent beaches.

A better analysis of sediment transport is needed because the repair alternatives at present are an ever expanding pile of rock on an ever shrinking foundation of sand. The geological history includes more than 225 million cubic yards of dredging since 1956 from the MCR navigation channel, with most disposed offshore (EPA, 2009). The Southwest Washington Coastal Erosion Study (Gelfenbaum, et al, 2006) concluded, "The carrying capacity of beach sands of Columbia River to the estuary has been reduced by approximately two-thirds over the last century." The missing sediment from the system and ongoing erosion of the shoals that help protect the jetties all point toward a need for a more rigorous investigation of sediment transport and alternatives that could reduce the loss of sediment and subsequent project O&M costs.

Significance – High:

The rehabilitation project will not be successful if ongoing sediment loss continues and the shoals and jetty foundation wash away.

Recommendations for Resolution*:*

1. Eliminate or justify the unrealistic assumption of sudden jetty failure and large volumes of sediment rapidly moving into the navigation channel. Instead, compare alternatives based on life-cycle costs including ordinary jetty repairs and maintenance dredging costs.
2. Provide a real analysis of sediment transport. Include review and reference to data and findings from maintenance dredging records and the studies of the MCR prepared for the multi-agency Southwest Washington Coastal Erosion Study.
3. Describe how implementation of this project will reduce ongoing erosion of the shoals.

Literature Cited:

CHL (2007). Analysis of Jetty Rehabilitation at the Mouth of the Columbia River, Washington/Oregon, USA, Part 2: Regional Circulation, Sediment Transport, and Morphology Change. Draft Report (K. J. Connell and J. D. Rosati). USACE Coastal and Hydraulics Laboratory and Portland District joint product, June.

EPA (2009). 2009 Annual Use Plan: Management of Open Water Dredged Material Disposal Sites, Mouth of Columbia River, OR and WA. http://www.delawareestuary.org/pdf/RSM%20Workshop/MCR_Site_Usage_Plan_2009.pdf

Gelfenbaum, G. R., Kaminsky, G. M., et al. (2006). Southwest Washington Coastal Erosion Study. U.S. Geological Survey Coastal and Marine Geology Program and Washington Department of Ecology – Coastal Monitoring & Analysis Program. http://www.ecy.wa.gov/programs/sea/swces/overview/findings.htm.

Comment 3:
The underlying assumption that navigational impacts will not occur is not substantiated.
Basis for Comment:
The report clearly explains why navigation benefits were not analyzed. The method used to calculate NED benefits is based on the assumption that navigation will not be affected; the economic analysis is therefore based on a least cost analysis. This assumption, however, is not supported by the analysis presented in the report. A North Jetty breach in the winter is assumed to result in immediate mobilization of sediment that may impact navigation. If this assumption is true, it does not necessarily follow that emergency dredging will successfully occur to enable deep draft vessel access. As stated on p. 3-14 of the main report, under base conditions, during winter months, emergency jetty repairs and emergency dredging may not be possible, potentially resulting in impacts to navigation until the emergency activities are completed. The main report also states (p. 1-48) that operating a hopper dredge at the MCR during winter months has not yet been attempted. The report does not address the impact of project construction and dredging activities on navigation. For example, the operation of a dredge in the MCR, especially under extreme winter conditions, could have an adverse impact on navigation in the MCR. The Panel was unable to fully understand the potential impacts on navigation of shoaling resulting from a jetty breach. Since navigation benefits were not evaluated, impacts to the MCR or Lower Columbia River (LCR) channels as a result of shoaling after a jetty breach, in the absence of emergency dredging, is only presented in qualitative terms such as “navigation would be significantly impaired” (p. A2-34). The extent of the impacts are not described (i.e., bar closure, vessels delayed due to having to use tides to access the channel, reduced under-keel clearances, vessel lightloading, etc.). Due to the dismissal of potential navigation impacts, no mitigation is defined.
Significance – High:
Conflicting assumptions concerning impacts to navigation invalidate the logic behind calculating NED benefits using a least cost analysis and impacts the selection of the NED, or recommended, plan.
Recommendations for Resolution:
1. Conduct a transportation cost savings analysis to calculate NED benefits. 2. Include a description of the expected channel depths available after a breach event, and in the absence of emergency dredging, include a description of the portion of the fleet using the channel that will be impacted by the resulting shoaling.

Comment 4:
The SRB model by itself has very limited value for analyzing alternatives and is not a substitute for conventional economic and engineering analysis.
Basis for Comment:
The SRB model results cannot be verified, as it is a custom-made engineering and economics model applicable only to this project and there is no means for the Panel to examine the inner workings of the SRB model and its internal calculations to assess its "adequacy and acceptability". It is not possible to verify model results, or to repeat the application of the SRB model because there is no User's Manual or detailed description of model inputs and how the model was applied for the Mouth of Columbia River project. Furthermore, the model has not been peer reviewed or tested. Without documentation of successful application, the Panel cannot validate the model or have confidence in the results. The SRB model internal calculations and logic are not a commonly applied method for calculating rubble mound structure reliability and damage. The model analyzes more than 600 variables, stacking process upon process, each with wide error bars, resulting in the accumulation of errors. Significant processes do not appear to be included in the model, such as armor rock breakage and deterioration and deep seated slip-circle failures. Figure A2-18a shows model output for jetty cross-section progressive damage. This figure provides one of the few insights into the inner workings of the SRB model. The figure indicates the physics and process of jetty decay are not modeled correctly because the output is not consistent with cross-sections of observed damage. The engineering evaluation does not include much about the physical modeling (i.e., wave tank results). It seems the wave tank model was used to develop the input and equations within the numerical SRB model. It is more conventional to proceed in the opposite sequence, to use a wave tank model to verify a final design concept and verify numerical model predictions. The wave tank model effort was substantial and likely yielded good insights. However, it does not appear that results were used to their fullest potential because the model output and findings were only applied through the SRB model process. The wave tank model results could have been used as part of an independent evaluation, providing an additional line of evidence along with other investigations, data, and findings. The SRB analysis should only be used as one of many tools in the alternatives evaluation rather than a substitute for the preliminary engineering design. Additional engineering analysis and design documentation needs to be provided as part of the preliminary engineering design report. Documentation through the preliminary engineering design process will lead to improved confidence and reliability of SRB analysis.
Significance – High:
The SRB model functions as a "black box" and does not allow an alternatives analysis that is clearly based on sound technical evidence of engineering design performance.

Recommendations for Resolution:

1. Move the SRB model to an appendix, as supplemental information, and assign it a weight of 10% in the evaluation of alternatives. No further work on the SRB model is recommended as part this project.
2. Include a detailed description of the SRB model application allowing verification of model calculations and how the model was applied to the Mouth of Columbia River project.
3. Demonstrate that the model has been peer reviewed and tested.
4. Move the calculations and elements of the study currently within the SRB model (such as rubble-mound damage, slope stability failure, design wave heights and water levels, economic calculations, and much more) out of the SRB model and provide as separate calculations that can be checked and verified.
5. Provide documentation of preliminary engineering analysis and design which would constitute the basis for the SRB analysis. The preliminary engineering analysis should be provided in the report, with details in appendices. Elements that appear missing or inadequate at this level of design include the following:
    - Design criteria and basis of design
    - Structure condition assessment and existing condition survey
    - Subsurface geotechnical investigation
    - Development of jetty repair/rehabilitation alternatives
    - Hydrodynamic analysis (waves, currents, sediment transport) specifically related to the alternatives
    - Determination of stone sizing for alternatives
    - Alternative evaluation
        - Development of evaluation criteria
        - SRB analysis
    - Detailed volume and cost estimate for the alternatives.

Comment 5:
The base condition, as formulated, does not represent the current O&M practice.
Basis for Comment:
The present and future base condition maintenance strategy for the MCR jetties, as currently described in the report, conforms most closely with the fix-as-fails strategy. Under this scenario, jetties will be allowed to deteriorate to the point that just-in-time repairs may not prevent a breach in the jetty, which would result in expensive, winter dredging activities. As the project is currently formulated, the base condition life-cycle costs are the basis for estimating project benefits for all action alternatives. Historical maintenance efforts for MCR jetties are best described by an interim repair strategy. As a result of monitoring and advance repair activities, historically there have been no jetty breaches that have impacted navigation, nor has winter dredging been needed to maintain navigation. EP 1130-2-500, Appendix C, p. C-1 (USACE, 2006) states that for Major Rehabilitation Projects, under the base condition, "maintenance is increased as needed (but within limits) and components or sub-features are repaired on an emergency basis. This essentially represents the current O&M practice." Based on the report, this condition would resemble an interim repair strategy, rather than the fix-as-fails strategy currently described as the base condition.
Significance – High:
Inaccurate formulation of the base condition may increase life cycle costs, and may erroneously escalate project benefits for all action alternatives thus impacting the benefit to cost ratios.
Recommendations for Resolution:
1. Refine the base condition to more closely resemble the current O&M practice, in accordance with EP 1130-2-500, Appendix C (USACE, 1996).

Literature Cited:

USACE (1996). Project Operations – Partners and Support. Department of the Army, U.S. Army Corps of Engineers, Washington, D.C. Engineer Pamphlet 1130-2-500. 27 December.

Comment 6:
The reported analysis and design to mitigate a potential breach of the foreshore dune at the South Jetty root is not adequate.
Basis for Comment:
Potential breaching of the foreshore dune at the South Jetty root, to form a new connection to Trestle Bay, is discussed briefly in a few places, including a proposed cobble berm to mitigate this risk in the main report (Section 3.5.3.3, pp. 3-40 - 3-41, p. 7-1 and elsewhere). Additional analysis is appropriate given the consequences of breaching at this location. It is not clear what analysis has been conducted to evaluate the performance of the proposed dune augmentation. It is not known if the volume of material per linear foot is sufficient to provide the required width of cobble beach for stable conditions upon adjustment after initial placement. Maintenance requirements are not known for this design. Studies by DOGAMI (Allen, 2005) have been conducted on dynamic revetments for shoreline stabilization on the Oregon Coast but do not appear to have been applied. The breaching potential will likely increase with increasing shoreline erosion and loss of sediment from the system. However, potential beneficial use of dredged sediment is not analyzed as part of a design solution for a breach. Long-term erosion trends are assumed and are not adequately addressed in the report. The information provided is inconsistent in this area, with some sections saying the South Jetty dune erosion/augmentation issue will be addressed as part of a separate project, whereas other report sections include South Jetty dune augmentation as part of this project. Foreshore dune breaching has occurred at other coastal inlet navigation jetty structures along the Pacific Coast such as the South Jetty at Grays Harbor, Washington. Beach renourishment with dredged material and jetty structure modification improvements to prevent dune breaching were made with varying levels of success. It is not clear whether these similar project conditions and performance have been evaluated as part of the development and analysis of alternatives at the Columbia River South Jetty location.
Significance – High:
Breaching the dune at the South Jetty root appears to be a substantial risk, with more immediate consequences than breaching of a jetty because of the potential for forming a new tidal inlet with relatively rapid widening and deepening.
Recommendations for Resolution:
1. Either include the South Jetty dune augmentation/stabilization as part of the alternatives, and include costs and preliminary engineering, or state that it is not an element of the proposed work and is part of a separate project. Either way, potential breaching scenarios should be evaluated/modeled and included in the sediment transport and hydraulic analysis. This major investigation is the logical place to add studies of the MCR system (including jetties, navigation channel, estuary, and beaches). 2. Account for long-term shoreline erosion/recession trends in the design.

3. Review other jetty rehabilitation project solutions and performance at coastal inlet navigation facilities such as those conducted at the Grays Harbor South Jetty (Wamsley, 2006).

Literature Cited:

Allen, J. (2005). Cape Lookout shoreline stabilization study: Don't take the cobbles. Cascadia, News from the Oregon Department of Geology and Mineral Industries (DOGAMI). Winter. http://www.oregongeology.com/sub/quarpub/CascadiaWinter2005.pdf

Wamsley, T.V., M.A. Cialone, K. J. Connell, and N.C. Kraus (2006). Breach History and Susceptibility Study, South Jetty, Grays Harbor, Washington. USACE, Coastal and Hydraulics Laboratory. Report ERDC/CHL TR-06-22. September. http://www.dtic.mil/cgi-bin/GetTRDoc?AD=ADA456060&Location=U2&doc=GetTRDoc.pdf

Comment 7:

The basis of design and design environmental criteria are vague, not consistent within the report, and not consistent with conventional coastal engineering design practice.

Basis for Comment:

The document “design_criteria_info.doc” is vague. It discusses “50 year alternatives,” but the term is not defined. It could mean many things, including the following:

1. The project life is 50 years, with complete replacement assumed after 50 years.
2. Design jetty repairs that have the least life-cycle costs over a 50 year period.
3. The economic planning horizon, benefits and costs, are calculated for 50 years.
4. Design to withstand a series of storms over a 50 year period.
5. Design to withstand a single 50 year return period storm event.

Section 3.5.2.1 (Cross Section Intent and Design Philosophy) states, “The repair template must … allow the maximum repair within funding limitations.” This indicates the main design criterion is to provide the most repair possible within a budget limit, rather than design to withstand environmental loads and forces. The “funding limitations” are not stated, yet appear to be behind many of the design and planning decisions. Using funding limitations as a design criterion is not the same as an engineered design that meets environmental loading criteria. The funding limits design criteria are not consistent with the environmental loading design criteria in “design_criteria_info.doc.”

Note that a 50 year project life does not necessarily mean one should apply a 50 year return period event for the design environmental criteria. For example, a petroleum development platform may have only a 35 year project life, but the project may be designed to withstand a 100 year return period storm event or longer. The consequences of jetty failure should be considered in establishing the design criteria. ISO standards are sometimes applied in practice, but do not seem to be included in this work. Additionally, USACE (1995; paragraph 2-4) states rubblemound structures should be designed to successfully withstand the conditions that have a 50% probability of being exceeded during the project’s economic service life. The economic service life needs to first be established as a criterion and then the design storm formulated to meet the acceptable risk level for that service life.

A span of 50 years may be appropriate for an economic planning horizon; however, a 50 year project life or a 50 year return period storm event does not seem reasonable for engineering design considering the importance of navigation through the MCR. The structures should be designed to last indefinitely, as permanent structures, with regular maintenance requirements estimated and included in an economic analysis.

The 50 year criterion may not be consistent with parts of the report that mention a longer period of time. The SRB model discussion in Appendix A2, p. 78 states, “The period of analysis for future condition simulations was 64 years (2006 to 2070) for the North Jetty and Jetty A and 63 years (2007 to 2070) for South Jetty.”

Appendix A2 (p. A2-8) states, “The MCR jetties were constructed to achieve an expected service life of 50-100 years,” and concludes that 0.7% per year is the expected maintenance cost based on the 50-100 years service life. The 50-100 years service life, and associated 0.7% figure is used to inform the analysis and to demonstrate a lack of maintenance. However, the original 50-100 years service life, and 0.7% annual expected maintenance cost are arbitrary assumptions. The historic assumed service life and maintenance needs are not supported by the information presented, and largely irrelevant to today’s design and maintenance criteria.

The design criteria, if any, from 100 years ago when the jetties were built are not presented and previous maintenance are considered an operational cost. Analysis of past maintenance also may distract from the main problem afflicting the jetties: poor design 100 years ago, not deferred maintenance.

The original builders, working before the development of modern coastal engineering methods, underdesigned the jetties with only 7 ton armor rock, at their angle of repose of 1.25h:1v, or steeper. In addition, they constructed the immense structures on ever shifting sand shoals, locating them where the shoal happened to be at the time of construction, without adequate design features to account for shifting channels and currents.

The starting assumptions and criteria and alternatives are so narrowly constrained that there is questionable value in much of the analysis. The Major Rehabilitation Evaluation study is set up so that the end result is always the same; more rock within the existing jetty footprint. Conventional coastal engineering practice for a project of this scope would include the following:

1. Analysis to determine how much jetty is really needed today to maintain the navigation channel at reasonable cost. The Panel questions whether all 9+ miles of jetty are optimal. There has been no upward trend in maintenance dredging volumes since 1956, despite continued jetty tip recession, which indicates shorter jetty lengths would be equally functional at less cost.

2. Evaluation of alternatives that are not constrained to the original footprint, not built to the maximum crest elevation and authorized length feasible, not constrained only to rock, and discussed or considered beneficial use of dredged material as a design element.

3. Evaluation of durability issues and lessons learned from related projects. For example, the Dover Pier in England has lasted well over 100 years. Similarly, the Humboldt Bay jetties and Crescent City jetties in Northern California have effectively stopped jetty head recession using 40 ton dolos concrete armor units, and the Japanese are building breakwaters with 90 ton dolos concrete armor units.

Significance – High:

The lack of criteria prevents NED analysis and evaluation of whether the structure design meets standards.

Recommendations for Resolution:
1. Establish conventional project criteria including project life, standards of performance and function to be met, and environmental loads and return period events, which are part of conventional coastal engineering design practice. Document in a Preliminary Design Report. 2. Establish Design Environmental Conditions that have a specific return period. 3. If unable to meet the design criteria due to budget limits, state the budget limits as a criterion, and estimate what the equivalent design life or expected performance will be for the compromised design. 4. Expand the starting assumption to allow: a. Beneficial use of dredged material as a component of jetty rehab. b. A design outside the existing jetty footprint c. A design that may allow jetty head recession up to a point when maintenance dredging needs increase. d. A design that can include a partially submerged jetty cross-section. 5. Use a longer return period than 50 years for the design environmental criteria and consider ISO standards. 6. Consult with Dover Pier representatives and other jetty builders to discuss durability issues and lessons learned from their project in order to benefit the MCR project.

Literature Cited:

USACE. (2005). Design of Coastal Revetments, Seawalls, and Bulkheads. Department of the Army, U.S. Army Corps of Engineers. Manual EM 1110-2-1614. June.

Comment 8:

The models and analyses of jetty failure do not include all significant processes.

Basis for Comment:

The SRB and STWAVE models cover many significant processes and variables that affect long-term jetty stability; however, some variables and processes are missing that should be presented in the SRB model and the Major Rehabilitation Evaluation Report:

- Armor rock breakage, rounding and wear, which can significantly affect jetty performance, do not appear to be included in the analysis.
- Deep seated slip surface failures through the jetty section, a global failure similar to a landslide, also do not appear to be analyzed and may be a significant risk.
- Wave height in combination with currents can cause significantly higher sediment transport rates than waves only or currents only. It is not clear if sediment transport analysis, considering both waves and currents acting together, has been done.
- Long-term changes in outlet channel morphology do not appear to be analyzed. The process of jetty decay through tidal channel scour appears different at Jetty A than at the North or South Jetties. Tidal channel scour at the tip of Jetty A will not be mitigated by adding spur groins, therefore a different system will need to be designed at Jetty A and accounted for in the jetty performance analysis.

The STWAVE model is not sufficient for modeling detailed wave transformations. Important processes such as wave structure interactions, refraction, and diffraction are incorporated in STWAVE using approximate methods. Other models like BOUSS-2D and CGWAVE are readily available and model the physics of these important processes more directly. STWAVE is appropriately applied as a regional wind-wave generation model for regions without a complex bathymetry. However, the Mouth of the Columbia River morphology near the jetties and navigation channel is complex. A phase-resolving wave transformation model such as BOUSS-2D or CGWAVE should be applied at this level of design in addition to STWAVE.

Significance – High:

The analysis of potential jetty failures, waves, currents, and sediment transport is incomplete for this level of design, and may result in significant errors in the evaluation of alternatives. Errors could include underestimating the design wave height, leading to undersized armor rock, excessive maintenance requirements and structure failure.

Recommendations for Resolution:

1. Estimate future repair needs and armor rock characteristics based on past performance of rock at the jetties. This requires a more detailed survey of existing condition, including quantifying existing armor rock size, gradation, and shape.
2. Analyze foundation stability based on measured geotechnical properties. A subsurface geotechnical investigation, including borings and soil testing, is recommended.
3. Provide a design concept for scour protection at Jetty A and check its stability against design environmental criteria, including specific current speed and wave height.

4. Apply models and use analysis methods to investigate sediment transport patterns and jetty foundation erosion under a combination of both waves and currents.
5. Supplement the STWAVE model with a wave transformation model such as BOUSS2D or CGWAVE to help determine design wave heights near the jetties.

Literature Cited:

Demirbilek; Z., and V. Panchang (1998). CGWAVE: A Coastal Surface Water Wave Model of the Mild Slope Equation. USACE Coastal and Hydraulics Laboratory, Report CHL-TR-98-26, 120 pp.

cgwave_man3.pdf (3 MB .pdf)

Nawogu; O. G., and Z. Demirbilek (2001). BOUSS-2D: A Boussinesq Wave Model for Coastal Regions and Harbors - *Report 1: Theoretical Background and User's Manual*. USACE Coastal and Hydraulics Laboratory, Report ERDC/CHL TR-01-25, 92 pp.

BOUSS-2D.pdf (2.2 MB .pdf)

Comment 9:
The alternative selection process may fail to meet the requirements of NEPA Section 1502.14.
Basis for Comment:
The design alternatives presented in the document are limited to the repair and rehabilitation of the jetties within the present configuration. The Panel is concerned about the adequacy of the alternatives analysis and the limited range of alternatives considered. NEPA Section 1502.14 requires a rigorous examination of all reasonable alternatives to any proposal and justification of eliminated design alternatives. The Panel finds that there is little examination of alternative approaches to the principal function of the MCR jetties, which is to secure a consistent navigation channel across the bar at the MCR. As such, the narrow scope of alternatives presented weakens this project. Insufficient information is provided to justify limiting the improvements to the existing footprint. For example, the report does not provide the technical basis for maintaining the 1895 jetty design, length, and orientation to the exclusion of considering other configurations. Considering reasonable alternatives, under NEPA guidance, would allow USACE to use hydrodynamic modeling tools to evaluate alternatives such as the use of weir jetties (Seaburgh, 2002) and other sediment management methods that facilitate bypassing sediment at coastal inlets, as well as low wave and high wave depositional basins in a manner which may reduce long term operation and maintenance costs. The impact of not considering additional alternatives leaves the overall justification of the project less defensible and may lead to questions of the overall merit of the rehabilitation project
Significance – Medium:
Consideration of alternatives beyond rehabilitating the original jetty structures within their existing footprint would comply with NEPA directives, and provide critical information that may reduce long-term costs and improve jetty life and efficacy.
Recommendations for Resolution:
1. Assess, and validate or reject, the technical basis for the initial jetty design, length, and orientation using appropriate physical coastal process models. 2. Assess structural efficacy and cost of alternatives which are not constrained by the existing footprint. 3. Develop modeling efforts for hydrodynamic models and/or sediment transport models that would provide insights into the following areas: a. Thorough analysis of the existing jetty structures focusing on why some areas have survived without repair and others have needed repeated repairs b. Examination of why Jetty A had such a large O&M cost relative to predictions. c. Addition of subsurface berms potentially created through the beneficial use of project dredged material that may reduce wave impact and subsequently reduce wave overtopping and toe scour.

Literature Cited:

Seaburgh, W. C. (2002). Weir Jetties at Coastal Inlets: Part 1, Functional Design Considerations. U.S. Army Corps of Engineers, ERDC/CHL CHETN-IV-53. December.

Comment 10:
A failure analysis for the original structure design and past trends of Operation and Maintenance (O&M) costs has not been provided.
Basis for Comment:
The extent of structure failure or partial failure is well documented and the repairs made to the structure are well documented, as shown in Figures 1-12, 1-15, and 1-16. These figures, however, do not distinguish between areas repaired and areas that are substandard but have not failed and so were not actually repaired. Failure analyses for the groin tips and the runnel formation weakening Jetty A (p. 3-5) are presented, but the report does not include a general failure analysis. A failure analysis would be helpful in determining why one section of jetty failed/degraded whereas another remained intact. This information is needed to derive alternatives that resist both degradation and failure, and result in an informed design of jetty repairs. Maintenance histories (Figures 1-21 through 1-23) show that actual O&M costs have trended significantly above and below the expected O&M costs, based on annual expenditures equivalent to 0.7% of the initial construction costs. Specific causes of actual O&M costs being higher or lower than the assumed 0.7% annual average cost have not been analyzed but can be presumed to be directly related to full or partial failure of portions of the structures. Knowledge of the specific causes of failure combined with the cost of constructing a jetty resistant to these causes taken in consideration of maintaining a jetty less resistant to these causes may be useful in determining or presenting the most cost effective alternative design. A specific presentation of individual jetty failure events would serve to bolster the alternative selection process and the projections of future maintenance costs.
Significance – Medium:
Uncertainty regarding the specific causes of failure and their relationship to trends of past O&M costs creates a functional uncertainty in the corrective measures in the alternatives for repair and rehabilitation.
Recommendations for Resolution:
1. Include an analysis of the causes of failure for each repair event (e.g., Figure 1-15) even if only a statement of "storm intensity" in order to provide assurance that the repairs address the actual causes of previous jetty failures. 2. Relate construction costs of more resistant designs to repair costs of less resistant designs for each causal condition of failure and the associated selected alternative.

Comment 11:
Sea level rise and potential increases in wave height have not been examined sufficiently under different model scenarios.
Basis for Comment:
The issue of climate change, sea level rise, and increased wave action is important to consider in the evaluation of long-term projects (USACE, 2009). There is no discussion in the main report of sea level rise and its impact on this project over the 50+ year project timeline. There is a limited discussion of climate change in Appendix D (p. 5), where the conclusion is that since the projected historical trend of sea level at the project site is estimated to be -0.05 feet in 50 years, sea level rise is not projected to be a significant climate change factor at the project site. Appendix D states the "comprehensive analysis of historical storm events is expected to adequately capture the present deep water contribution of potential wave height variation for this project site. The above approach forms the basis for estimating the potential changes in wave climate that could affect the MCR jetty system." However, this discussion on wave height trends is not compelling. The main report states (p. 1-6), "As the tidal shoals continue to recede (erode), the MCR jetties will be exposed to larger waves and more vigorous currents. To make matters worse, the regional wave climate along the Northwest Pacific Coast has become more severe in the last 10 years. The offshore 100-year wave height has been revised from 41 to 55 feet." (see also Appendix D). The main report states (p. 3-42), "The limit of cross-section resiliency is reached for jetties when the core stone becomes exposed to wave attack." Therefore, this issue may affect jetty erosion and a larger range of wave heights should be included in both the SRB and STWAVE model scenarios. Wave overtopping is central to the environment deteriorating the existing jetties. As the planning horizon of this project is 50+ years, it seems that a discussion would be useful of sea level rise and modeling potential wave heights and the wave overtopping impacts on the jetties given different rates of recession under a wider range of wave heights. Jetty height and crest elevation are variables that should be modeled given the potential larger wave heights possible under sea level rise. Although the selection of the recommended plan may not change, long-term maintenance costs may be affected, therefore consideration is warranted. Appendix B states that transient internal hydraulic effects of wave impact may be the most important parameter in the stability of the jetties. However, it is the least certain of all of the parameters. Internal hydraulic pressures in jetties have not been measured. Given this, it seems especially important to consider more extreme wave heights beyond the wave height analyzed, with respect to sea level rise and potential increasing wave height.
Significance – Medium:
The discussion of potential impacts of sea level rise and increased wave action on jetty structures is critical to understanding the potential impacts to the project and in designing a project with lower long-term maintenance costs.

Recommendations for Resolution:
1. Add a separate section to the Major Rehabilitation Evaluation Report that examines climate change, sea level rise, potential wave height changes, and resulting wave overtopping impacts on the jetties given different rates of recession under different model scenarios.

Literature Cited:

USACE (2009). Water Resource Policies and Authorities Incorporating Sea-Level Change Considerations in Civil Works Programs. Department of the Army, U.S. Army Corps of Engineers, Washington, D.C. Engineer Pamphlet EC 1165-2-211. 1 July.

Comment 12:

Construction cost estimates cannot be evaluated because the assumptions and details have not been provided.

Basis for Comment:

A detailed construction cost estimate summary should be provided for the recommended plan, otherwise the basis for the total cost values provided in Section 6.5.9 cannot be reviewed and assessed to determine if they are realistic and complete. The cost estimate information provided in the main report (Section 6.0) and in Appendix E is not sufficient to support the recommended plan:

- Table 6-3 provides a detailed summary of stone volumes for each jetty by construction year, but there is no correlation with construction costs or to the cost estimates provided in Section 6.5.9 or Appendix E.
- Specific cost estimating details are provided in Sections 6.5.7 and 6.5.8, but the assumptions and criteria defining the basis for the cost estimates do not include any summary unit costs for the individual work items.
- Unit costs are provided in Tables A2-9 to A2-11 but pertain to the SRB modeling effort. There is no discussion regarding how they relate to the final project costs presented in Section 6.5.9.
- Appendix E includes budget summary costs for construction, planning/engineering, construction management, and land acquisition. Detailed cost estimates for the Civil Works construction budget numbers are not provided and the basis for the costs cannot be reviewed or verified.
- Costs for the barge offloading and material re-handling area facility installation and maintenance are not described, yet they could be a large direct and indirect cost to the project based on wave exposure (for type and size of barge offload facility structures). The structural requirements (and corresponding construction costs) for an exposed vessel berth will be many orders of magnitude larger than the same berth in protected waters. Stone delivery cost represents a very large percentage of the total cost. Ensuring a cost feasible method of delivery to the jetty structures is critical for development of an accurate cost estimate.

Significance – Medium:

Detailed construction cost estimates need to be provided in order for the cost analysis to be complete and verifiable.

Recommendations for Resolution:

1. Provide a detailed cost breakdown by work item for the Civil Works project item, Breakwater & Seawalls. Provide detailed cost estimates for each major element of work (e.g., mobilization, stone supply and install, site preparation, material re-handling facility installation, maintenance of re-handling facilities, etc.). Give details regarding work item quantity, unit costs, contingency, and escalation.

2. Provide a detailed cost summary within Appendix E, and an additional detailed description of the basis for the costs estimates in Section 6.
3. Conduct an additional investigation of re-handling facility requirements to adequately determine the costs for facility installation and maintenance.

Comment 13:
Potential environmental impacts on sensitive species, upland habitats, and water quality have not been thoroughly discussed or specifically mitigated in the document.
Basis for Comment:
Appendix D and main report (pp. 5-17--5-20) list potential in-water, wetland, and upland impacts. These impacts should be addressed in the mitigation plan. The mitigation plans currently address these three general categories, but do not provide mitigation for potential impacts to specific species, upland habitats and water quality. The mitigation plans are incomplete because the final wetland delineation for the project has not been conducted, and the impact to wetlands and upland habitat is uncertain and therefore not quantified. A vegetation restoration plan is needed to address potential impacts to upland habitats, especially the rare and vulnerable species discussed below. At a minimum, the mitigation plan should state that these plans will be prepared prior to construction activities. Although the extent of the upland impact on this habitat is uncertain, a replanting contingency plan and a clear plan for avoidance are important to include in the mitigation plan. Similarly, potential water quality impacts from spills should be addressed in the mitigation plan with a statement about the spill prevention plan, as discussed below. Section 5.1 (Environmental Effects) of the main report provides details on biological resources, but is missing a vegetation section. Appendix D contains two reports including the Wetland and Waters of the U.S. Delineation Report and The Plant Communities Investigation Report, April 2007, which provides details on the vegetation communities; however, this information is not presented in the main report and therefore the main report lacks a definition of the plant species of concern within the project area. The revised EA states (p. 6) that at least three of these vegetative communities (shorepine-slough sedge, shorepine-Douglas fir, and coast willow-slough sedge) "have been ranked globally and by the State for their rarity and vulnerability to extinction and should be protected from impacts." This information on sensitive species should be integrated into Section 5.1. Furthermore, potential land construction activities as shown on Figure 5-1 of the main report may affect plant communities, including sensitive habitats, warranting a discussion of existing vegetation in the project area. Vegetation impacts that may result from construction are not detailed in the document, and just briefly mentioned in regards to the South Jetty. Mitigation plans should include specific protective measures to avoid potential impacts to these rare and vulnerable species. In general, the main report discusses Endangered Species Act (ESA) species, but does not provide detailed data on specific animal or plant populations. In 2005, critical habitat was designated for all Columbia River steelhead and Columbia River salmon evolutionarily significant units (ESU), with the exception of lower Columbia River coho salmon ESU. Although a wide range of potential impacts are discussed (p. 5-16), ranging from loss of habitat to an increase in perching and in-water habitat for predators that prey on listed species, the mitigation section of the Major Rehabilitation Evaluation Report does not address these impacts. The main report concludes (pp. 5-19 – 5-20) that there will be overall benefits to these species from this project. Additional details would be helpful to ensure that these species suffer no impacts. The Panel realizes that as a specific mitigation plan is developed, this may

likely be incorporated.

Water quality may also be affected over the project duration due to the large volume of container ships, construction dredges, barges, and cruise ships operating in the area, sometimes in adverse extreme weather conditions. For example, there may be a loss of hydraulic fluid or oil spills (p. 3-70). In the discussion of the mitigation plan in Section 5.4 (p. 5-17), the increased risk of pollutant release and spill potential is raised as a potential impact on ecosystem function. A sentence earlier in the document (p. 5-2) states that the Contractor "will provide a spill prevention plan to include measures to minimize the potential for spills and to respond quickly should spills occur." This sentence belongs in Section 5.4 of the main report as well.

Any history of spills in the Mouth of Columbia River area should also be reported in the document. Providing these details will enable a more thorough analysis of environmental impacts and enable additional protective actions to be implemented.

Significance – Medium:

Additional biological resources data and potential impacts to sensitive species, upland communities and water quality is needed to adequately protect the environment and define the mitigation needed to reduce these impacts to less than significant.

Recommendations for Resolution:

1. Incorporate additional information into Section 5 of the report:
   a. A vegetation section defining the sensitive species within project area.
   b. A statement to ensure that stockpiling activities shown in Figures 5.1 – 5.3 of the main report minimize the land impacts to sensitive habitats and wetlands. State whether a survey will be conducted prior to construction activities with sensitive habitats flagged to ensure avoidance.
   c. Provide detailed data on specific animal or plant populations that are listed species
   d. Specific text in the mitigation section for potential impacts to steelhead and salmon.
2. Add the wording from p. 5-2 into Section 5.4 of the mitigation plan regarding the contractor's requirement to prepare a spill prevention plan to address potential water quality impacts. Document any known history of spills in the area.

Comment 14:
Potential impacts to recreational use during project construction, as identified in public comments, are not adequately discussed or mitigated.
Basis for Comment:
The Major Rehabilitation Evaluation Report does not provide detail on the impact of the project construction activities on recreational use, an issue that came up in public comment letters (main report, Section 5.4). The last sentence in Section 5.3 states that there will be no significant impacts on recreation. Appendix C states that there is a growing cruise ship industry and it is unclear how construction activities will affect passenger cruise ship access. On p. C-3 it states that 5/7 day cruise ship tours carry 15,000 passengers annually, and thousands of tour boat passengers take day trips and dinner cruises. These activities generate about $15 to $20 million in revenue annually for local economies. Public access during construction may be an issue. In addition, other recreational uses of the area may be reduced, such as kayaking and hiking. These impacts should be defined, rather than concluding that no recreational or economic impacts to tourism are expected. Omitting this issue may lead to unforeseen consequences for the cruise ship and tourism industries.
Significance – Medium:
Recreational impacts are not adequately presented in the report and subsequently, no mitigation is identified for this potential impact.
Recommendations for Resolution:
1. Add a discussion of the cruise ship industry and other recreational uses at the project site. 2. Examine potential impacts on cruise ships and other recreational activities that may result from the dredging operations and jetty repair operations. 3. Provide potential mitigation options to reduce recreational impacts to less than significant levels. 4. Make a distinction between recreational impacts during construction and after construction.

Comment 15:
There is not sufficient information on the evaluation of barge offloading and material re-handling facilities to ensure these sites can operate as intended and to ensure the construction costs are adequately represented.
Basis for Comment:
Contract-provided barge offloading facilities for the South and North Jetties are described in Sections 6.3.3 and 6.3.4 and shown in Figures 5-1 and 5-3 of the main report. Based on the information presented, it is not clear that these sites have been adequately investigated and are suited for their intended use. The barge offloading and material re-handling facilities at these outer exposed locations should be further investigated to ensure they are economically and operationally feasible. The proposed facilities are referred to as "temporary," but this is questionable if they will be in place for 20 years. The life-cycle costs of the docks and other structures are not trivial and do not seem adequately analyzed. The largest cost and a substantial risk for the recommended plan involves the purchase, transportation, delivery, and offloading of the stone in a very difficult environment over a relatively long time. The USACE-provided sites also need to be operationally feasible in order to use a permitted method of delivering material to the site. Providing contractors with better information on the limitations and usability of these sites at the time of bidding could result in substantial cost savings. There is no discussion in the report of any engineering work performed to evaluate the feasibility of installing structures at these exposed locations, nor any mention of operational feasibility for the size of vessels and wave climate for the periods of construction. These locations are subject to wave heights of more than 15 feet, which will impose very large wave impact loads on fixed structures (dolphins and sheet pile walls), resulting in high risk and cost facilities. USACE intends to permit these sites and provide them to the contractor as the primary point of access. This establishes a certain level of perceived usability to bidders. If they are later determined not to be feasible (i.e., during contract bidding or during construction), it would result in substantial cost and schedule changes. Use of the re-handling facilities will be limited to a "summer" work period (April to October). There is no analysis of sedimentation rate in the report to verify whether the floatation channels will remain open for the summer construction work period. Maintenance dredging estimates for barge offloading facilities are provided in Table 6-1, but it is not clear for what time period (annually or total over the entire duration of the project). Jetty A is listed at 80,000 cubic yards for maintenance dredging. Other options, such as dredging within the Ilwaco channel to the trunk end of Jetty A and developing an offloading facility adjacent to the staging area could be considered.
Significance – Medium:
Insufficient information on the limitations and usability of the offloading and re-handling sites could affect construction cost estimates and project schedule due to operational and physical environment constraints.

Recommendations for Resolution:
1. Conduct a feasibility level engineering analysis and design for the contract-provided offloading and rehandling sites to ensure that selected sites and facilities are feasible and provide reliable estimates of construction cost. The feasibility evaluation should at a minimum include the following: a. Evaluate feasibility of constructing pile supported structures within an extreme hydrodynamic environment. This includes wave/current loads on moored vessels during the construction period and wave/current loads berth structures during extreme winter conditions. b. Evaluate downtime of barges at the proposed sites relative to the wave and current climate during the proposed construction work period. c. Refine the type of structure that is feasible for these locations for inclusion into project permits and cost estimates. 2. Evaluate the need for alternative barge offloading and material re-handling site locations based on the results of the feasibility analysis. 3. Evaluate design concepts for permanent barge/dock facilities, possibly incorporated into the inside face of the jetties near their root. 4. Develop environmental data specific to the proposed offloading site locations for bidders/contractors to use in developing their estimates of downtime and infrastructure requirements at USACE provided rehandling sites. Extreme event offshore wave data and jetty structure design criteria will not be sufficient for contractors to use in evaluating short-term operational and design requirements.

Comment 16:
The requirements, costs, and history associated with emergency dredging compared to scheduled maintenance dredging activities have not been specified.
Basis for Comment:
Dredging is a substantial component of this project and has been historically, yet there is no clear discussion of the role of dredging in the Major Rehabilitation Evaluation Report. Typical annual dredging rates are not presented in the document itself, although Appendix A1 (p. A1-3) states, “Each year, the Portland District dredges 3 to 5 million cubic yards (MCY) of sand at MCR to maintain the 5-mile long deep draft navigation channel.” It is unclear if the Portland District dredging is conducted exclusively at MOCR. Analysis of the project area maintenance dredging requirements – past, present, and future – have not been presented. Controlling dredging costs is critical to this project. The EPA publishes a report annually analyzing dredged sediment disposal in the nation. About 4 million cubic yards is dredged at the MCR every year at an annual cost of about $10 million. The fact that maintenance dredging volumes in the project area have not increased (no clear trend) since 1956, despite ongoing jetty tip recession, raises the question of how much jetty is now needed to maintain the MCR navigation channel. However, the main report does not discuss details of the maintenance dredging. Appendix B states the geological history includes 225 million cubic yards of dredging from the MCR navigation channel since 1956. The volumes, history, and fate of these dredged sediment volumes should be described in the main report and are missing from the analysis. The fact that most of this sediment was dumped far offshore and lost to the nearshore may have something to do with the erosion experienced in the area. This large quantity of dredged material warrants discussion and additional consideration of strategies to reduce this volume. The discussion of emergency dredging is also lacking in the main report. The historical downtime for dredging at the dock and jetty repair work during the time period of October to March (peak period for large waves) is not provided. Page 3-70 states, “Given the winter wave conditions that the dredges would be performing in, it is highly likely that damage would occur to the drag arm of the dredge while working.” Page A2-65 states that within the SRB model “there is a 0.3 probability that one dredge will lose a drag-arm while performing dredging during winter or a 0.7 probability that one dredge would realize equipment damage,” thereby increasing dredging costs. Several places reference the difficulty of dredging in the winter. Conditions may preclude effective dredge use, or the dredge may break and become inoperable, suggesting dredging may be postponed until summer. In terms of dredge operation, p. 1-48 gives the operational limitations of hopper dredges, and admits that operating a hopper dredge at the MRC during winter months has not yet been attempted. Therefore, the inadequate demonstration of equipment effectiveness, lack of documentation of the basis of dredge damage probabilities, and lack of historic utilization increases the risk associated with estimating costs associated with emergency dredging. The document states on p.1-50 that the rate of shoaling within the MCR channel would not be high enough to require emergency dredging; therefore, the increased shoaling volume could be dredged the following summer and would not be considered emergency dredging. The

document never presents operational triggers for when emergency dredging would occur.

The main report indicates that there are four dredges capable of working in winter (p. 3-111), but these dredges are not mentioned earlier, when it was presented that only one or two dredges are available in the short term. A discussion of emergency dredging history, success in other areas, and a description of the equipment available is warranted.

The analysis considers long-term O&M costs of dredging, but does not explain the criteria used in the calculation estimates.

There is no mention of any historic environmental impacts from the dredge operations, such as spills. If spills have occurred, data should be presented.

Significance – Medium:

Additional information on dredging may enable better analysis and lead to a long-term reduction in dredging costs and the development of a contingency plan to successfully avoid navigation impacts.

Recommendations for Resolution:

1. Develop a paragraph on dredging in the main report that specifies clearly what the maintenance dredging program has been, rates, and frequencies, and if they are scheduled or "as needed." Present all the historic maintenance costs, schedules, and frequencies.
2. Provide a detailed history of emergency dredging with success and failures and costs.
3. Add information to specify what rate of shoaling requires emergency dredging compared to scheduling maintenance dredging activities.
4. Present the criteria used in the calculations of dredging O&M costs.
5. Provide any information on historic spills related to dredging operations.

Comment 17:
The current jetty structure condition is not well described, making it difficult to confirm the confidence of the SRB model analysis and selection of a recommended plan.
Basis for Comment:
Although there is a good description of historical failures and repair actions for each jetty, there is no discussion or documentation of current jetty condition or detailed condition assessments of structure and functional condition. A condition assessment of each jetty structure should be conducted through a combination of visual inspection (stone size, gradation, slope defects, stone defects, loss of armor stone, core exposure, etc.) and evaluation and comparison of historical electronic surveying results (single beam, multi-beam, or side scan sonar data). These elements will provide the basis for determining the present condition, assess risk of current condition to failure, and help classify structure along various reaches of each jetty. These data would enable better assessment of vulnerabilities, analyzing why some areas in the jetty have maintained without repair and other areas have needed multiple repairs. A better understanding of these dynamics may reduce O&M costs over the long term. Rubble-mound structures have a tolerance for deterioration before suffering catastrophic failure. A thorough understanding of current and historical structure condition is critical to developing an estimate of the mechanisms causing failure, establishing the timeframe for catastrophic failure, and conducting maintenance/repair work. The SRB model evaluation of alternatives using the base condition depends upon an adequate understanding of current jetty conditions and corresponding impact on estimated future repair and maintenance. The current SRB analysis is based on a "hindcasting" of jetty performance relative to historical performance, but without consideration of the details of condition and causes of failure. The current and historical condition relative to structural and functional rating should be conducted following USACE procedures (USACE, 1998) to establish the baseline conditions for the SRB model analysis. Evaluation of stone source and quality relative to length of service on the structure should be conducted as part of the jetty condition assessment.
Significance – Medium:
A detailed description of the current jetty structure as part of a condition assessment is necessary to understand the accuracy of the SRB model.
Recommendations for Resolution:
1. Conduct a detailed condition assessment of each jetty structure, including visual inspection and historical survey comparison. 2. Compare historical survey data for the validation of interpreted historical conditions and corresponding perceived modes of failure. Incorporate results into the development of baseline conditions for the SRB model. 3. Use a condition rating system such as that outlined in the USACE Manual REMR-OM-24 (USACE, 1998) for evaluation of current condition. Assess both the structural and functional condition of the structures and incorporate the results into the SRB model analysis.

4. Incorporate the results of the condition assessment into Section 1.4, description of project history.
5. Provide an additional description of existing condition in Section 1.4 and 3.3.2 of the main report, including the service life of stone sources used for previous repair and maintenance activities.
6. Based on the results of the condition assessment, the relation between the stone sources reviewed (in Appendix B, Section 5) and the corresponding observed service life of that stone should be discussed and incorporated in the SRB analysis.

Literature Cited:

USACE (1998). Condition and Performance Rating Procedures for Rubble Breakwaters and Jetties. REMR Management Systems—Coastal/Shore Protection System Devices. Technical Report REMR-OM-24, U.S. Army Corps of Engineers, Washington, D.C.

Comment 18:

The mechanisms causing jetty head scour have not been sufficiently analyzed to allow selection of the appropriate jetty head repair measure.

Basis for Comment:

Causes of jetty head scour have not been sufficiently investigated. Tidal shoal and outlet channel geomorphic processes should be further evaluated and analyzed to ensure that proper jetty head repair measures are selected. The mechanisms causing the "scour holes" and undermining of the jetty in the vicinity of the jetty tips (North Jetty and Jetty A) have not been sufficiently analyzed for selection of the jetty head repair measure. Figure A1-32 indicates a progressive erosion of ebb tidal shoals in the vicinity of the North Jetty (between Stations 60 and 90) undermining the south toe of the structure.

The report understates the situation when it notes (Appendix A1, p. 28), "If the jetty foundation washes away, jetty reconstruction is problematic." A solid understanding of the environment and bathymetry changes is essential for development of a reliable design alternative.

Spur groins installed along the south slope of the North Jetty will assist in addressing scour generated by localized currents, but will not provide protection from overall MCR tidal shoal and channel morphological changes. Continued ebb shoal erosion and potential tidal channel movement could undermine the head of the proposed offshore spur groins (located near Stations 90 and 70).

It seems likely that scour holes are related to the observed jetty tip recession. The 100 foot deep scour hole at the end of Jetty A is particularly alarming from a structural design perspective. Equally alarming is the discussion of "Vertical scour along the toe of the MCR jetties has exceeded 10 meters in some reaches" (Appendix A2, p. A2-11). If there really is, or was, a more than 30 foot high underwater scarp in places along the toe of the jetties, then more investigation is warranted.

Figures showing typical sections often do not extend to the toe of slope, and show details that aren't feasible, such as rock limits ending in a small angle without an engineered toe. (See Appendix A1, Figure A1-258).

Strategies to deal with scour, especially at the jetty tips appear undeveloped. Design features could include scour blankets, launched toes, or a program of regular fill using dredged material.

Significance – Medium:

Inadequate evaluation of the geomorphic processes responsible for the deterioration at the jetty tips (North Jetty and Jetty A) could lead to an incorrect approach to rehabilitation of those areas of damaged structures.

Recommendations for Resolution:

1. Conduct a more detailed evaluation of historical geomorphic changes in the outlet channel and shoals in order to evaluate tidal shoal erosion and tidal channel migration. Comparative analysis of historical bathymetric surveys would be helpful in developing a better understanding of historical trends and associated correlation with jetty structure historical damage, failure, and repair activities. Additionally, use historical geomorphic change analysis and hydrodynamic analysis to estimate long- term changes and impacts to the North Jetty and Jetty A to formulate jetty head rehabilitation alternatives and development of design criteria.
2. Do not limit the jetty repair preliminary designs to the footprint of the authorized jetties. Evaluate scour protection alternatives extending past the jetty tips.
3. Draft plans, profiles, and sections at this level of design using suitable software, such as AutoCAD® or MicroStation®. Microsoft Excel® is not an adequate substitute for drafting software.
4. Draft the jetty design typical sections to scale and extend past the scour holes and navigation channel.
5. Conduct a subsurface geotechnical investigation to obtain the geological properties needed to verify or design an adequate foundation.

Comment 19:
Risk thresholds for selected alternatives are not clearly defined.
Basis for Comment:
Risk thresholds are used in repair frequency predictions as triggers for maintenance response and subsequently in maintenance cost predictions. The frequency of reaching degradation thresholds is predicted by risk thresholds. Combining degradation thresholds with repair costs (minor vs. major) can also be used to determine the threshold for triggering maintenance actions, balancing multiple small repairs against the cost of a single major repair. The Major Rehabilitation Evaluation Report includes extensive discussions of risks related to different portions of the project; however, while this discussion of risk is extensive, defined thresholds are not presented in the document. It is to be expected that the risk (probability) of surpassing thresholds may vary among alternatives in both configuration (number and placement of spurs, jetty length) and in cross sections considered. The risk associated with each alternative considered should be assessed based on materials, cross sections, supporting geological features, currents, and storms. It is also proper procedure to examine how the risk of one design component may be altered by the inclusion or exclusion of a second design component.
Significance – Medium:
Undefined risk thresholds may serve to undermine the logic of the cost and maintenance predictions and, to a lesser extent, the alternatives selected.
Recommendations for Resolution:
1. Define risk thresholds for alternatives, including source of risk and effect of exceeding the threshold.

Comment 20:
It is not clear how uncertainty and derived risk analyses were considered in the structure and application of the model.
Basis for Comment:
Project life-cycle cost analyses should consider the risk of construction cycle and operational cycle downtime, which does not appear to be included. However, risks cannot be evaluated without understanding the level of uncertainty associated with the SRB model result. The uncertainty associated with actual future conditions, which may deviate from the modeled future conditions, is not apparent. The SRB model includes 600 variables (Section 9, p. A2-91) each of which has a data set which can be expected to reflect an associated variance. Depending on the calculation stream, these variances, applied geometrically, will lead to accumulated statistical errors and uncertainties. These cumulative internal variances can be expected to result in high uncertainty in the output of the SRB model, which should be considered in the evaluation of alternatives.
Significance – Medium:
Potentially wide error bars (uncertainty) may compromise life-cycle maintenance and repair schedules.
Recommendations for Resolution:
1. Quantify and explain the uncertainty (i.e., error bars) associated with each variable when analyzing processes that involve a chain of events. 2. Identify, analyze, and define errors that may accumulate to assess model reliability.

Comment 21:

The model output parameters and wave height components are not clearly explained and supported.

Basis for Comment:

The meaning of the following SRB model output parameters is not clear:

- Functional Reliability
- Structural Reliability
- Probability of Unsatisfactory Structure Performance.

For example, the main report (Section 3.6.1, p. 3-43) includes the following: "Functional reliability is the likelihood that a structure will satisfactorily perform its intended function within a given time interval. Functional reliability is derived by combining structural reliability metrics with metrics that describe the present structure cross-section configuration." One difficulty is that the understanding of "Functional Reliability" requires first understanding "structural reliability metrics", (which are not to be confused with "metrics that describe the present cross-section configuration"). However, the "structural reliability metrics" are not clearly defined either. A word search of Appendix A2 for the term "Structural Reliability" does not reveal a set of equations for calculating the parameter or a clear explanation.

Similarly, much of the SRB model includes terminology and variables that are hard to understand. For example, Table A2-12, Jetty Maintenance Thresholds, (p. A-60) consists of numbers and parameters not connected to anything that has a physical meaning. Conventional calculations and metrics such as volumes, areas, and depths are parameters with physical meaning that would improve the understanding of the SRB model. Understanding the SRB model outputs would be improved with graphics that are connected to parameters with physical meaning.

The wave height component of the SRB model is not supported by standard coastal engineering practice. Progressive jetty damage in the SRB model is based on a stochastic time series of wave heights, which is derived from "An ensemble of 52 storm events … recorded at NDBC buoys… during 1998 to 2008." It is unclear why only 10 years of buoy data were used when a longer record of more than 17 years with gaps removed is available (Appendix A1, pp. 34 and 37). It is also not certain that extreme wave height events were properly included in the SRB model process. It is common industry practice to test a coastal engineering design using a specific design environmental criterion, such as the 100 year return period wave height.

Significance – Medium:

The model parameters that compare alternatives lack a physical meaning, such as a volume of rock or depth of scour. It is therefore difficult to verify, calculate, or evaluate whether the parameters used or model results are reasonable.

Recommendations for Resolution:
1. Explain and demonstrate how the model output parameters relate to physical performance measures, with graphics or figures. 2. Measure jetty damage and performance with conventional calculations, and commonly applied metrics, for example: a. Volume of sediment entering the navigation channel, or dredge volume, b. Depth or volume of scour at the jetty toe c. Volume or area of armor rock displaced from the jetty. 3. Test the design against a specific storm event, such as the 100 year return period event. 4. Calculate the return period of extreme events using the complete record of measured offshore wave data.

Comment 22:

The culvert installation details, as well as potential impacts, need further clarification.

Basis for Comment:

The Major Rehabilitation Evaluation Report states that the existing culvert has increased scour and adversely affected the North Jetty, and that it will be relocated. There are a few sentences in the main report and in Appendix D that mention the culvert, but there is not enough information provided in the main report to determine if there will be any potential impacts from the new discharge location. The table at the end of Appendix D provides the most detail anywhere in this report regarding the culvert relocation. On p. 6-6 in the main report there is a sentence stating work will begin in 2014 to install a culvert to divert overland flow to another area that will not impact the North Jetty root stability. While this sounds like a reasonable approach to protect the North Jetty, more information is needed to clarify the impact such as the source of the water, an assessment of the water quality, and an estimate of the flow rate involved. Without knowing the exact new location, it is not possible to assess the potential environmental impact of relocating this water flow.

Significance – Medium:

More detailed information on the new location of the culvert as well as water quality, flow rates, and source of the water is necessary to determine the environmental impact of the relocation.

Recommendations for Resolution:

1. Add one paragraph in the main report that addresses the culvert relocation.
2. Present any available data on the water quality, flow rates, and water source of water discharged through the culvert.
3. Provide the specific location planned for new culvert.

Comment 23:
The various base years cited in the report and the difference between project life and period of analysis require additional explanation.
Basis for Comment:
The terms “project life” and “period of analysis” are not defined or differentiated, and the project base year varies throughout the report: • In the economic spreadsheet models, the NPVs are calculated for differing periods of analysis (2009-2070 for South Jetty, 2008-2070 for Jetty A, and 2008-2070, 2008-2057 and 2008-2069 for the North Jetty); whereas the AACs are based on a 50 year period of analysis. • The period of analysis extends 50 years beyond the base year of 2011 when discussing sea level rise (pp. A1-38 and A2-68). • The period of analysis for future condition simulations is 64 years (2006 to 2970) for the North Jetty and Jetty A and 63 years (2007 to 2070) for the South Jetty (p. A2-78). • The AAC is calculated using an amortization factor applied to the present year cost stream from the NPV implementation year (2006/2007) to 2069 (p. A2-51). • The base year of the economic analysis is not identified in Section 2 or Appendix C, but is stated as 2014 elsewhere in the report (pp. ES-3 and A2-78). • Within the SRB model, the base year is stated as 2011 when discussing sea level rise (pp. A1-38 and A2-68). • Within the SRB model, the base year for NPV cost discounting is 2006 for the North Jetty and Jetty A, and 2007 for the South Jetty (p. A2-51).
Significance – Low:
Inconsistencies in terminology and periods of analysis can lead to misunderstanding of findings and results.
Recommendations for Resolution:
1. Define and differentiate between the terms “project life” and “period of analysis.” 2. Revise the report to eliminate inconsistencies between the varying periods of analysis. 3. Use a consistent base year throughout the analysis, and revise the report to reflect consistency. 4. Revise Section 2 and Appendix C of the report to state the year that is considered to be the base year, the length of the period of analysis, and the calendar years that are included in the period of analysis. 5. Provide definitions of all terms in a Glossary.

Comment 24:
Cargo tonnage and vessel trip statistics presented throughout the report are inconsistent.
Basis for Comment:
Data presented throughout the report have inconsistencies that should be corrected. The following are examples of inconsistencies in values for cargo tonnages, vessel trips, and value of cargo: • Page ES-1 – cargo on the MCR is 45 million (M) tons and 3,500 vessel crossings based on 2008 Waterborne Commerce Statistics Center data. These data are not cited in the body of the report. • Page 1-2 – cargo on the MCR is 40 M tons worth $17 billion, with 12,000 commercial vessels navigating the MCR annually. • Pages 2-1 and C-1 – cargo on the MCR is 40 M tons valued at $17 billion based on a 2009 Pacific Northwest Waterways Association (PNWA) factsheet cited in Appendix C. • Pages 1-4 and C-4 – cargo on the MCR is 32 M tons in 2003 and projected at 43 M tons in 2020 based on 2005 Center for Economic Development and Research (CEDER) data, cited as a footnote in Appendix C. • Page C-5, Table C-1 – 5,364 total vessel trips on the MCR based on 2005 Waterborne Commerce Statistics Center data. • Page A1-3 – cargo on the MCR is 48 M tons worth $16 billion, with 12,000 commercial vessels navigating the MCR annually. The cargo and vessel trip statistics presented in the report appear to include all traffic on the MCR and Lower Columbia River (LCR). The report assumes all traffic accessing the MCR is dependent on the MCR jetties. The without-project condition channel depths are not adequately described. The cargo and vessel trips that would be impacted by the jetties, that is, the portion of the fleet transiting the MCR that would be restricted by the without-project condition channel depths, is not described.
Significance – Low:
Consistent cargo and vessel trip data for the MCR are needed in order to develop an understanding of the significance of the jetties.
Recommendations for Resolution:
1. Describe the cargo tonnages, vessel trips, and value of cargo consistently throughout the report, or supply an explanation of the differences and why various data sources were used. 2. Describe the portion of the fleet accessing the MCR that is dependent on the jetties (i.e., what are the without-project condition channel depths and what portion of the fleet transiting the MCR would be restricted by the without-project condition channel depths).

Comment 25:

Terminology related to jetty rehabilitation and failure is defined inconsistently or vaguely in some places.

Basis for Comment:

Inconsistencies in terminology can make understanding the project difficult. Commonly used terms in the document, such as “failure,” are not clearly and qualitatively defined. Phrases such as “close to failure” appear frequently, in a qualitative sense, but without an understanding of how much jetty damage, if any, constitutes a “failure.”

Another example is in the SRB model where “fix-as-fails” repairs are described as, “To defer jetty maintenance for as long as possible, the jetty is maintained close to the margin of functional loss.” The concept makes sense but how the model deals with terms like “as long as possible” and “close to the margin of functional loss” is unclear.

Other phrases, such as “scheduled repair” and “rehabilitation” seem to be inconsistent as well. For example, “scheduled repair” includes “head capping” in the executive summary of the main report, but does not include “head capping” in some alternatives analyzed by the SRB model.

Significance – Low:

Without clear, consistent definitions of terminology, it is difficult to understand exactly what is being proposed or analyzed and can lead to misinterpretations.

Recommendations for Resolution:

1. Add a Definitions list or Glossary to the document.

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APPENDIX B

Final Charge to the Independent External Peer Review Panel
as
Developed by USACE and Submitted to the Panel on December 28, 2010

on the

Mouth of Columbia River IEPR

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CHARGE FOR PEER REVIEW

Members of this IEPR Panel are asked to determine whether the technical approach and scientific rationale presented in the Columbia River at the Mouth, Oregon and Washington Major Rehabilitation Evaluation Report are credible and whether the conclusions are valid. The Panel is asked to determine whether the technical work is adequate, competently performed, properly documented, satisfies established quality requirements, and yields scientifically credible conclusions. The Panel is being asked to provide feedback on the economic, engineering, environmental, geomorphology, and plan formulation. The panel members are not being asked whether they would have conducted the work in a similar manner.

Specific questions for the Panel (by report section or Appendix) are included in the general charge guidance, which is provided below.

General Charge Guidance

Please answer the scientific and technical questions listed below and conduct a broad overview of the Mouth of the Columbia River ER. Please focus on your areas of expertise and technical knowledge. Even though there are some sections with no questions associated with them, that does not mean that you cannot comment on them. Please feel free to make any relevant and appropriate comment on any of the sections and appendices you were asked to review. In addition, please note the following guidance. Note that the Panel will be asked to provide an overall statement related to 2 and 3 below per USACE guidance (EC 1165-2-209; Appendix D).

1. Your response to the charge questions should not be limited to a “yes” or “no.” Please provide complete answers to fully explain your response.
2. Assess the adequacy and acceptability of the economic and environmental assumptions and projections, project evaluation data, and any biological opinions of the project study.
3. Assess the adequacy and acceptability of the economic analyses, environmental analyses, engineering analyses, formulation of alternative plans, methods for integrating risk and uncertainty, and models used in evaluation of economic or environmental impacts of the proposed project.
4. If appropriate, offer opinions as to whether there are sufficient analyses upon which to base a recommendation.
5. Identify, explain, and comment upon assumptions that underlie all the analyses, as well as evaluate the soundness of models, surveys, investigations, and methods.
6. Evaluate whether the interpretations of analysis and the conclusions based on analysis are reasonable
7. Please focus the review on assumptions, data, methods, and models.

Please **do not** make recommendations on whether a particular alternative should be implemented, or whether you would have conducted the work in a similar manner. Also please **do not** comment on or make recommendations on policy issues and decision making.

Comments should be provided based on your professional judgment, **not** the legality of the document.

1. If desired, panel members can contact one another. However, panel members **should not** contact anyone who is or was involved in the project, prepared the subject documents, or was part of the USACE Independent Technical Review.
2. Please contact the Battelle Deputy Project Manager (Richard Uhler, uhlerr@battelle.org) or Project Manager (Karen Johnson-Young, johnson-youngk@battelle.org) for requests or additional information.
3. In case of media contact, notify the Battelle Project Manager immediately.
4. Your name will appear as one of the panel members in the peer review. Your comments will be included in the Final IEPR Report, but will remain anonymous.

Please submit your comments in electronic form to Richard Uhler, uhlerr@battelle.org, no later than January 31, 2011, 5 pm EST.

Independent External Peer Review
Columbia River at the Mouth, Oregon and Washington
Major Rehabilitation Evaluation Report

Final Charge Questions

GENERAL QUESTIONS

1. To what extent has it been shown that the project is technically sound, environmentally acceptable, and economically justified?

2. Are the assumptions that underlie the economic, engineering, and environmental analyses sound?

3. Are the economic, engineering, and environmental methods, models, and analyses used adequate and acceptable?

4. In general terms, are the planning methods sound?

5. Are the interpretations of analysis and conclusions based on the analysis reasonable?

MAIN REPORT

SECTION 1.0 -- INTRODUCTION

6. Is the project's purpose and scope complete and understandable?

7. What other information, if any, should be included in this section?

8. Has adequate public, stakeholder, and agency involvement occurred to determine all issues of interest and to ensure that the issues have been adequately addressed to the satisfaction of those interested parties?

9. Comment on the extent to which the existing conditions are clearly and adequately described.

10. Comment on whether the information presented supports the problem identified under the base condition.

SECTION 2.0 -- ECONOMIC CONSIDERATIONS

11. Has the base condition, without-project condition and summary of costs and benefits been adequately described, analyzed, and explained?

12. Does the National Economic Development (NED) Plan contrast to the base condition?

13. Is it clearly explained why navigation benefits were not analyzed?

SECTION 3.0 -- ENGINEERING CONSIDERATIONS

14. Is the description of functional and structural reliability clear and reasonable?

15. Was the Stochastic Risk-Based Life Cycle Simulation (SRB) model used in an appropriate manner? Is the description of how the model functions, the relative influence of model parameters and model calibration process clear and logical?

16. Comment on the repair and rehabilitation alternatives. Is the description of the different plans clear and distinct?

17. Comment on the engineering features for alternatives. Do the plan descriptions clearly indicate which features are incorporated into the various plans?

18. Comment on the evaluation of engineering features. Is the scope, function and analysis of the engineering features clearly described?

19. Comment on the general alternative development approach. Does the alternative evaluation presented follow USACE guidance?

20. Comment on the engineering evaluation of alternatives. Are the plans adequately evaluated based upon their engineering merit?

21. Has the sediment analysis been adequately performed and documented to support the movement of material that occurs during a breach event?

22. Has the analysis been adequately performed and documented to support reductions in channel maintenance dredging?

23. Does the analysis adopt adequate risk thresholds for different alternatives and are such thresholds uniformly consistent?

24. Are potential life safety issues accurately and adequately described under existing, future without project, and future with project conditions?

25. Has the rationale for head capping locations at each jetty been adequately explained?

26. Has the basis for the number and location of spur groins been adequately explained?

SECTION 4.0 -- ASSESSMENT OF ALTERNATIVES

27. Does plan selection reflect a full range of design alternatives?

28. Are the problems and opportunities appropriately defined and addressed in this study?

29. Are there any other constraints or objectives that should be considered as part of the project that would be important to reaching the projects final goals?

30. Do the alternatives adhere to the USACE Plan Formulation Criteria? Do they appropriately address the needs and objectives of the project? What additional information, if any, should be discussed?

31. Comment on the completeness of the project-specific criteria used in the comparison of alternatives.

32. Was the NED Plan appropriately identified and selected?

SECTION 5.0 -- ENVIRONMENTAL CONSIDERATIONS

33. Comment on the completeness of the environmental documentation. Have all National Environmental Policy Act (NEPA) requirements been satisfied?

34. Have the water resources in the project area been accurately described?

35. Comment on the thoroughness and accuracy of the marine and estuarine resource information presented.

36. Comment on the overall discussion of environmental effects due to the project.

37. Comment on the adequacy of available information used to characterize wetland resources within the study area.

38. Comment on whether the special status species and resource areas in the project area have been accurately described.

39. Comment on the adequacy of the environmental and without-project condition summaries in terms of data quality, timeliness of the data, and breadth of information covered.

SECTION 6.0 – CONSTRUCTION AND COST ESTIMATE

40. Comment on the overall adequacy and reasonableness of the detailed cost estimates.

41. Comment on the extent to which the cost summary is complete and consistent with the detailed analyses shown in this section.

42. Is the construction schedule adequate for completion of the recommended activities?

SECTION 7.0 – RECOMMENDATIONS

No questions.

SECTION 8.0 – REFERENCES

No questions.

APPENDICES

Appendix A1 – Coastal Engineering

43. Does Appendix A1 describe the coastal engineering history and challenges specific to the Mouth of the Columbia River?

44. Does Appendix A1 contain adequate information to assess coastal engineering at the Mouth of the Columbia River?

Appendix A2 – Reliability Analysis, Event Tree Formulation and Life-cycle Simulation

General Questions

45. Is the purpose of the model clearly defined?

46. Is the model diagram easily understood?

47. Does the model follow a logical programming path?

48. Does the model adequately capture and evaluate all of the relevant variables?

49. Can the model as described achieve the stated purpose?

50. Does the model accurately describe (model) repair activities and sequences? Is it modeling the repair activities similarly to how the repairs will be sequenced and performed?

Technical Quality

51. Comment on the overall technical quality of the model.

52. Is the model a realistic representation of the actual system?

53. Are the analytical requirements of the model properly identified?

54. Does the model address and properly incorporate the analytical requirements?

55. Are the assumptions clearly identified, valid, and do they support the analytical requirements?

56. Comment on the ability of the model to calculate benefits for total project life.

57. Has the design wave height of 55 feet been appropriately calculated and documented?

58. Have the waves generated by the model been validated against observed wave data?

Usability

59. Comment on the model's usability.

60. Are the model results easily understood?

61. Do the model results support the project objectives?

62. Is user documentation available and complete?

63. Is the model transparent and does it allow for easy verification of calculations and outputs?

Appendix B – Geotechnical Studies

64. Does the background information adequately describe the geologic history and conditions at the Mouth of the Columbia River and surrounding area?

65. Are all of the site specific and distinct geological features relevant to the project described and appropriately addressed in the engineering design?

66. Were risk and uncertainty sufficiently considered?

Appendix C – Economic Analysis

67. Comment on the assumptions and forecast methods used to calculate project benefits.

68. Comment on the reasonableness of the scenarios used to calculate benefits.

69. Comment on the method used to calculate the National Economic Development (NED) benefits.

70. Comment on the assumptions used in the calculation of present value of benefits.

71. Comment on the extent to which the NED benefits summary is consistent with and justified in the economic analysis.

Appendix D – Environmental Documentation

72. Comment on the ability of the proposed mitigation plans to address adverse impacts from the project.

73. Are the conclusions regarding the type and projected magnitude of adverse impacts to resources within the study area reasonable?

74. Comment on the appropriateness and comprehensiveness of the identified mitigation projects considered for addressing predicted impacts arising from the project.

Appendix E – M-CACES Cost Estimate for Recommended Plan

75. Comment on the overall adequacy and reasonableness of the detailed cost estimates.

76. Discuss the appropriateness of the explicit or implicit assumptions that are included in the cost estimates and whether assumptions are adequately addressed.

77. Comment on the extent to which the cost summary is complete and consistent with the detailed analyses provided in the study report.

Appendix F – Project Management Plan

No questions.

Appendix G – Schedule of Fully Funded Project Costs

No questions.

FINAL OVERVIEW QUESTION

78. What is the most important concern you have with the document or its appendices that was not covered in your answers to the questions above?

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October 4, 2011

U.S. Army Corps of Engineers, Portland District
Attn: Mark Brodesser
PO Box 2946
Portland, OR 97208-2946

Subj: Review and Recommendations for Life-Cycle Simulation Model for the Jetties at the Mouth of the Columbia River, Oregon and Washington
Contract No. W912PL-08-D-0016; Task Order No. DT03

Dear Mr. Brodesser:

The purpose of this letter is to provide the results of an assessment of the Stochastic Reliability Based lifecycle simulation model (SRB) which evaluates maintenance strategies for the rubble mound jetties located at the Mouth of the Columbia River (MCR). Moffatt & Nichol (M&N) is under contract with the U.S. Army Corps of Engineers (USACE), Portland District, to prepare this review and provide recommendations for proceeding towards meeting the requirements of an approved planning model as defined by *EC 1105-2-412 - Assuring Quality of Planning Models*.

BACKGROUND

The SRB model is a computer simulation MATLAB® code that stochastically evaluates the environmental loading affecting each of the MCR jetties, and relates structural response (cross-section evolution) of each jetty to functional performance. The structure response is evaluated in terms of cross-section area change (loss) over time due to jetty degradation. Jetty repairs are activated within the SRB model after the jetty cross-section is reduced below a specified threshold value. Jetty repairs are calculated in terms of the tonnage of armor stone required to re-establish the jetty cross section to its standard dimensions. Life-cycle costs estimated by the SRB model include jetty repair and incremental dredging attributed to jetty degradation and loss of function. Because life-cycle costs are estimated using stochastic methods, their realization can be considered probabilistic. Although reliability is also calculated within the SRB model, reliability is not used to simulate structure response and related consequences (life-cycle cost). Reliability is modeled as a function of repair and maintenance, and is used as a supplemental metric to inform on overall jetty performance.

As part of the USACE review process, the model underwent an Independent External Peer Review (IEPR) and was subject to Headquarters (HQUSACE) review for approval of use. The IEPR panel had four highly critical comments regarding the SRB model; subsequently, the panel did not approve the model for one-time use.

The M&N approach towards assessing the model is based on a tiered approach as follows:

- Assessment of the critical IEPR comments for possible resolution;
- Review overall modeling approach to verify inclusion of all critical mechanisms;
- Review formulation of the critical mechanisms;
- Review model documentation for adequacy in describing mechanism formulations;
- Review implementation of the mechanism formulation in the MATLAB® code;
- Review calibration/validation of processes incorporated in the model; and
- Preliminary review of MATLAB® code for efficiency and transparency.

This evaluation focuses solely on the model approach for the North Jetty as it is assumed the overall approach will be similar for the South Jetty and Jetty A. Also, there has been some modification of the North Jetty model to address ATR Comments so it presumably represents the latest and best formulation.

The results of our assessment of the model and our conclusions and recommendations are described in the following sections of this letter. The evaluation of the IEPR comments is discussed first since appropriate resolution of these comments is critical for model approval. The remainder of the report deals with the assessments of the overall approach, the MATLAB® code, and the model documentation. The conclusions and recommendations are in the last section.

EVALUATION OF IEPR COMMENTS

There are four significant comments from the IEPR that require resolution if the model is to be accepted as an authorized planning model. Each of these comments is addressed in this section.

Comment # 2: The analysis of the sediment transport process is not comprehensive, and the data and analysis do not support the conclusions concerning large movement of sediment during a breach event.

This comment addresses the sediment transport into the navigation channel as a result of a breach in the Jetties. The breakwater has breached in the past which has allowed sediment transport into the navigation channels, but the quantities and mechanisms have not been well documented. The disagreement between the Coastal Modeling System (CMS) Model Study is also of concern, although clearly the CMS model evaluation utilized a time scale inconsistent with the actual processes. The CMS model simulated the breach over a period of 6.5 days whereas the time frame for the observed shoaling related to the breach occurrence was on the order of months. This time frame difference would explain the difference in shoaling magnitude.

The recommendation from the IEPR that a more thorough investigation of the shoaling processes be incorporated is likely inconsistent with the time frame for the model implementation. After evaluation of the costs associated with the breach occurrences, a more appropriate approach may be to incorporate the emergency repair to the Jetty and disregard the dredging costs associated with the breach. This approach would satisfy the bulk of the IEPR comment. If the breach is considered in a planning scenario, some reasonable cost could be incorporated in the planning outside of the model framework.

Comment # 4: The SRB model by itself has very limited value for analyzing alternatives and is not a substitute for conventional economic and engineering analysis.

This IEPR comment is a blanket statement which leaves very little room for a response. However, it appears that there is a clear misunderstanding about what the model does and how it performs. The primary response to this comment would be to provide more transparency in the model formulations and how these formulations are appropriate for the MCR jetties. The formulations need to be validated to illustrate confidence in the predictive capability of the model based on historical jetty maintenance experiences.

It should also be emphasized that the model should be considered as a comparison tool and that it does not make the final decision. The IEPR review seemed to believe the model concluded with a decision which is incorrect. Engineering and economic judgment is still required once the model evaluation of alternatives is completed.

The portion of the comment related to armor rock breakage and slip circle failure is beyond the scope of the model and the comment should be considered invalid. The model is based on the assumption that the bulk of the damage is related to coastal processes and that these processes are included in the model with additional damage sources accounted for in the selection of the damage function calibration factor. This comment can also be addressed similar to the response to Comment #8 below.

Comment # 7: The basis of design and design environmental criteria are vague, not consistent within the report, and not consistent with conventional coastal engineering design practice.

The resolution to this comment is to clarify that the model is for a 50-year planning horizon and that all design criteria should be based on 100-year return interval. All other references to various 50-year periods should be clarified within the documentation.

Comment # 8: The models and analyses of jetty failure do not include all significant processes.

This comment suggests that additional geotechnical data should be gathered in the vicinity of the jetties, specifically boring data. Based on discussions with the Portland District personnel, we understand the generally feeling that there is adequate geotechnical data for the design of the jetties. This comment is best addressed by documenting and explaining the extent of the geotechnical data that has been assembled for past maintenance efforts. It can also be pointed out that the predominant processes impacting the stability of the jetties is related to the coastal processes more than geotechnical issues based on historical experience with the jetties.

To a great extent, the soil properties related to scour are addressed in the model based on calibration against historical observations and this implicitly considers this facet of the geotechnical factors.

ASSESSMENT OF MODEL APPROACH

Model approach was reviewed with a general purpose to identify fundamental issues and discrepancies in the model. The main comments are provided below.

1. The model calculations and most of governing input parameters were defined with a hard coded jetty segment size of 100 ft. It is understood, that the segment length was selected as a typical length of repairs and damage. Greater flexibility in the model application and calibration could be achieved if the internal segment size for calculations is made adjustable.

2. The present approach defines one year as overall time step in the model and calculates damage to each segment cumulatively based on the number of storms in each year. It would be more logically correct to iterate over a sequence of storms in each year and then calculate damage to the jetty segments in each storm. That would allow more flexibility to evaluate damage on any different time step and, if needed, on a storm-by-storm basis.

3. The number of storms is limited to 52 historically observed storms, for which measured storm parameters are applied. The selected set of storms represents the general population of storms in the area sufficiently well. However, use of preselected storms and water levels in Monte Carlo simulations may impose some limitation in the analysis. During the storms which have a potential to damage the jetties wave heights at the structures are limited by depth. Therefore, wave direction (which governs distribution of wave heights along the jetties) and more importantly water level are the main parameters which control the level of damage and distribution of damage along the structure. The model presently utilizes only three water levels for each storm, while more variability could be added to water levels in the MC simulations. Additionally, it would be advantageous to provide a guidance on how to define a set of synthetic storm conditions which represent the population of storms in the area where detailed observations of the storms is not available.

4. The wave parameters for segment damage function were extracted from STWAVE model output. It is expected that the wave parameters vary along each segment of the jetty and for every segment a single set of parameters (wave height, period, etc) was identified. A description of how to select these values from the STWAVE results would be beneficial.

5. Tidal currents, river floods and storms cause significant morphological changes around the jetties such as scour, channel migration, and shoal evolution. These changes were approximated in the model by historic trends. It would be advantageous to include the possibility to modify these trends as a part of “what if” alternative simulations. For example, what if scour at the toe of the North jetty expanded and resulted in additional damages.

6. The deterministic and random variables should be clearly defined in the model. The random variables are defined in the beginning of each MC simulation. The deterministic are either preset or calculated using formulas based on other variables.

7. Formulas for static (toe scour and slope failure) and dynamic (wave breaking and overtopping) effects on jetty damage needs to be verified. These formulas define the governing procedure of each jetty's response to a storm. Accuracy of these formulations is crucial. Most formulas from accepted procedures deal with prediction of damage to a breakwater from a single storm under the assumption that the breakwater keeps the initial profile shape. If the jetty sustains damage from one storm to another, the profile will adjust by stone displacements. Currently, the model accumulates damage from multiple storms in one year without considering adjustment of the structure between the storms. It is assumed that the second storm will have the same damage as the first one, which may lead to overestimation of the total damage.

8. The model utilizes a simplified parameterization of the cross-section profile of the jetty. The cross-section is divided at −5 ft MLLW into top and bottom layers. The top layer is affected by dynamic damage, and the bottom layer is affected by static damage. Since damage is calculated as loss of area, additional assumptions were applied to the slopes, top width and jetty height to match the remaining area. It is clear that the resulting profile is only an approximation of the actual damaged profile. A clear explanation of the process of profile adjustment would help in understanding how stone volumes in the top and bottom layers are calculated, as well as reused and lost stone.

9. Approximation of jetty damage from a storm is the key element of the entire model. The damage functions were defined from lab tests for selected conditions, such as normal profile, damaged profile, etc. They represent relationships between wave heights and lost cross-section areas as A = f(H). The damage functions were calibrated in the model by using shift in wave height as $A = f(H - H_{shift})$, which essentially moves the threshold when damage begins. It was identified that each damage function could have its own shift parameter, but only if that function was utilized in the calculations. It is possible that damage functions for a new configuration of the jetty may be slightly different, which make it difficult to select the appropriate shifts for forecast conditions under new alternatives.

10. Shoreline erosion/accretion is approximated in the model from the historic trend which is a reasonable approximation. Additional flexibility in the model could be achieved by allowing easy modifications to these trends or specifications of new ones based on the jetty repair alternatives. For example, if an alternative can cause acceleration in shoreline erosion/accretion. It is also very conservative to assume that <u>all</u> eroded sediments are transported into the navigation channel.

11. Two independent components, financial and structural, should not be combined into one MC simulation. It would be better to separate them into two MC analyses by making

structural components (storms, damages, and repairs) completely independent of financial components (price for repairs and dredging). This should answer the question—what if the storm sequence is the same, but the strategy on the repairs changes, would the jetty reliability be the same? Then results of these MC simulations can be recalculated with variable prices. This second simulation would tell if the prices change, will this affect an earlier decision about the repair strategy?

COMMENTS ABOUT MATLAB® CODE

The comments about the model code are given below.

1. The simulation folder contains many files of different types, including Excel spreadsheets, text files, and MATLAB® binary files. There is no distinct difference between the names of input and output files or perhaps folders to isolate input and output files in different locations.

2. The main input file is called *AA_XLS_new.mat*, where AA is the jetty name. The variables in this file were derived by a preprocessing script from Excel files. There are many variables in the file but no descriptions. Some references can be found by referencing the preprocessing script, but without MATLAB®, there is no easy way to modify the file or check the content.

3. The main model script is called *event_tree_NNN.m*, where NNN is name of the jetty and alternative. The file consists of more than 7300 lines. About 2000 lines are dedicated to plotting and output. This is a very large file to edit and navigate, considering the fact that most modifications to model control variables should be done in that file. Additionally, there are four subroutines which are stored in separate files. None of the scripts include online help or detailed description of the input/output parameters. Some subroutines have more than 20 input variables. The input/output and variable handling is not done in a structured manner.

4. Many variable names reflect the name of the jetty that the routine was developed for. This practice creates unnecessary difficulties for comparing between different versions of the code. For example, it would be difficult to compare codes between NJ and SJ to verify if the two routines work similar.

5. The routines create too many variables which are stored in the same workspace. Some structuring of the variables could potentially help in review of model results.

6. There are too many hard-coded coefficients in the scripts. Many of them are not placed in the same part of the code and are spread throughout the code. The hard-coded coefficients are mixed with process control parameters. This creates difficulties in identification of parameters which can be changed to modify the way MC simulations are performed.

7. There are many parameters which define particular events, for example, *Repair_Crest_el_1939* or *Crest_El_2006*. These variables probably have very little information for forecast mode. Therefore, it is clearly a question if hindcast and forecast modes can be separated into different subroutines, while forcing functions remain the same.

8. The alternatives are implemented within the same main code. The selection is done by setting a single variable *fut* in the beginning of the code. It is not transparent how additional alternatives can be added or existing ones modified. There are numerous IF statements, which seem to depend on the value of *fut*.

9. Some graphical output is created for a jetty segment selected before the MC simulation. There is probably a way to create plots for another segment without the need to rerun simulations, however it is not obvious. Graphical output could be completely separated from the main routine to allow more flexibility in creation of figures without the need to rerun a simulation. This is especially important, since MC simulations give stochastic (variable) results.

COMMENTS ABOUT DOCUMENTATION AND USER'S MANUAL

The *Model Documentation Report* provided a general description of the model background and principal algorithms. Sufficient details were given on the basic model organization, principles of operation, and main input and output. A part of the report named *Model Operation Guide* included some information on the calibration process, model setup, selection of alternatives (repair strategies), and model inputs and outputs. This part was found to be rather brief and in most cases only indicated general locations (a script name or data file) where modifications can be done to allow the user to change inputs into the model. Explanation of the model calibration was not complete. In particular, specific details about how the values of calibration parameters were used in the forecast mode were not included.

Most of input parameters (damage function, STWAVE model output, jetty configurations) were defined in a series of Excel files. However, most of the parameters in these files were self explanatory, and it would be difficult to make significant changes to the model inputs without modifications to the main code of the model. For example, the damage functions were defined by hard-coded variables with fixed sizes. Any changes to the damage function array size would require modification in the corresponding Excel file, preparation script, and the main code. A detailed description of how would be accomplished is not provided.

CONCLUSIONS AND RECOMMENDATIONS

Our overall recommendation is to retain the existing model and make improvements to satisfy planning model approval requirements. The basic premise of the model is sound and a great deal of effort has gone into formulating the important processes impacting the jetties and the maintenance procedures available for jetty repair.

The recommendation to retain the existing model is based on several considerations. The first consideration is the requirement to complete the evaluation of maintenance plan alternatives and recommend the most appropriate plan within the next few months. Several years have gone into the development of this model. Knowing that objectives for the model evolved over this time period, it should not take as long to develop a model from scratch. However, we do estimate that model development from scratch would require at least a year or two including model approval for use in the evaluation of planning alternatives. This time frame does not meet the requirements of the Portland District schedule.

The second consideration for retaining the existing model with improvements is the engineering cost associated with development from scratch. While we have not worked up a detailed cost estimate for a scope of this magnitude, the fee for M&N to do this work would likely be approximately $400,000. Portland District personnel as well as review personnel would also be participating in this project requiring additional engineering costs. Working with the existing model and making the recommended modifications will be significantly less, likely less than half of this budget.

Improvements are required to meet the requirements for an authorized planning model. Specifically, the following improvements should be implemented:

1. Modularize the model code using the existing approaches where they are appropriate. Specifically, separate parts of the code related to the following:
    - Setup of global variables
    - Setup of MC simulation
    - Specification of alternatives
    - Calculation of damage functions
    - Geometry adjustment after damage
    - Creation of output and plotting
2. Validate independent modules based on available literature and previous experience with the MCR jetties. Alternative formulations of the damage functions used in the model should be provided for comparison of model results with alternative published analytical formulations.
3. Calibration results for the model need to be clearly documented. To accomplish this, the calibration process and parameters must be clearly documented within the model and in the model output and reporting. Additional performance metrics can also be extracted from the model results and clearly presented. This will help improve the transparency of the model for those not directly involved with setting up and running the model.
4. During the process of modularizing the existing model, the structure should be changed to allow a single model code capable of evaluating alternatives for all three jetties.

5. Improvements are required in the user interface to allow the user to easily review all input and output parameters. Existing hard-coded parameters should be removed from the model code to provide greater transparency.

6. A well-documented user's manual needs to be prepared to allow qualified modelers to apply the model to evaluate alternatives. The majority of this effort would be improvements to the *Model Operation Guide*.

7. The economic and structural analyses should be separated into independent routines. The economic analysis calculations would be based on the output from structural simulations with an interface between the two models. This approach also permits the use of different economic analysis approaches for a single structural simulation.

8. Additional metrics for evaluating alternatives can be output from the model to assist in the economic evaluation of the alternatives. These include structural and functional reliabilities, stone volumes which were lost, placed, or moved, and others. A facility can be created to easily calculate and output new metrics as needed. These additional metrics will add to the transparency of the model results and go a long way towards gaining approval for the model as an authorized planning model.

9. The shoaling related to jetty breaching should be eliminated while the repair requirements to the jetty section should be retained for the breaching. This recommendation is based on IEPR comments suggesting that it will be difficult to get a professional consensus regarding the appropriate shoaling volume and distribution. As this shoaling volume is relatively small compared to the morphological changes related to jetty tip retreat, the impact to costs in the alternative analysis is relatively minor.

There are two additional issues which are fundamental to an appropriate modeling approach. The first issue is the morphological assessment within the model related to recession of the jetty tips. Decisions regarding future maintenance of the jetties needs to address whether the current location should be retained as the optimal location or whether the tips should be allowed to recede further. The current approach for morphological impacts as implemented within the model does not address this decision. A much more sophisticated morphological modeling approach is required to address this issue. However, given the available time to evaluate the jetty maintenance alternatives and the high likelihood that whatever approach is used will extend controversy of the model applicability, we do not recommend development of a more detailed morphological model at this point. However, this component could be included at a later date when scheduling or application requirements permit.

The second fundamental issue that should be addressed further is the damage functions currently used in the model. The damage functions are fundamental to the model results and therefore their application in the model should be accurate and transparent. An analysis should be performed in order to define the possibility of a clearer approximation for the damage functions derived from physical model results. The calibration process for the shift parameter in the damage functions will also be reviewed with an attempt to improve the calibration process. This task may or may not result in a better damage function specification or calibration parameter selection; however, it will become a part of code modulation and restructuring task and would permit comparison of alternative damage function approaches.

Given the recommended tasks above for model improvements and realizing that time is of the essence in getting the model approved for this application, we estimate that the work to accomplish these tasks would require approximately 3.5 months. If work begins immediately, the project would be completed by approximately mid-January 2012. This work would include getting approval for model use, simulating the currently identified maintenance alternatives, and assistance in preparing the alternatives assessment report.

It has been a pleasure to be involved with this challenging project. We hope to continue to be of assistance with moving this model forward and making it a useful tool for evaluating maintenance strategy alternatives. Please do not hesitate to contact me if you have any questions or concerns regarding our assessment of the model and the potential for application to the MCR jetty maintenance planning.

Sincerely,

MOFFATT & NICHOL

David H. Dykstra

David H. Dykstra
Project Scientist

STATEMENT OF WORK FOR
MODIFICATION No. 2

CONTRACT NO. W912PL-08-D-0016, MOFFATT & NICHOL
TASK ORDER NO. DT03, LIFE-CYCLE SIMULATION MODEL SUPPORT FOR THE JETTIES AT THE MOUTH OF THE COLUMBIA RIVER, OREGON AND WASHINGTON

1. BACKGROUND. During Phase 1 of the task order, the AE team assessed the current SRB model architecture, code, and documentation; the three outstanding IEPR comments and Assuring Quality of Planning Models (EC 1105-2-412), and made a recommendation on the most efficient approach to obtain model approval. The AE team was asked to provide details on how to achieve model approval and respond to open IEPR comments by either:

(1) Improve and revise existing model architecture and code;
or
(2) Start over with entirely new planning model

The AE team's recommendation is to improve and revise the existing model code. The team identified nine specific recommendations to improve the model. Those recommendations will be used as the first nine tasks for this modification. Additional tasks will be identified for technical writing, plan formulation and Report Editing.

2. OBJECTIVES. This modification of the task order is for phase II.

During Phase 2 the CENWP's product delivery team will work collaboratively with the AE team to develop the following:

- A fully documented model which has been validated and verified, with input and output files, and a user's manual – meeting the requirement of EC 1105-2-412.
- Clearly defined design criteria and basis for design.
- A range of alternatives leading to a least-cost plan.

The AE Team members under this task order shall possess the following skill sets:

- MATLAB programmer with 5 years experience.
- Senior coastal engineer with 20 years experience in the design of coastal structures.
- Economist with 10 years USACE plan formulation experience (Phase 2).

3. MANDATORY SERVICES TO BE PROVIDED.

a. <u>Task 1: Modularize the model code</u> The model code architecture will be modified utilizing the existing modeling approaches where they are appropriate, and separating the parts of the code related to the following:

- Setup of global variables

- Setup of Monte Carlo simulation
- Specification of alternatives
- Calculation of damage functions
- Geometry adjustment after damage
- Creation of output and plotting

b. Task 2: Validate Independent modules The independent modules that are established in Task 1 will be validated for functionality and accuracy utilizing available literature and previous experience with the MCR jetties. Alternative formulations of the damage function used in the model will be developed by the AE team for comparison of model results with alternative published analytical formulations.

c. Task 3: Document Calibration Results The AE team will calibrate the revised model clearly documenting the calibration process and the parameters used in the model and in the model output and reporting. Additional performance metrics will also be extracted from the model results and clearly presented when feasible. The goal of documenting the calibration process and parameters used is to provide transparency of the model functions for reviewers not directly involved with setting up and running the model.

d. Task 4: Develop Single Model Code for all Three Jetties During the process of modularizing the existing model code, the structure will be changed to allow a single model code capable of evaluating all three jetties.

e. Task 5: Improve User Interface. Develop a user interface that will permit the user to easily review all input and output parameters. Existing hard-coded parameters will be removed from within the model code to provide greater transparency of how individual parameters affect model output.

f. Task 6: Prepare Users Manual. A well documented user's manual will be prepared in order to allow qualified modelers to apply the model to evaluate alternatives. The majority of this effort will be improvements to the existing Model Operation Guide.

g. Task 7: Separate the Economic and Structural Analysis. The economic and structural analysis will be separated into two independent routines. The economic analysis calculations will be based on the output from the structural simulations with an interface between the two models. This approach will permit the use of different economic analysis approaches for a single structural simulation.

h. Task 8: Provide the Capacity to Output Additional Metrics from Model. Create a facility to calculate and output additional metrics as needed. New metrics may include structural and functional reliability, stone volumes which were lost, placed or moved and others not yet identified. Additional metrics will be used to enhance the transparency of the model results with the intent of facilitating model approval.

i. Task 9: Remove Breach Shoaling. The in-channel shoaling volumes and required additional dredging will be removed from within the model. Retain the damage repair requirements to the jetty section and track as a breach in order to distinguish from a repair volume related to general damage. Tracking the damage as a breach will enable the model to indicate at what point a breach is probable and it will help inform maintenance strategy and repair cost.

j. Task 10: Utilize Improved Model. Assist USACE Product Development Team with the evaluation of alternatives utilizing the improved SRB model. The alternatives should remain the same or similar to the previously used alternatives, however, the base condition will require to be altered to represent the changed site conditions that will occur as a result of the North Jetty Major Maintenance Report (NJ MMR) that was written after the MCR Major Rehabilitation Report and has been submitted for the FY 2012 budget. Provide an economist that will assist the USACE PDT with plan formulation, evaluation of the alternatives and performing the economic analysis.

k. Task 11: Incorporate New Data and Streamline Report. Assist USACE Project Development team with the incorporation of results from the new model runs into the existing Major Rehabilitation Report. During and prior to the process of incorporating the new model data the AE team will review the report and with PDT concurrence make modifications that increase the readability of the report. The goal of the modifications shall be to retain the existing information while shaping the report into a more concise document.

4. MANDATORY SUBMITTALS TO BE PROVIDED. Under this modification, the Contractor shall provide the following:

> **a. Submittal 1 Model code and Documentation** user's manual, revised A1 and A2 appendices reflecting model code changes and validation and verification files.
>
> **b. Submittal 2 Revised Major Rehab Report.** Provide the text and technical writing services to revise the existing Major Rehabilitation report as follows; describe the basis of design and engineering criteria used for plan formulation incorporating modifications to the alternatives, justification for head-capping and spur groin locations and selection of alternative.

5. SCHEDULE. All services required under this task order modification shall be completed no later than 20 January 2012. It is anticipated that the Notice to Proceed (NTP) for this modification will be issued by Oct 14, 2011.

6. ONLY WHEN AUTHORIZED (OWA) SERVICES. The following OWA tasks will be negotiated and funded at time of award. The Contractor shall not perform any OWA services without specific written direction from the Contracting Officer's Representative.

a. <u>Additional Meetings</u>. Establish two (2) units of additional OWA meetings. Each unit shall be for three (3) people for two (2) days. Costs shall include travel and per-diem to Portland, Oregon.

DEPARTMENT OF THE ARMY
CORPS OF ENGINEERS, PORTLAND DISTRICT
PO BOX 2946
PORTLAND OR 97208-2946

REPLY TO
ATTENTION OF

AUG 07 2009

Planning, Programs and Project
Management Division

Bernard Moseby
National Deep Draft Navigation Planning Center of Expertise
Mobile District, USACE
PO Box 2288
Mobile, AL 36628-0001

Dear Mr. Moseby:

The purpose of this letter is to inform you that Portland District is submitting to the National Deep Draft Navigation Planning Center of Expertise (DDNPCX) a reliability model of the jetty system at the Mouth of the Columbia River (MCR). Portland District requests that the Center conduct the approval process of this model per EC1105-2-407.

This computer model is to be used in the Major Rehabilitation Study of the jetties at the Mouth of the Columbia River (MCR). The model is written in Matlab and is actually three separate models, one for each of the jetties there; North Jetty, South Jetty, and Jetty "A". The model and supporting files have been placed on the USACE public FTP location: ftp://ftp.usace.army.mil/pub/nwp/MCR_SRB_review/

These files will be available for ten days on the FTP site. The files will need to be re-posted if you do not download them within this timeframe.

NWP Points of Contact are as follows:

Rod Moritz 503-808-4864, Technical expert;
Jason Magalen, 503-808-4832, Technical assistant;
Tom Hackett, 503-808-4769, Planning POC;
Brian Shenk, 503-808-4221, Economics POC.

Because of the size and complexity of the model, we are recommending that the model reviewer or reviewers communicate periodically with key NWP personnel during the review process. We would like to work with you once the review team is developed to establish an appropriate way to check in on comments, and maintain the review schedule. If you would like, we are available to conduct a kick off meeting with the review team to introduce and explain the model.

Please provide the reviewers names, and the review and approval schedule. Tom Hackett of my staff is managing the review process for the District and he will be in contact with you during the review period. You may contact him at (503) 808-4769 or email at thomas.w.hackett@usace.army.mil.

Sincerely,

for Christine McBurdan

Laura Hicks
Chief, Project Management & Planning Branch

CENAE-EP-HG 24 August 2010

MEMORANDUM FOR: Mr. Bernard E. Moseby, CESAM-PD-FE, Chief, Economic Analysis and Deputy Director, Deep Draft Navigation Planning Center of Expertise

SUBJECT: Review and Certification Letter for the Mouth of the Columbia River (MCR) Stochastic Reliability Based (SRB) Lifecycle Model for the MCR Major Rehabilitation Report

The following is the background information on the review process for the certification of the MCR SRB Lifecycle Model:

1. In October 2009, a request was made by the NWP PM to the ATR team leader to assist in obtaining model certification of the Mouth of the Columbia (MCR) Stochastic Reliability Based (SRB) model. This process was conducted using current USACE planning guidance and coordinated through the Deep Draft Navigation PCX to request from USACE Headquarters an "approved for use" status of the MCR SRB model.

2. A technical review of the MCR SRB model was initiated in November 2009 and has continued to date utilizing both part of the ATR team (Mr. Robert C. Patev, Team Leader and Mr. Wally Brassfield, ATR cost team member) and Mr. John Winkelman, a Coastal Regional Technical Specialist (RTS), from North Atlantic Division (NAD). Since the MCR SRB model was developed using the MATLAB language/software, Mr. Winkelman was an important part of this team due to his knowledge of the software, his technical position as a coastal engineer/planner Regional Technical Specialist with the HSDR PCX, and his past work experience in SPD on West Coast coastal navigation projects.

3. The review was begun in November 2009 by Mr. Patev and Mr. Winkelman and included a visit to CENAE by Mr. Hans Moritz, who is the developer of the MCR SRB model. The meeting lasted approximately two days and included a detailed presentation of the model code, model development assumptions, variable and model input descriptions, a discussion of the model output, and a lengthy discussion of model philosophy. Questions or comments generated prior to and during the meeting were documented and addressed as part of the Dr. Checks review process. Twenty three comments were generated and submitted into Dr. Checks in January 2010. Questions and comments were related to model coding, model variables and model constant value selection, model assumptions, and limited coastal engineering issues. Each issue and question was answered and/or addressed satisfactorily.

4. Following this meeting and installation of the MCR SRB MATLAB code at NAE, a number of variables and their ranges were defined to investigate model performance, sensitivity, and stability of the code. This was performed in terms of engineering reliability aspects of the program only. During this phase of the review, Mr. Moritz provided the review team with a list of key variables and constants within the code for validation. Many of these variables were discussed further during a number of

email/phone exchanges during this phase. After these communications and detailed examination of the code, the values selected in the model for engineering parameters were determined to be reasonable and based upon a sound engineering decision process. When these values were changed in the model, noticeable changes to the model output were recognized, but the model did not produce any unreasonable results in terms of engineering reliability.

5. The values for costs included in the MCR SRB model were reviewed and modified by Mr. Brassfield in July 2010. However, the validation of the methods and mathematical calculation for the estimation of the economic consequences produced by the model has not been reviewed by any team member since this was outside of their areas of expertise.

The following limitations, review assumptions and technical recommendations were drawn by the review team during their review:

1. With a model of this size and complexity it is difficult to determine if all of the code is error proof or if the model is providing the exact correct answer. However, based on the review, as described, the model, from a coastal analysis/performance stand point does appear to be reasonable and is a reasonable tool for determining the future, relative performance of various maintenance schemes for the MCR jetties discussed in the MRR. As with any model of this complexity, and for a system of this complexity, the precise numbers and resulting values are likely not absolutely correct but instead are reasonable and relatively correct between alternatives.

2. This model and code has only been reviewed as to what was included in the code installed at NAE in 2009. This review was limited only to the aspects of the engineering reliability and not the actual consequence determination in the program. The cost inputs have been reviewed by the ATR cost team member but the application of the economics to the outputs has not been validated as part of this review. In addition, any additional changes or modifications of the code should be reviewed by the ATR team to determine the validation of those modifications to the code and the replication of the results with previous versions of the code.

3. The MCR SRB model was developed to perform an integrated analysis of both engineering reliability and consequence assessment. Typically, major rehabilitation models are developed separately into stand alone models for engineering reliability and economic consequences. If the schedule permits, I would strongly recommend that the SRB process and results be validated with a simpler model using hazard functions from the SRB reliability curves and the development of consequences using a traditional economic simulation model.

4. During the Independent External Peer Review (IEPR), it is important to provide the additional documentation and explanations discussed in my previous comments. Also, the face to face meeting for explaining the model is essential due to the complexity of the model. This is a model that is trying to meet a difficult USACE planning objective that covers an immensely complicated coastal engineering project and forecasts an uncertain

future. It should also be made clear what the purpose of the model is, and that this is a project specific model that has been developed, honed, and calibrated for this specific project area. The numerous factors and variables, etc. within this model, to a great extent, are project specific and are not to be used in a generalized model for other USACE projects.

5. Based on the information presented above, I recommend that the MCR SRB lifecycle model be certified as is and a request be sent to USACE Headquarters as “approved for use” for the MCR Major Rehabilitation Report only.

If there are any questions regarding this memorandum, please do not hesitate to contact me at your earliest convenience.

Robert C. Patev
ATR Team Leader
NAD Navigation RTS

CESAM-PD-FE

18 January 2011

MEMORANDUM FOR COMMANDER, South Atlantic Division, ATTN: WILBERT V. PAYNES, (CESAD-PDS-P)

SUBJECT: Model Certification – Approval for Use, Columbia River at the Mouth, Oregon and Washington, Major Rehabilitation of the Jetty System at the Mouth of the Columbia River, Stochastic Reliability-Based (SRB) Model

1. References:

   a. EC 1165-2-209, Civil Works Review Policy, 31 January 2010

   b. EC 1105-2-412, "Assuring Quality of Planning Models" dated 20 July 2009,

   c. EC 1105-2-407, "Planning Models Improvement Program: Model Certification" dated 31 May 2005.

   d. Memorandum, CECW-CP, 30 March 2007, Subject: Peer Review Process

   e. Supplemental information for the "Peer Review Process" Memo, dated March 2007

2. In accordance with EC 1165-2-209, "Civil Works Review Policy" Model Certification – Approval for Use, the Major rehabilitation of the Jetty System at the Mouth of the Columbia River, Stochastic Reliability-Based (SRB) Model, has been coordinated with and executed through the Deep Draft Navigation Planning Center of Expertise (DDN-PCX).

3. The review was a Level I review - for highly complex models used in decision-making where there could be a high risk of making an incorrect investment decision.

4. The review was performed by Robert C. Patev, CENAE-EP-WG, Team Leader and John Winkelman, CENAE-EP-WM, New England District, Corps of Engineers. The Model Assessment Criteria documentation that supports a recommendation of 'Approval for Use' for the SRB Model is enclosed. The Deep Draft Center is requesting coordination of the enclosed certification package through the Planning CoP Leader for processing, review and recommendation.

4. The Deep Draft Navigation Planning Center of Expertise (DDN-PCX) point of contact is Bernard Moseby, CESAM-PD-FE, (251)-694-3884.

FOR THE COMMANDER:

Encls

BERNARD E. MOSEBY
Technical Director, DDN-PCX

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Attachment 7a

(Appendix H)

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DEPARTMENT OF THE ARMY
MOBILE DISTRICT, CORPS OF ENGINEERS
P.O. BOX 2288
MOBILE, ALABAMA 36628-0001

REPLY TO
ATTENTION OF:

CESAM-PD-D (1105-2-40a) 4 June 2012

MEMORANDUM FOR MR. ERIC V. BLUHM (CENWP-PM-F), PROJECT MANAGER, PORTLAND DISTRICT, U.S. ARMY CORPS OF ENGINEERS, POST OFIICE BOX 2946, PORTLAND, OREGON 97208-2946

SUBJECT: Review Plan Approval, Mouth of the Columbia River Jetties Major Rehabilitation O&M, Portland District, Portland, Oregon

1. The Deep Draft Navigation Planning Center of Expertise (DDNPCX) has reviewed the Review Plan (RP) for the subject study and concurs that the RP satisfies peer review policy requirements outlined in Engineering Circular (EC) 1165-2-209 Civil Works Review Policy, dated 31 January 2010.

2. The review was performed by Mr. Bernard E. Moseby, Technical Director, DDNPCX. The RP checklist that documents the review is enclosed.

3. The DDNPCX recommends the RP for approval by the MSC Commander. Upon approval of the RP, please provide a copy of the approved RP, a copy of the MSC Commander Approval memorandum, and the link to where the RP is posted on the District website.

4. Thank you for the opportunity to assist in the preparation of the RP. Please coordinate any Agency Technical Review (ATR), Independent External Peer Review (IEPR), and Model Certification efforts outlined in the RP with the Deputy Director, DDNPCX at (251) 694-3884.

Encls

CURTIS M. FLAKES
Chief, Planning and Environmental Division

CF:
CESAD-PDS/PAYNES
CESAD-PDS/STRATTON
CESAD-PDS/SMALL

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Attachment 7b

(Appendix H)

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Review Plan Checklist
For Decision Documents

Date: 5/30/2012
Originating District: Portland District
Project/Study Title: Mouth of the Columbia River Jetties Major Rehabilitation O&M
District POC: Eric V. Bluhm Project Manager
PCX Reviewer: Bernard Moseby

Please fill out this checklist and submit with the draft Review Plan when coordinating with the appropriate PCX. Any evaluation boxes checked 'No' indicate the RP may not comply with EC 1165-2-209 (31 Jan 2010) and should be explained. Additional coordination and issue resolution may be required prior to MSC approval of the Review Plan.

REQUIREMENT	REFERENCE	EVALUATION
1. Is the Review Plan (RP) a stand alone document?	EC 1165-2-209 Para 7a	Yes ☒ No ☐
a. Does it include a cover page identifying it as a RP and listing the project/study title, originating district or office, and date of the plan?		a. Yes ☒ No ☐
b. Does it include a table of contents?		b. Yes ☒ No ☐
c. Is the purpose of the RP clearly stated and EC 1165-2-209 referenced?		c. Yes ☒ No ☐
d. Does it reference the Project Management Plan (PMP) of which the RP is a component?		d. Yes ☒ No ☐
e. Does it succinctly describe the three levels of peer review: District Quality Control (DQC), Agency Technical Review (ATR), and Independent Technical Peer Review (IEPR)?		e. Yes ☒ No ☐
f. Does it include a paragraph stating the title, subject, and purpose of the decision document to be reviewed?		f. Yes ☒ No ☐
g. Does it list the names and disciplines of the Project Delivery Team (PDT)?* **Note: It is highly recommended to put all team member names and contact information in an appendix for easy updating as team members change or the RP is updated.*	EC 1165-2-209 Appendix B Para 4a	g. Yes ☒ No ☐ **Comments:**

2. Is the RP detailed enough to assess the necessary level and focus of peer review?	EC 1165-2-209 Appendix B Para 3a	Yes ☒ No ☐
a. Does it indicate which parts of the study will likely be challenging? b. Does it provide a preliminary assessment of where the project risks are likely to occur and what the magnitude of those risks might be? c. Does it indicate if the project/study will include an environmental impact statement (EIS)? *Is an EIS included? Yes ☐ No ☒* *If yes, IEPR is required.* d. Does it address if the project report is likely to contain influential scientific information or be a highly influential scientific assessment? *Is it likely? Yes ☒ No ☐* *If yes, IEPR is required.* e. Does it address if the project is likely to have significant economic, environmental, and social affects to the nation, such as (but not limited to): • more than negligible adverse impacts on scarce or unique cultural, historic, or tribal resources? • substantial adverse impacts on fish and wildlife species or their habitat, prior to implementation of mitigation? • more than negligible adverse impact on species listed as endangered or threatened, or to the designated critical habitat of such species, under the Endangered Species Act, prior to implementation of mitigation? *Is it likely? Yes ☐ No ☒* *If yes, IEPR is required.*	EC 1165-2-209 Appendix B Para 3a EC 1165-2-209 Appendix B Para 3a EC 1165-2-209 Appendix B Para 1 EC 1165-2-209 Para 15d EC 1165-2-209 Appendix B Para 7a EC 1165-2-209 Para 11d(3)(a) EC 1165-2-209 Para 11d(3)(a) EC 1165-2-209 Para 11d(3)(a)	a. Yes ☒ No ☐ b. Yes ☒ No ☐ c. Yes ☒ No ☐ d. Yes ☒ No ☐ e. Yes ☒ No ☐ **Comments:** An EA will be included

f. Does it address if the project/study is likely to have significant interagency interest? *Is it likely? Yes ☒ No ☐* *If yes, IEPR is required.* g. Does it address if the project/study likely involves significant threat to human life (safety assurance)? *Is it likely? Yes ☒ No ☐* *If yes, IEPR is required.* h. Does it provide an estimated total project cost? *What is the estimated cost: >$45.0 million* *Is it > $45 million? Yes ☒ No ☐* *If yes, IEPR is required.* i. Does it address if the project/study will likely be highly controversial, such as if there will be a significant public dispute as to the size, nature, or effects of the project or to the economic or environmental costs or benefits of the project? *Is it likely? Yes ☒ No ☐* *If yes, IEPR is required.* j. Does it address if the information in the decision document will likely be based on novel methods, present complex challenges for interpretation, contain precedent-setting methods or models, or present conclusions that are likely to change prevailing practices? *Is it likely? Yes ☒ No ☐* *If yes, IEPR is required.*	EC 1165-2-209 Appendix B Para 7a EC 1165-2-209 Appendix E Para 1a EC 1165-2-209 Para 11d(1)(b) EC 1165-2-209 Para 11d(1)(d) EC 1165-2-209 Para 16c(2) ,	f. Yes ☒ No ☐ g. Yes ☒ No ☐ h. Yes ☒ No ☐ Comment: Estimated costs are Greater than $45 million. i. Yes ☒ No ☐ j. Yes ☒ No ☐ **Comments:**
3. Does the RP define the appropriate level of peer review for the project/study?	EC 1165-2-209 Para 7a	Yes ☒ No ☐
a. Does it state that DQC will be managed by the home district in accordance with the Major Subordinate Command (MSC) and district Quality Management Plans? b. Does it state that ATR will be conducted or managed by the lead PCX?	EC 1165-2-209 Para 8a EC 1165-2-209 Para 9c(1)	a. Yes ☒ No ☐ b. Yes ☒ No ☐

c. Does it state whether IEPR will be performed? *Will IEPR be performed? Yes ☒ No ☐* d. Does it provide a defensible rationale for the decision on IEPR? e. Does it state that IEPR will be managed by an Outside Eligible Organization, external to the Corps of Engineers?	EC 1165-2-209 Para 7a EC 1165-2-209 Para 7a EC 1165-2-209 Para 11c	c. Yes ☒ No ☐ d. Yes ☒ No ☐ e. Yes ☒ No ☐ n/a ☐ **Comments:**
4. Does the RP explain how ATR will be accomplished?	EC 1165-2-209 Para 9 & Appendix C	Yes ☒ No ☐
a. Does it identify the anticipated number of reviewers? b. Does it provide a succinct description of the primary disciplines or expertise needed for the review (not simply a list of disciplines)? c. Does it indicate that ATR team members will be from outside the home district? d. Does it indicate that the ATR team leader will be from outside the home MSC? e. Does the RP state that the lead PCX is responsible for identifying the ATR team members and indicate if candidates will be nominated by the home district/MSC? f. If the reviewers are listed by name, does the RP describe the qualifications and years of relevant experience of the ATR team members?* **Note: It is highly recommended to put all team member names and contact information in an appendix for easy updating as team members change or the RP is updated.*	EC 1165-2-209 Appendix B Para 4f EC 1165-2-209 Appendix B Para 4g EC 1165-2-209 Para 9c(1)(a) EC 1165-2-209 Para 9c EC 1165-2-209 Para 9c(1) EC 1165-2-209 Appendix B Para 4k(5)	a. Yes ☒ No ☐ b. Yes ☒ No ☐ c. Yes ☒ No ☐ d. Yes ☒ No ☐ e. Yes ☒ No ☐ f. Yes ☒ No ☐ n/a ☐ **Comments:**
5. Does the RP explain how IEPR will be accomplished?	EC 1165-2-209 Para 10	**Yes ☒ No ☐ n/a ☐**

a. Does it identify the anticipated number of reviewers?	EC 1165-2-209 Appendix B Para 4f	a. Yes ☒ No ☐
b. Does it provide a succinct description of the primary disciplines or expertise needed for the review (not simply a list of disciplines)?	EC 1165-2-209 Appendix B Para 4g	b. Yes ☒ No ☐
c. Does it indicate that the IEPR reviewers will be selected by an Outside Eligible Organization and if candidates will be nominated by the Corps of Engineers?	EC 1165-2-209 Para 11c	c. Yes ☒ No ☐
d. Does it indicate the IEPR will address all the underlying planning, safety assurance, engineering, economic, and environmental analyses, not just one aspect of the project?	EC 1165-2-209 Para 11a	d. Yes ☒ No ☐ **Comments** IEPR is required.
6. Does the RP address peer review of sponsor in-kind contributions?		Yes ☐ No ☒
a. Does the RP list the expected in-kind contributions to be provided by the sponsor? b. Does it explain how peer review will be accomplished for those in-kind contributions?	EC 1165-2-209 Appendix B Para 4j	a. Yes ☐ No ☐ b. Yes ☐ No ☐ n/a ☒ **Comments:**
7. Does the RP address how the peer review will be documented?		Yes ☒ No ☐
a. Does the RP address the requirement to document ATR and IEPR comments using DrChecks?	EC 1165-2-209 Para 7d	a. Yes ☒ No ☐
b. Does the RP explain how the IEPR will be documented in a Review Report?	EC 1165-2-209 Para 7a	b. Yes ☒ No ☐ n/a ☐
c. Does the RP document how written responses to the IEPR Review Report will be prepared?	EC 1165-2-209 Para 7d(2)	c. Yes ☒ No ☐ n/a ☐
d. Does the RP detail how the district/PCX will disseminate the final IEPR Review Report, USACE response, and all other materials related to the IEPR on the	EC 1165-2-209 Para 7d(2)(a)	d. Yes ☒ No ☐ n/a ☐

internet and include them in the applicable decision document?		**Comments:** IEPR will be performed
8. Does the RP address Policy Compliance and Legal Review?	EC 1165-2-209 Appendix C Para 3a	Yes ☒ No ☐ **Comments:**
9. Does the RP present the tasks, timing and sequence (including deferrals), and costs of reviews?	EC 1165-2-209 Appendix B Para 4c	Yes ☒ No ☐
a. Does it provide a schedule for ATR including review of the Feasibility Scoping Meeting (FSM) materials, Alternative Formulation Briefing (AFB) materials, draft report, and final report? b. Does it include interim ATR reviews for key technical products? c. Does it present the timing and sequencing for IEPR? d. Does it include cost estimates for the peer reviews?	EC 1165-2-209 Appendix C Para 3g(3) EC 1165-2-209 Appendix C Para 3g(3)	a. Yes ☒ No ☐ b. Yes ☒ No ☐ c. Yes ☒ No ☐ n/a ☐ d. Yes ☒ No ☐ **Comments:**
10. Does the RP indicate the study will address Safety Assurance factors? Factors to be considered include: • Where failure leads to significant threat to human life • Novel methods\complexity\ precedent-setting models\policy changing conclusions • Innovative materials or techniques • Design lacks redundancy, resiliency of robustness • Unique construction sequence or acquisition plans • Reduced\overlapping design construction schedule	EC 1165-2-209 Appendix E	**Yes** ☐ **No** ☐ **n/a** ☒ **Comments:** This is neither a FRM or Storm Damage Reduction Project
11. Does the RP address model certification requirements?	EC 1165-2-209 Appendix B Para 3a	Yes ☒ No ☐
a. Does it list the models and data anticipated to be used in developing recommendations (including mitigation models)?	EC 1165-2-209 Appendix B Para 4i	a. Yes ☒ No ☐

b. Does it indicate the certification/approval status of those models and if certification or approval of any model(s) will be needed? c. If needed, does the RP propose the appropriate level of certification/approval for the model(s) and how it will be accomplished?	EC 1165-2-209 Appendix C Para 3k(1) EC 1165-2-209 Appendix C Para 3k(1)	b. Yes ☒ No ☐ c. Yes ☒ No ☐ n/a ☐ **Comments:**
12. Does the RP address opportunities for public participation?		Yes ☒ No ☐
a. Does it indicate how and when there will be opportunities for public comment on the decision document? b. Does it indicate when significant and relevant public comments will be provided to reviewers before they conduct their review? c. Does it address whether the public, including scientific or professional societies, will be asked to nominate potential external peer reviewers? d. Does the RP list points of contact at the home district and the lead PCX for inquiries about the RP?	EC 1165-2-209 Appendix B Para 3a EC 1165-2-209 Appendix B Para 4e EC 1165-2-209 Appendix B Para 4h EC 1165-2-209 Appendix B Para 4a	a. Yes ☒ No ☐ b. Yes ☒ No ☐ c. Yes ☐ No ☒ d. Yes ☒ No ☐ **Comments:** c. External Peer Review is required
13. Does the RP address coordination with the appropriate Planning Centers of Expertise?	EC 1165-2-209 Appendix D Para 3	Yes ☒ No ☐
a. Does it state if the project is single or multi-purpose? Single ☒ Multi ☐ List purposes: Deep Draft Navigation b. Does it identify the lead PCX for peer review? Lead PCX: **DD** c. If multi-purpose, has the lead PCX coordinated the review of the RP with the other PCXs as appropriate?	 EC 1165-2-209 Appendix D Para 3c	a. Yes ☒ No ☐ b. Yes ☒ No ☐ c. Yes ☒ No ☐ n/a ☐ **Comments:**
14. Does the RP address coordination with the Cost Engineering Directory of Expertise (DX) in Walla Walla District for ATR of cost	EC 1165-2-209 Appendix D Para 3	Yes ☒ No ☐

estimates, construction schedules and contingencies for all documents requiring Congressional authorization?		
a. Does it state if the decision document will require Congressional authorization? b. If Congressional authorization is required, does the state that coordination will occur with the Cost Engineering DX?		a. Yes ☒ No ☐ b. Yes ☒ No ☐ n/a ☐ **Comments:**
15. Other Considerations: This checklist highlights the minimum requirements for an RP based on EC 1165-2-209. Additional factors to consider in preparation of the RP include, but may not be limited to: a. Is a request from a State Governor or the head of a Federal or state agency to conduct IEPR likely? b. Is the home district expecting to submit a waiver to exclude the project study from IEPR? c. Are there additional Peer Review requirements specific to the home MSC or district (as described in the Quality Management Plan for the MSC or district)? d. Are there additional Peer Review needs unique to the project study?	EC 1165-2-209 Appendix D Para 1b(3&4) EC 1165-2-209 Para 11d	**Comments:** a. Yes ☐ No ☒ b. Yes ☐ No ☒ **Comments:** IEPR will be performed c. Yes ☐ No ☒ d. Yes ☐ No ☒
Detailed Comments and Back check:		

Attachment 7c

(Appendix H)

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REVIEW PLAN
FOR
Mouth of the Columbia River Jetties Major Rehabilitation
O&M

U.S Army Corps of Engineers

Portland District

July 16, 2010
(revised September 23, 2010 and October 21, 2011)

DRAFT

Table of Contents

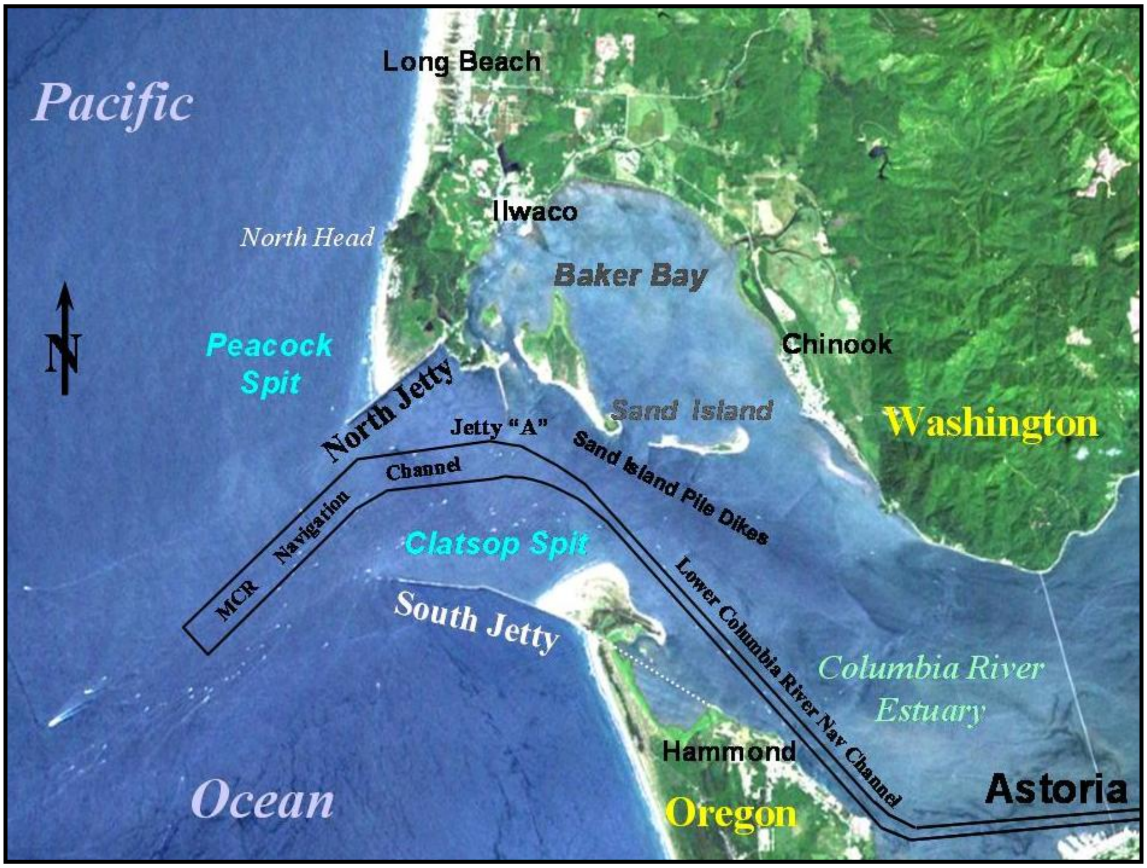
1. INTRODUCTION

The North Jetty and Jetty A are located in Pacific County, Washington, near Ilwaco and Long Beach on the Long Beach Peninsula (Figures 1 and 2). The North Jetty was completed in 1917. Jetty A, positioned on the south side of the North Jetty, was constructed in 1939 to a length of 1.1 miles. Jetty A was constructed to direct river and tidal currents away from the North Jetty foundation. The South Jetty is located in Clatsop County, Oregon near Warrenton/Hammond and Astoria. The initial 4.5-mile section of the South Jetty was completed in 1895, with a 2.4-mile extension completed in 1913. Jetty construction realigned the ocean entrance to the Columbia River, established a consistent navigation channel that was 40 feet deep across the bar, and significantly improved navigation through the MCR. Improvements made from 1930 to 1942 (including addition of Jetty A and Sand Island pile dikes) produced the present entrance configuration.

Prior to improvement in 1885, the tidal channels through the MCR shifted north and south between Fort Stevens and Cape Disappointment, a distance of about 5.5 miles. The controlling depth of dominant channel through the ebb tidal delta varied between 18 to 25 feet deep below MLLW. The ebb and flood tidal deltas at MCR entrance were distributed over a large area immediately seaward and upstream of the river mouth. Ships often had trouble traversing the Columbia River bar, the area in which the flow of the estuary rushes headlong into towering ocean waves. On many occasions, outbound ships had to wait a month or more until bar conditions were favorable for crossing. To make navigating through the MCR even worse, sailing ships had to approach either of the two natural channels abeam to the wind and waves. The natural channels often shifted widely within the course of several tidal cycles. At best, crossing the bar was dangerous. At worst, it was not possible.

Offshore of the MCR is the northeast Pacific Ocean. Inshore of the MCR is the Columbia River and estuary, the coastal outlet for a drainage basin of 250,000 square miles where the headwaters emanate from the western slope of the Rocky Mountains. The course of the Columbia River is 1,210 mile long, dropping over 2,600 feet from its Canadian headwaters to the sea. The river accounts from 60% in the winter to 90% in the summer of the total freshwater discharge into the ocean between the Canadian border and San Francisco, California. The Columbia River estuary is the largest fluvial dominate estuary in the Pacific Northwest. Its upriver limit, defined in terms of salt water intrusion, varies from river mile (RM) 28 to 38 and is a function of fluvial flow and sequencing of the tidal cycle. Current reversal due to tide can occur as far inland as RM 70. Tidal effects (fluctuation of water surface elevation) extend upriver to Bonneville Dam (RM 145).

Figure 1. Location of the Jetty System at the MCR



The 6-mile long deep-draft navigation channel at the MCR has become the ocean gateway for navigation access to and from the 500-mile long Columbia/Snake River inland navigation system. It is a critical regional and national gateway linking agricultural, mineral and goods production across the Northwest, Mountain, Midwest, and East Coast states to growing markets in the Pacific Rim. Economies of many states rely on the trade and commerce that flows up and down the system. Each year, ocean-going vessels on the Columbia River carry about 40 million tons of cargo with an estimated value of $17 billion on an annual basis. More than 12,000 commercial vessels and 100,000 recreational/charter vessels navigate through the MCR annually. According to the Center for Economic Development and Research,[1] the Columbia/Snake River navigation system is the #1 export gateway for the Nation's wheat and barley exports. It is also a primary paper/paper products export gateway; bulk minerals export gateway; and automobile import gateway for the West Coast. Also, marine traffic passing the entrance of the Columbia River is projected to increase by 35% from 32 million tons (2003) to 43 million tons by 2020.

[1] Center for Economic Development and Research. June 2005. Columbia/Snake River System and Oregon Coastal Cargo Ports Marine Transportation System Study. Prepared by PB Ports and Marine, Portland, OR; BST Associates, Bothell, WA; and Pacific Northwest Waterways Association, Portland, OR.

Figure 2. Rubble-mound Jetties at the MCR

South Jetty

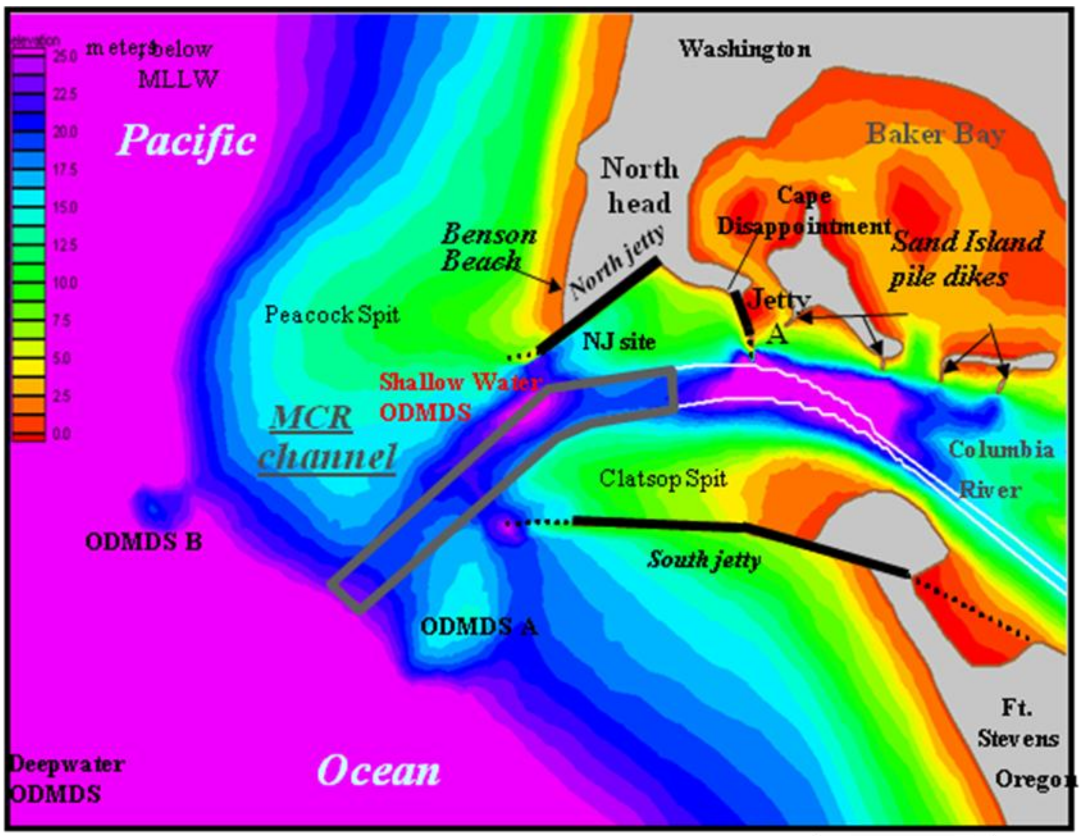
Jetty A

North Jetty

2. PROJECT BACKGROUND

The jetties at the MCR were constructed on massive tidal shoals and these shoals have been changing since the time of jetty construction. The longevity of the jetties is tied to the stability of the shoals on which the jetties were built, and the stability of the shoals is now a function of the jetties. The jetties and shoals act as integrated units to confine tidally driven circulation through the MCR and maintain the present channel configuration. Figure 3 illustrates the extensive underwater shoal system at the MCR.

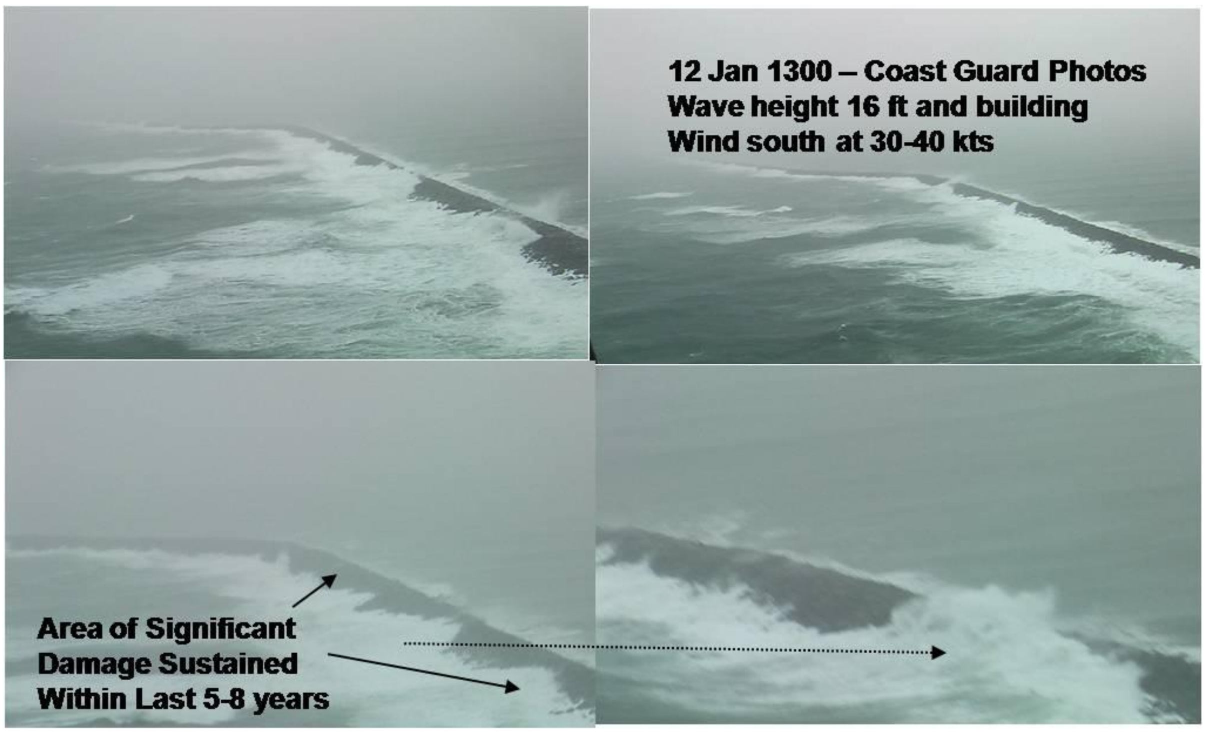
Figure 3. Bathymetry and Underwater Shoal System at the MCR



Through phased jetty construction (1885-1939) and the associated response of MCR morphology, each project feature at the MCR now is dependent on the other, both in terms of structural integrity and project feature functional performance. Severe deterioration of any of these features can jeopardize the MCR federal navigation channel and adversely affect the other structures. Should the North Jetty experience substantial deterioration from its present condition, the navigation channel, South Jetty, Jetty A, and ultimately the Sand Island pile dikes would be negatively affected. A similar scenario would likely occur if the South Jetty experienced substantial deterioration from its present condition. In this regard, the project features at the MCR are interrelated.

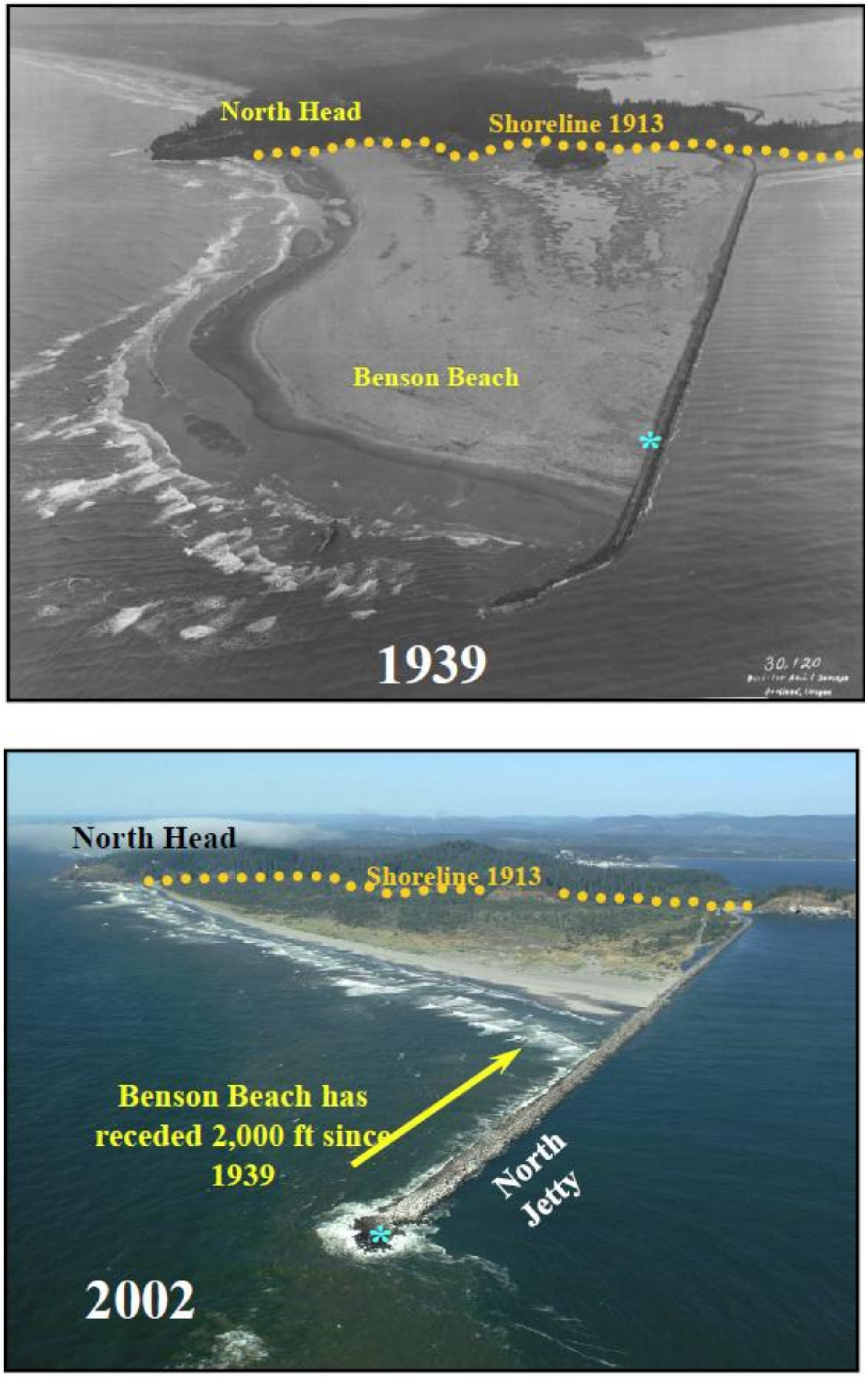
Structural degradation of the +100-year old MCR jetty system has accelerated in recent years because of increased storm activity and loss of sand shoal material upon which the jetties are constructed (Figure 4 shows waves attacking the South Jetty). In addition, beaches on the ocean sides of the North and South jetties, which formed as a result of jetty construction, have been receding gradually over the years, exposing previously protected jetty sections at the beach line to storm waves (Figure 5 shows Benson Beach recession at North Jetty).

Figure 4. Wave Action on South Jetty



The orientation of the shoals/spits at the MCR has arisen due to waves and currents; the morphology and coastal processes at the MCR are linked. Eddies that form within the MCR arise due to the interaction of flow with the jetties and the morphology greatly influences flow and shoaling within the federal navigation channel. The littoral dynamics north and south of the MCR are drastically different than at "open coast" areas away from the entrance. Depending on the regional wind field, the "coastal current" up-drift and down-drift from the MCR can attain speeds of 3 feet/second. As the tidal shoals continue to recede (erode), the MCR jetties will be exposed to larger waves and more vigorous currents.

Figure 5. Shoreline Response North of North Jetty



Despite intermittent repair and partial rehabilitation efforts, all of the MCR jetties are currently in a significantly deteriorated condition (Figures 6 and 7). Intermittent repairs were conducted in 2005 on the North Jetty and in 2006 and 2007 on the South Jetty. The last partial rehabilitation on the North Jetty was conducted in 1964 and addressed 17% of its length; the last partial rehabilitation on the South Jetty was conducted in 1982 and addressed 25% of its length; and the last partial rehabilitation on Jetty A was conducted in 1961 and addressed 56% of its length. The lengths of the North and South jetties, which have never been repaired since original construction, are 55% and 36%, respectively. The jetties continue to recede back from their original length. The head positions for the South and North jetties and Jetty A are currently shorter than authorized lengths by 6,200 feet, 2,120 feet, and 900 feet, respectively. Due to the interaction of wave patterns and currents with the jetty configuration, the shorter jetty lengths can increase underwater shoal erosion, influence shoreline position adjacent to the jetties, and alter the forcing climate at the project.

Figure 6. South Jetty Trunk Damage

Figure 7. North Jetty Damage Areas

Progressive damages to one of the jetties could result in a significant breach which can trigger an emergency repair to the jetty, rapid infill into the navigation channel, and emergency dredging activities. The current major rehabilitation approach for the MCR jetty system focused on adequately defining the larger processes affecting the jetty system, and then describing the jetty system reliability over time. Consequences evaluated included frequency and costs of future jetty repairs, as well as potential impacts to dredging and navigation. Each alternative adds additional elements of either process stabilization or above or below water cross section stabilization, as well as varying degrees of cross section reliability improvement.

In summary, taking no action to rehabilitate the MCR jetties to extend the functional life would result in further deterioration of the structures and the sand shoals upon which they rest, and would increase the likelihood of a jetty breach. Recent interim jetty repairs have addressed immediate critical needs. However, additional modifications and repairs to the jetties are necessary to address critical near- and long-term needs and to reduce the potential for emergency repairs, emergency dredging, and impacts to the Columbia-Snake River inland navigation system.

3. STUDY PURPOSE

Budget guidance [Budget Engineer Circular (EC) 11-2-199, dated 31 March 10] defines major rehabilitation based on these thresholds: "The work will extend over at least two full construction seasons and will require at least $6.6 million in outlays. For inland waterways projects, the reliability threshold will be $14 million." The work on all three of the MCR jetties fits the definition of major rehabilitation and therefore, this report is prepared using that guidance.

This evaluation was undertaken to address problems related to the structural stability of the MCR jetty system in order to extend their functional life and maintain deep-draft navigation.

This Review Plan (RP) outlines the review plan as required by EC 1105-2-410. This RP supplements the Project Management Plan (PMP). There are three levels of peer review required for this Study: District Quality Control (DQC), Agency Technical Review (ATR), and Independent External Peer Review (IEPR) based on the scale, impacts, and cost of this project.

Engineer Circular (EC) 1105-2-410 (Circular) dated 22 Aug 2008 "Review of Decision Documents" provides the procedures for improving the quality and credibility of U.S. Army Corps of Engineers (USACE) decision documents through an independent review process. It complies with Section 515 of Public Law 106-554 (referred to as the "Data Quality Act "); and the Final Information Quality Bulletin for Peer Review by the Office of Management and Budget (referred to as the "OMB Bulletin. It also provides guidance for the implementation of Section 2034 of WRDA 2007 (P.L. 110-114). This Circular also presents a framework for establishing the appropriate level and independence of review and detailed requirements of review documentation and dissemination.

A. Requirements. All decision documents and their supporting analyses will undergo DQC and ATR and may also require IEPR, to "ensure the quality and credibility of the government's scientific information", in accordance with this circular and the quality management procedures of the responsible command. The Circular addresses review of the decision document as it pertains to both approaches and planning coordination with the appropriate Center. The Circular also requires that DrChecks (https://www.projnet.org/projnet/) be used to document all ATR and IEPR comments, responses, and associated resolutions accomplished.

The types of technical review are provided below and have been redefined and renamed for consistency with recent legislation and to establish a more comprehensive lexicon. This Circular uses the terms "home district" or "home MSC" to refer to the office that has been assigned responsibility for a study or project and whose commander will sign any recommendations or decision document. Where studies are conducted by non-Federal interests, the "home district" will be the district which has the area of responsibility that contains the proposed project.

(1) **District Quality Control** (DQC). DQC is the review of basic science and engineering work products focused on fulfilling the project quality requirements defined in the Program Management Plan (PMP). It is managed in the home district and may be conducted by staff in the home district as long as they are not doing the work involved in the study, including contracted work that is being reviewed. Basic quality control tools include a Quality Management Plan providing for seamless review, quality checks and reviews, supervisory reviews, Project Delivery Team (PDT) reviews, etc. Additionally, the PDT is responsible for a complete reading of the report to assure the overall integrity of the report, technical appendices and the recommendations before approval by the District Commander. It is expected that the MSC/District quality management plans address the conduct and documentation of this fundamental level of review. DQC is not covered by this Review Plan.

(2) **Agency Technical Review** (ATR). ATR (which replaces the level of review formerly known as Independent Technical Review) is an in-depth review, managed within USACE, and conducted by a qualified team outside of the home district that is not involved in the day-to-day production of a project/product. The purpose of this review is to ensure the proper application of clearly established criteria, regulations, laws, codes, principles and professional practices. The ATR team reviews the various work products and assures that all the parts fit together in a coherent whole. ATR teams will be comprised of senior USACE personnel (Regional Technical Specialists (RTS), etc.), and may be supplemented by outside experts as appropriate. To assure independence, the leader of the ATR team shall be from outside the home MSC.

(3) **Independent External Peer Review** (IEPR). This is the most independent level of review, and is applied in cases that meet certain criteria where the risk and magnitude of the proposed project are such that a critical examination by a qualified team outside of USACE is warranted. The criteria for application of IEPR include, but are not limited to (1) the total project cost exceeds $45 million; (2) there is a significant threat to human life; (3) it is requested by a State Governor of an affected state; (4) it is requested by the head of a Federal or state agency charged with reviewing the project if he/she determines the project is likely to have a significant adverse impact on resources under the jurisdiction of his/her agency after implementation of proposed mitigation (the Chief has the discretion to add IEPR under this circumstance); (5) there is significant public dispute regarding the size, nature, effects of the project; (6) there is significant public dispute regarding the economic or environmental cost or benefit of the project; (7) cases where information is based on novel methods, presents complex challenges for interpretation, contains precedent-setting methods or models, or presents conclusions that are likely to change prevailing practices; or (8) any other circumstance where the Chief of Engineers determines IEPR is warranted. IEPR may be appropriate for feasibility studies; reevaluation studies; reports or project studies requiring a Chiefs Report, authorization by Congress, or an EIS; and large programmatic efforts and their component projects. IEPR is managed by an outside eligible organization (OEO) that is described in Internal Revenue Code Section 501(c)(3), is exempt from Federal tax under

section 501(a), of the Internal Revenue Code of 1986; is independent; is free from conflicts of interest; does not carry out or advocate for or against Federal water resources projects; and has experience in establishing and administering IEPR panels. The scope of review will address all the underlying planning, engineering, including safety assurance, economics, and environmental analyses performed, not just one aspect of the project.

(4) **Policy and Legal Compliance Reviews** In addition to the technical reviews described above, decision documents will be reviewed throughout the study process for their compliance with law and policy. Guidance for policy and legal compliance reviews is addressed further in Appendix H, ER 1105-2-100. The technical review efforts addressed in this Circular are to augment and complement the policy review processes by addressing compliance with published Army policies pertinent to planning products, particularly policies on analytical methods and the presentation of findings in decision documents. DQC and ATR efforts are to include the necessary expertise to address compliance with published planning policy.

(5) **Planning Center of Expertise (PCX) Coordination.** The Circular outlines PCX coordination in conjunction with preparation of the review plan. Districts should prepare the plans in coordination with the appropriate PCX and appropriate consultation with the allied Communities of Practice. The MSC Commander's approval of the review plan is required to assure that the plan is in compliance with the principles of this Circular and the MSC Quality Management Plan (ER 5-1-11). The review plans must anticipate and define the appropriate level of review. All reviews are expected to be completed and documented before the District Commander signs the report.

The PDT is presented in Appendix 1. The project manager, Eric Bluhm, is the main point of contact at Portland District for more information about this project and the review plan.

4. PROPOSED PLANNING MODELS

The MCR SRB model was developed to be a statistical tool to assist engineers and project managers in determining the most cost-effective and reliable method of maintaining and repairing the MCR jetties into the future. The SRB model was written for use in MATLAB® (The Mathworks Inc. 2009). A detailed description of the SRB model is provided in Appendices A2 and A3. Described below is a general overview of the intent, operation, and organization of the model, the coastal engineering functions, and an overview of the model inputs and outputs.

MCR SRB Model Intent

The general intent of the MCR SRB model is to predict the lifecycle costs of repairing and maintaining the MCR jetties based on several repair and maintenance alternative plans. The ultimate objective is to utilize the predicted lifecycle cost ranges and reliabilities computed from each modeled plan to select the option that best balances least cost with highest reliability. The SRB model provides estimates, not definitive answers and is useful in comparing alternatives, costs and consequences but is not the only basis for plan selection. At the foundation of the model is a Monte Carlo simulation which comprises numerous model runs (in the hundreds), each with varying random parameter values. The model, therefore, relies heavily on statistical analysis. Random variation of specific parameters is necessary due to the uncertainty involved in predicting the future demand on, and resultant response of, the jetty structures. Also through this analysis, it is possible to observe the parameters that are most sensitive to random variation and have the largest impacts on lifecycle costs and/or reliability. If the impacts of these parameters are understood and their variation can be controlled to a certain degree, it is logical to conclude that the lifecycle costs can likewise be managed to a similar degree.

MCR SRB Model Operation

The SRB model can be operated in two distinct manners, as a *hindcast* model or a *forecast* model. The hindcast mode incorporates historical jetty geometries (e.g., cross-sectional elevations and widths), costs, and other relevant information from the actual repairs that occurred to each structure since original construction (or since a specified historical date in the case of the South Jetty). Generally, if there is good agreement between modeled and measured data, then the model has good skill (predictability) and is deemed to be performing well. In calibrating the SRB model, *historical* costs and repair schedules were compared to *modeled* costs and schedules. Based on analysis of modeled results (i.e., plots of costs and repair schedules), the hindcast predictions for the MCR jetties are judged to have good model skill.

The hindcast model results are also used to initialize the model for operation in the forecast mode. In the forecast mode, the SRB model predicts structural damages (based on randomized storm conditions), implements repairs and rehabilitations, and calculates dredging and stone quantities over an anticipated jetty lifecycle. The forecasting procedure is similar to the hindcast procedure in the model. For simplicity, only the model forecasting procedures will be described below, but the general methods are essentially equivalent.

Typical simulation using the SRB model is as follows:

1. Simulate Structure’s Previous Life Cycle – Hindcast: Calibrate model to ensure the model replicates observed life-cycle quantities and timing and location of observed repairs. Key inputs include actual repair history, location, timing, and frequency.
2. Simulate Future Life Cycle – Forecast: Establish base condition to evaluate potential maintenance/rehabilitation scenarios against. A base condition is selected that is most likely to be implemented in a “non-intervention” framework.
3. Simulate Future Life Cycle – Alternative Analysis Forecast: Evaluate alternatives by life-cycle dredging and stone quantities and other metrics.

4. Select the alternative which achieves best reliable life-cycle performance.

For this project, the SRB model provides estimates, not definitive answers and is useful in comparing consequences for alternatives, but is not the only basis for plan selection.

The SRB model was used to hindcast the life-cycle performance of each jetty from initial construction (early 1910s) to the present (2010). Accurate hindcasting of jetty performance served as a basis for model verification. Metrics provided by the SRB model, which were used to evaluate life-cycle performance include:

- Jetty cross section evolution;
- Time-varying structural and functional reliability and residual risk;
- Jetty repair occurrence – expected frequency and location of jetty repairs;
- Jetty breach occurrence – expected frequency and location of jetty breaches;
- Potential for loss of jetty function to impact navigation function of the inlet; and
- Jetty end-state condition.

The SRB model was used in forecast mode to formulate an optimal plan for rehabilitating each jetty, predicated on the need to minimize life-cycle costs or maximize.

5. REVIEW SCHEDULE

ATRs will be conducted for all major GI phase documents (i.e, without-project report, feasibility scoping documents, plan selection report, and Draft FR/EA) and major engineering and scientific documents products (e.g., cultural resources overview, geomorphology report, and programmatic biological assessment). The review schedule is included in the Project Management Plan (PMP) and will be updated as reviews are scheduled.

Review	**Date**
EA out for public Review	February 2010
DQC of Main Report and Appendices	July/August 2010
ATR of Main Report/Appendices	23 August 2010
Draft Major Rehab Report complete	31 October 2010
IEPR completed	7 April 2011
SRB Model disapproved by HQUSACE	30 April 2011
Moffatt & Nichol: SRB model revised	30 March 2012
SRB model certified by ATR lead	30 March 2012
SRB model approved by HQUSACE	27 April 2012
DQC draft Major Rehab Report (MRR)	4 May 2012
Final MRR sent to NWD for approval	9 May 2012
Major Rehabilitation Report approved	8 June 2012

6. INDEPENDENT EXTERNAL PEER REVIEW (IEPR)

An independent external peer review was completed on the draft final main report and EA. The IEPR focused on the logic and understandability of the Planning and NEPA process and the analysis and rationale of the selected alternative for each jetty. The review panel was composed of individuals with expertise in, specific to the Pacific Northwest, coastal engineering, modeling (in Matlab), environmental compliance, cost engineering and economics. The entire decision document and EA with appendices was provided to the IEPR team on searchable CD. The IEPR was be done in DrChecks.

The IEPR was conducted by a contractor and managed by the Deep-draft center of expertise (DDNPCX). The DDN-PCX followed the process established in EC 1105-2-410 in managing the IEPR. The IEPR Team member disciplines can be found in Appendix 3.

The information from the IEPR was documented in a Report. This IEPR Report included the formal USACE responses and position on all IEPR comments. The information from the Report was included in the decision-making process.

The IEPR panel met with the study PDT and the public to determine areas of controversy in the feasibility report, and reviewed the written feasibility report documentation and files, including the technical appendices. The external peer review team will ensured:

- Scientific data used in the study was accurate and complete.
- Modeling methods used were pertinent to the type of study results required, and sound modeling methodology was used
- The analysis contained clearly justified and valid assumptions
- concepts, features, analytical methods, analyses, and details are appropriate, fully coordinated, and correct
- Problems/issues are properly defined and scoped
- Conclusions and recommendations are reasonable and justified.

The cost for the IEPR was approximately $250,000.

7. PUBLIC REVIEW OPPORTUNITIES

The public has been provided the opportunity to comment in Feb. 2010 on the EA as part of NEPA compliance. If the selected plans change significantly as a result of significant changes to the selected plan causing great environmental impacts, another draft of the EA will be posted for 30-day review by the public with a 15-day comment window.

8. ANTICIPATED NUMBER OF REVIEWERS

The current ATR plan included least six reviewers from outside of the Northwestern Division. This number was based on the disciplines required to develop the draft main report and EA.

9. PRIMARY DISCIPLINES & EXPERTISE NEEDED FOR ATR

The disciplines and expertise required for the ATR team are presented in Appendix 2.

The Agency Technical Review Team was selected on the basis of having the proper knowledge, skills, and experience necessary to perform the task and their lack of affiliation with the development of the main report, EA, and associated appendices. The review team will be developed by the Deep-Draft Navigation Center of Expertise to ensure that the technical work and products from each discipline achieve a quality product. The ATR was completed through DRCHECKS.

Technical review used appropriate analytical methods for each technical area. Technical review relied on periodic technical review team meetings to discuss critical plan formulation or other project decisions, and on the review of the written feasibility report documentation and files. Independent technical review ensured that:

- the draft main report and EA is consistent with current criteria, procedures and policy
- clearly justified and valid assumptions that are in accordance with established guidance and policy have been utilized, with any deviations clearly identified and properly approved
- concepts, features, analytical methods, analyses, and details are appropriate, fully coordinated, and correct
- problems/issues are properly defined and scoped
- conclusions and recommendations are reasonable and justified.

Funding in the amount of $100,000 was budgeted for Agency Technical Review.

Upon disapproval of the SRB model on 30 April 2011, the PDT engaged an AE firm to revise the model. Subsequently, the ATR lead reviewed and approved the revised model prior to review and approval by HQUSACE. Since the assumptions and plan selection process remained consistent from the draft to final Major Rehabilitation Report, another ATR and IEPR was not conducted.

APPENDIX 1: PROJECT DELIVERY TEAM

Discipline	Name	Office/Agency
Project Manager	Eric Bluhm	CENWP-PM-FP
Program Manager (O&M)	Tracy Williams	CENWP-PM-PD
Program Analyst	Tanya Young	CENWP-PM-PD
Plan Formulation	Laura Hicks	CENWP-PM
Environmental Coordinator	Jody Marshall	CENWP-PM-E
Environmental Compliance	Barbara Cisneros	CENWP-PM-E
Civil Design/Technical Lead	Mark Brodesser	CENWP-EC-DC
Survey/ CADD Mapping/GIS	Doug Swanson	CENWP-EC-TG
Geotechnical	Jeremy Britton	CENWP-EC-DC
Hydraulics & Hydrology	Cindy Thrush	CENWP-EC-HY
Hydraulics & Hydrology	Rod Moritz	CENWP-EC-HY
Economic Evaluation	Pat McCrae	CENWP-PM-FE
Cost Engineering	Phil Ohnstad	CENWP-EC-CC
Real Estate	Enrique Godinez	CENWP-RE
Public Affairs Office	Michelle Helms	CENWP-PA
PCX POC	Bernard Moseby	CESAM-PD-FE

APPENDIX 2: AGENCY TECHNICAL REVIEW (ATR)

Discipline	**Reviewer**
Review Team Leader	Robert Patev CENAE-EP-WG
Coastal Engineering	Alan Jeffries CEPOA-EN-CW-HH
Environmental	Kevin McKeag CENWS-PM-PL-ER
Environmental	Kenneth Brunner CENWS-PM-PL-ER
Economic Evaluation	Kevin Knight CEIWR-GW
Cost Engineering	Wally Brassfield CENWW-EC-X

APPENDIX 3: INDEPENDENT EXTERNAL PEER REVIEW

Discipline	**Reviewer**
Coastal Engineer/Modeling	Nels Sultan
Coastal Engineer/Const.	Shane Phillips
Environmental Specialist	Felicia Orah Rein
Economist	Daniel Mahar
Plan Formulator	Thomas Cuba

Attachment 8

(Appendix H)

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NWP RESPONSES TO NWD REVIEW COMMENTS FOR THE MCR JETTIES MAJOR REHABILITATION REPORT

June 15, 2012

BLUF (Bottom Line Up Front)

(1) NWD Comment (5/31/12): There has not been an ATR review on the base condition, evaluation, and recommendations as currently described in the report.

NWP Response (6/7/12): Concur. The ATR lead Robert Patev (CEIWR-RMC-ED) has agreed to conduct such a review in DrChecks along with ATR team members Alan Jeffries, a coastal engineer (CEPOA-EN-CW-HH) and Kevin Knight, an economist (CEIWR-GW). The plan is to ATR the May 2012 report to specifically review the base condition, the evaluation process and recommendations. Upon resolution of NWD comments, we will have only the ATR Lead, Bob Patev, recheck the final report.

Comment resolved: conditional upon ATR certification of report, 6/15/12

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(2) NWD Comment (5/31/12): There was a premature screening out of alternative based solely on estimated averaged annual costs when the costs are virtually indistinguishable. An explanation of the screening process and evaluation factors should be summarized in the report.

NWP Response (6/7/12): Concur. The following information will be incorporated into Chapter 4:

The Corps began looking at applying a system approach to the MCR entrance in 1999. Throughout FY 06-10, NWP considered where the end of each of three jetties should be at the mouth of the Columbia River and developed three jetty length options:

- rebuild the jetties to their authorized lengths
- rebuild the jetties to the midpoint between the authorized length and the existing jetty end station
- rehabilitating the jetty to the current end station

NWP has considered major alternatives to the authorized cross-section that included designs that stayed on the existing footprint and those that went off the existing footprint, including realigning the entire system.

Alternatives that extended the jetty lengths significantly beyond the existing end station or reconstructed the jetties off the existing footprint were deemed infeasible. Plans that extended beyond the authorized length or off the authorized footprint were outside the authority for this project.

In FY 2010-11, a 90% draft of the MRR underwent District Quality Control (DQC) and Agency Technical Review (ATR). The underlying tenets of that report included a base condition involving a fix-as-fails approach where each jetty was allowed to degrade as low as 20% of the originally authorized cross-section remaining above MLLW -5, resulting in forecasted breaches. The hypothetical breaches would release material into the navigation channel, leading to emergency dredging. Breaches were forecasted to primarily occur in the winter, thus emergency dredging was high-risk and very expensive, and reliability of the navigational channel became questionable. Moreover, potential breach volumes entering the navigation channel were difficult to predict. In an attempt to model these effects, the SRB model code became more complex as the analysis was developed and the timing of the runs became very long and the economics was embedded within the model code. NWP also developed a qualitative numeric scoring of alternatives that included several factors beyond average annual cost.

The IEPR was conducted from December 2010 through April 2011. At the same time, the SRB model underwent substantial review, including ATR approval and DDN-PCX model certification in January 2011. This documentation was then forwarded to HQUSACE for final approval where it was disapproved in June 2011 because the IEPR panel raised concerns about the predicted frequency and severity of breaching and sediment transport in the base condition.

After consultation with NWD, it was decided that an MMR should be produced for the most critical portions of the North Jetty for inclusion in the FY 2013 budget submission. Therefore, the lagoon fill between STA 20 to 60 and critical repairs between STA 86 to 99 were removed from the MRR alternatives and included in the revised base condition. These repairs were deemed high-risk and were assumed to occur before the major rehab actions.

NWP decided to revise the SRB model, MRR and appendices per IEPR comments and hired Moffatt & Nichol, a coastal engineering consultant. The A/E task order emphasized improving the model code; showing compliance with current technology and Corps policy; providing additional documentation; improving practicality with data inputs and outputs; and user manual; and clearly identifying the use and limitations of the model consistent with EC 1105-2-412.

Due to the level of construction and high mobilization costs, the revised FY 12 base condition—identified as an interim-repair approach—was developed to replace the FY 11 "fix-as-fails" approach. The new base condition assumes the upper portion of the jetty is allowed to be degraded until approximately 35% of the cross-section is remaining prior to repair action being initiated. This change in the base condition allows for repair actions to take place prior to a breach event, and thereby eliminates breaching and sediment transport through the jetty, affecting the navigational channel and significantly reduces winter emergency dredging.

The economics analysis is now outside the model in a post-process spreadsheet. The code has been modularized and simplified so that there is one code for all three jetties. The user's manual provides enough detail for a knowledgeable coastal engineer to run the model. These changes improved the transparency of the model's sub-routines, dependant and independent variables, and damage functions leading to the ultimate approval of the model on 27 April 2012.

The above series of events resulted in a change in the selected plans for the three jetties.

ER 1105-2-100, Appendix G (pp. 7-8), states: "Identification of the NED plan is to be based on consideration of the most effective plans for providing different levels of output or service. Where two cost-effective plans produce no significantly different levels of net benefits, the less costly plan is to be the NED plan, even though the level of outputs may be less."

It is important to note that the purpose of the authorized project is to maintain a reliable, functioning, deep-draft navigation channel through the Columbia River entrance. It is not to compare the structural components of each of the alternatives so that if two alternatives still result in no impact to the navigation channel, their benefit is treated as the same. Therefore, the alternatives were evaluated based on least cost as long as they still provided for a usable channel.

In addition, the price of jetty stone and the quantity needed to construct the spur groins proposed outweighed the predicted benefit of repeated maintenance. This assumption will be monitored in the recommended plan throughout time and if foundation conditions deteriorate, threatening or affecting the jetty's stability, this decision will be revisited in the future.

Comment resolved: IRC 6/14

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(3) NWD Comment (5/31/12): There is not a concise description of the recommended plan. Additionally, there is a lack of clarity of alternative analysis (Chapter 4) in terms of inclusion of metrics into the Average Annual Cost (AAC), in particular constructability and structural and functional reliability as requested in an NWD Memo dated 30 June 2010.

NWP Response (6/7/12): Concur. The following text is proposed to be added to the report to Chapter 4 to address this comment:

The Corps began looking at applying a system approach to the MCR entrance in 1999. Throughout FY 06-10, NWP considered where the end of each of three jetties should be at the mouth of the Columbia River and developed three jetty length options:

- rebuild the jetties to their authorized lengths
- rebuild the jetties to the midpoint between the authorized length and the existing jetty end station
- rehabilitating the jetty to the current end station

NWP has considered major alternatives to the authorized cross-section that included designs that stayed on the existing footprint and those that went off the existing footprint, including realigning the entire system.

Alternatives that extended the jetty lengths significantly beyond the existing end station or reconstructed the jetties off the existing footprint were deemed infeasible. Plans that extended beyond the authorized length or off the authorized footprint were outside the authority for this project.

In FY 2010, a 90% draft of the MRR underwent District Quality Control (DQC) and Agency Technical Review (ATR). The underlying tenets of that report included a base condition involving a fix-as-fails approach where each jetty was allowed to degrade as low as 20% of the originally authorized cross-section remaining above MLLW -5, resulting in forecasted breaches. The hypothetical breaches would release material into the navigation channel, leading to emergency dredging. Breaches were forecasted to primarily occur in the winter, thus emergency dredging was high-risk and very expensive, and reliability of the navigational channel became questionable. Moreover, potential breach volumes entering the navigation channel were difficult to predict. In an attempt to model these effects, the SRB model code became more complex as the analysis was developed and the timing of the runs became very long and the economics was embedded within the model code. NWP also developed a qualitative numeric scoring of alternatives that included several factors beyond average annual cost.

The IEPR was conducted from December 2010 through April 2011. At the same time, the SRB model underwent substantial review, including ATR approval and DDN-PCX model certification in January 2011. This documentation was then forwarded to HQUSACE for final approval where it was disapproved in June 2011 because the IEPR panel raised concerns about the predicted frequency and severity of breaching and sediment transport in the base condition.

After consultation with NWD, it was decided that an MMR should be produced for the most critical portions of the North Jetty for inclusion in the FY 2013 budget submission. Therefore, the lagoon fill between STA 20 to 60 and critical repairs between STA 86 to 99 were removed from the MRR alternatives and included in the revised base condition. These repairs were deemed high-risk and were assumed to occur before the major rehab actions.

NWP decided to revise the SRB model, MRR and appendices per IEPR comments and hired Moffatt & Nichol, a coastal engineering consultant. The A/E task order emphasized improving the model code; showing compliance with current technology and Corps policy; providing additional documentation; improving practicality with data inputs and outputs; and user manual; and clearly identifying the use and limitations of the model consistent with EC 1105-2-412.

Due to the level of construction and high mobilization costs, the revised FY 12 base condition—identified as an interim-repair approach—was developed to replace the FY 11 “fix-as-fails” approach. The new base condition assumes the upper portion of the jetty is allowed to be degraded until approximately 40% of the cross-section is remaining prior to repair action being initiated. This change in the base condition allows for repair actions to take place prior to a breach event, and thereby eliminates breaching and sediment transport through the jetty, affecting the navigational channel and significantly reduces winter emergency dredging.

The economics analysis is now outside the model in a post-process spreadsheet. The code has been modularized and simplified so that there is one code for all three jetties. The user’s manual provides enough detail for a knowledgeable coastal engineer to run the model. These changes improved the transparency of the model’s sub-routines, dependant and independent variables, and damage functions leading to the ultimate approval of the model on 27 April 2012.

The above series of events resulted in a change in the selected plans for the three jetties.

ER 1105-2-100, Appendix G (pp. 7-8), states: "Identification of the NED plan is to be based on consideration of the most effective plans for providing different levels of output or service. Where two cost-effective plans produce no significantly different levels of net benefits, the less costly plan is to be the NED plan, even though the level of outputs may be less."

It is important to note that the purpose of the authorized project is to maintain a reliable, functioning, deep-draft navigation channel through the Columbia River entrance. It is not to compare the structural components of each of the alternatives so that if two alternatives still result in no impact to the navigation channel, their benefit is treated as the same. Therefore, the alternatives were evaluated based on least cost as long as they still provided for a usable channel.

In addition, the price of jetty stone and the quantity needed to construct the spur groins proposed outweighed the predicted benefit of repeated maintenance. This assumption will be monitored in the recommended plan throughout time and if foundation conditions deteriorate, threatening or affecting the jetty's stability, this decision will be revisited in the future.

NWD Response (6/14/12): Unfortunately the reviewer didn't clearly make the intended point. The response is good, but really more relevant to BLUF #3. The comments should have read "AAC should be reported to a defensible level of accuracy, presumably $millions. The NED plan would then be accurately portrayed as one of 3 or 4 of the lowest cost alternatives for the north and south jetties. Further screening of these NED plans could then be done through all the other metrics identified and discussed in great detail in the previous chapters."

Comment resolved: IRC 6/14/2012

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(4) NWD Comment (5/31/12): The Plan included commitments to Habitat Improvement Measures and establishing an adaptive management interagency team (AMT) that are not required or mitigation. The scope of the actions presented are disproportionate to the scope of short and long term impacts, are not within the MCR navigation project authority, and would require additional authority and documentation to complete. The measures also pose a potential fiscal law violation if the expenditures are not attributed to the proper authority. If they were to be included in the project, additionally, their cost would have to be accounted for in the project evaluation.

NWP Response (6/7/12): NWP's reference to habitat improvement measures may have confused NWD. We are not trying to improve the habitat, we are trying to mitigate for impacts from the federal action. One exception to this is the establishment of the snowy plover habitat. The compensation for impacts to wetlands habitat is 2:1, and waters of the US impacts is 1.5:1. The MCACES's cost estimate includes dollars for these impacts. NWP also identified areas in the cost estimate that were mislabeled as mitigation and have been corrected. This district will change the reference of habitat improvement measures (HIM) to compensatory mitigation for impacts to aquatic resources.

Impacts to aquatic resources require mitigation under the Clean Water Act (CWA) as clarified under 33 Code of Federal Regulations (CFR) 332. The district proposes to compensate for the aquatic impacts ranging from 1.5:1 to 2:1 ratio. Since the contractor may or may not use the sites NWP has identified and analyzed in the 2012 Environmental Assessment (EA) and Finding of No Significant Impact (FONSI), an AMT will help the Corps identify what actual in-water impacts need compensation. The AMT will be composed of federal and state agencies which have authority in regards to the mitigation.

Comment resolved: IRC 6/14

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(5) NWD Comment (5/31/12): Mitigation requirements are for CWA impacted wetlands comprised of 4.7 acres of wetlands and 11.52 acres of other waters of the U.S. The cost of mitigation does not appear to be included in the project alternatives evaluated using the CE/ICA framework and included in the BCR. Also note: Appendix E places mitigation costs at $6,548,886, which seems excessive for small acreage of low quality wetlands.

NWP Response (6/7/12): The cost estimate has been revised to account for only the compensatory mitigation for the major rehab report and not the major maintenance report, with the exception of snowy plover. Because the exact mitigation lands have not been identified yet, a representative site (Lois Island) was used for costing purposes. It should be noted that this is intended to be a maximum cost and therefore cost effectiveness and incremental cost analysis was not performed. The cost estimate is being certified by the NWW cost center of expertise. The district proposes to compensate for the aquatic impacts ranging from 1.5:1 to 2:1 ratio.

For further clarification, the Environmental Assessment (EA) encompasses three separate sets of actions: (1) South Jetty Dune augmentation/stabilization (without project condition: $5.5M in the President's budget for FY 13; (2) North Jetty Major Maintenance Report (MMR): lagoon fill and critical repairs STA 86-99; and (3) the selected plans described in the MRR as basis for an FY 14 budget submittal. The major rehab report is a subset of what is described in the EA.

Comment resolved: IRC 6/14

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(6) NWD Comment (5/31/12): The certification of the cost estimate is missing. This needs to be submitted with the final report sent for review.

NWP Response (6/7/12): Concur. The cost estimate certification is in process. The signed certification will be provided on 15 June with hard copies of the revised MRR.

Comment resolved: Cost estimate certified by NWW PCX on 13 June 2012

COMMENTS

GENERAL

1. NWD Comment (5/31/12): There were a couple of cases where the "proposed" plan features discussed in the main report did not appear to match the recommended plan. It was difficult to find a good, complete description of what the recommended plan for each jetty included. Recommend review all project descriptions throughout the report and making them concise and consistent.

NWP Response (6/7/12): Concur. NWP will review all project descriptions throughout the report to make them concise and consistent.

NWD Response (6/14/12): Comment resolved.

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2. NWD Comment (5/31/12): Section 3.5.3.1 – It is not clear which engineering features are in the recommended alternative. Spur groins are stated as being constructed for all the jetties and locations and are shown in Figure 3-26. Table 2-1 indicates that the spur jetties are not in the recommended plan. The basis of this concern is ER 1105-2-100 paragraph E-3. This is a significant concern as it is not clear which features are included in the recommended alternative.

NWP Response (6/7/12): 3.5.3.1 was edited in the following manner.

In areas where foundation scour threatens the overall jetty stability, spur groins were considered in some alternatives. If constructed, the spur groins would be perpendicular to the jetty to facilitate stabilization via accumulation of sediment along the jetty foundation. Historical experience and numerical modeling were used to select the type, depth, and length of spur groin necessary to impact the processes causing increased scour at each jetty (e.g., rip currents, eddies). A range of information was utilized in developing recommended spur groin applications along the MCR jetties. The recommended plan was determined within the framework of trying to specify the lowest impact spur groin layouts (size and number of spurs) suitable to achieving the intended long-term stability purpose of the structures. Information utilized included knowledge of problem erosion areas along the three primary jetties, experience of spur groin application at the South Jetty and Yaquina South Jetty, observation of jetty relic stone wing impacts on shoreward sedimentation, other spur groin studies, and numerical hydrodynamic modeling. The effectiveness of the spur groins is evaluated in the model and compared using average annual costs to decide whether it's more effective to have higher up-front costs by constructing them, or repeated maintenance in those areas to secure the foundation on the jetty trunks without them.

In Sections 4.5 (p. 4-11) and 7.2 (p. 7-2) are explicitly clear that spur groins are not included the recommended plans.

NWD Response (6/14/12): Comment resolved.

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3. NWD Comment (5/31/12): There is considerable concern about the current relevancy of the ATR which was performed in August – December 2009 and is not only very dated, but more importantly performed on a draft report with a significantly different base condition as well as significantly different recommendations.

NWP Response (6/7/12): The majority of the 2011 draft Major Rehabilitation Report has not changed in the 2012 document under review. The SRB model was modularized and the user's manual revamped; however, the selected plans changed because the base condition changed as a result of a significant IEPR comment. The ATR date referenced in comment is for the technical appendices, not the main report. Attachment 1 is a summary of key events and reviews regarding the MRR, as well as the differences between the 2011 and 2012 reports.

In addition, the ATR lead Robert Patev (CEIWR-RMC-ED) has agreed to conduct such a review in DrChecks along with ATR team members Alan Jeffries, a coastal engineer (CEPOA-EN-CW-HH) and Kevin Knight, an economist (CEIWR-GW). The plan is to ATR the May 2012 report to specifically review the base condition, the evaluation process, and recommendations. Upon resolution of NWD comments, the district will have only the ATR lead, Bob Patev, recheck the final report.

NWD Response (6/14/12): Comment resolved.

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4. NWD Comment (5/31/12): There is not a consistent applied definition of the base condition throughout the main report. The executive summary (page 2) states the cross section is allowed to deteriorate to 40% prior to repair actions. However on page A2-3-63 defines the base condition allowing deterioration to 35%. The executive summary (page 2) describes that preventive measures will be used in the base condition to avoid a breach of the jetty. However throughout the document (page 3-25, A2-3-60, A2-3-63, A2-3-67, and A2-3-85) breaches are described. The basis of this concern is ER1105-2-100 paragraph E-3. An accurate description and use of the base condition is necessary to evaluate alternatives. Please delete / correct inaccurate descriptions of the base condition.

NWP Response (6/7/12): The correct trigger for above-water cross-section remaining ranges between 30-40% for interim and scheduled repairs. It is not a discreet number because it is represented by a probability density function. NWP is using 35% throughout the report.

NWD Response (6/14/12): Comment resolved.

BACKGROUND & EXISTING CONDITIONS

1. NWD Comment (5/31/12): 2nd to last paragraph p. ii – Here and elsewhere need to provide a figure that illustrates what "..upper portion of the cross section is allowed to be damaged to approximately 40 percent remaining prior to repair actions…" Otherwise this is subject to a lot

of interpretation, upper portion could mean innumerable things from area/volume above the seabed, to area/volume above the MLLW, etc. Damaged could also be interpreted in innumerable ways from missing to fractured, to dislodged, etc…

NWP Response (6/7/12): Concur. Graphics will be added.

NWD Response (6/14/12): Comment resolved.

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2. NWD Comment (5/31/12): There appear to be inconsistent lengths provided for the South Jetty, e.g. 6.6 miles (Sect 1.2) and 7 miles (4.5 with a 2.5 mile extension) in Section 1.3. This may be due to the extension occurring after some recession occurred and if so that should be clear.

NWP Response (6/7/12): The authorized length of the MCR South Jetty is 6.6 miles. The report will be consistent with that length.

NWD (6/8/12): Comment resolved.

3**.** NWD Comment (5/31/12) Brad: Sect. 1.4, para 4; sect. 1.5.1, 3rd para, p 1-13; sect. 3.2.2, 3.2.5, storm events p. 3-51 and elsewhere. Throughout the document the case is clearly made and documented that degradation of the jetties has accelerated in recent years because of increase storm activity and loss of sand shoal material. Although this point is extremely important to decision making it isn't clear how/if it is incorporated into the SRB model or any attempt to quantify it, perhaps similar to the SLC Figure 3.1. Additionally, sect. 1.4 seems to document this phenomena and sect. 3.2.2 says "…storms may be increasing…". The increased storminess could potentially be a bigger issue than SLC in terms of alternative selection and long term planning. At a minimum, some discussion of the sensitivity of the design and decision making could be done beyond "adaptive management".

NWP Response (6/7/12): This particular issue has been addressed through ATR, IEPR, DQC, and with coastal experts and it was concluded that the model was appropriate. The district has excerpted the comment and response from the IEPR that was finalized in April 2011. Comment response is added here for clarification to see if this addresses and satisfies NWD's comment.

Sea level rise and potential increases in wave height have not been examined sufficiently under different model scenarios.
Basis for Comment:
The issue of climate change, sea level rise, and increased wave action is important to consider in the evaluation of long-term projects (USACE, 2009). There is no discussion in the main report of sea level rise and its impact on this project over the 50+ year project timeline. There is a limited discussion of climate change in Appendix D (p. 5), where the conclusion is that since the projected historical trend of sea level at the project site is estimated to be -0.05 feet in 50 years, sea level rise is not projected to be a significant climate change factor at the project site.

Appendix D states the "comprehensive analysis of historical storm events is expected to adequately capture the present deep water contribution of potential wave height variation for this project site. The above approach forms the basis for estimating the potential changes in wave climate that could affect the MCR jetty system." However, this discussion on wave height trends is not compelling. The main report states (p. 1-6), "As the tidal shoals continue to recede (erode), the MCR jetties will be exposed to larger waves and more vigorous currents. To make matters worse, the regional wave climate along the Northwest Pacific Coast has become more severe in the last 10 years. The offshore 100-year wave height has been revised from 41 to 55 feet." (see also Appendix D). The main report states (p. 3-42), "The limit of cross-section resiliency is reached for jetties when the core stone becomes exposed to wave attack." Therefore, this issue may affect jetty erosion and a larger range of wave heights should be included in both the SRB and STWAVE model scenarios. Wave overtopping is central to the environment deteriorating the existing jetties. As the planning horizon of this project is 50+ years, it seems that a discussion would be useful of sea level rise and modeling potential wave heights and the wave overtopping impacts on the jetties given different rates of recession under a wider range of wave heights. Jetty height and crest elevation are variables that should be modeled given the potential larger wave heights possible under sea level rise. Although the selection of the recommended plan may not change, long-term maintenance costs may be affected, therefore consideration is warranted. Appendix B states that transient internal hydraulic effects of wave impact may be the most important parameter in the stability of the jetties. However, it is the least certain of all of the parameters. Internal hydraulic pressures in jetties have not been measured. Given this, it seems especially important to consider more extreme wave heights beyond the wave height analyzed, with respect to sea level rise and potential increasing wave height.
Significance – Medium:
The discussion of potential impacts of sea level rise and increased wave action on jetty structures is critical to understanding the potential impacts to the project and in designing a project with lower long-term maintenance costs.

Recommendations for Resolution:

1. Add a separate section to the Major Rehabilitation Evaluation Report that examines climate change, sea level rise, potential wave height changes, and resulting wave overtopping impacts on the jetties given different rates of recession under different model scenarios.

USACE Draft Evaluator Response (#11)

Final Panel Comment #11 NON-CONCUR

Discussion of potential sea level rise as well as its impact on potential future loading on the MCR jetties has been included in Appendices A1 and A2. Portions of that discussion can be moved to the Main Report for completeness.

All of the factors discussed above have been incorporated into the wave height loading for the structures. An extremal analysis has been performed utilizing the period of record for the Columbia River NDBC buoy producing the expected long-term estimates of extremes at the project area. This estimate compares well with the recent analysis conducted by Ruggiero for the Oregon coast wave climate. An incremental increase in wave height has also been included to reflect the potential for an upward trend in storm intensity. The project event tree simulation includes a function that gradually increases the depth-limited wave height incident to the structure as the scour increases and the water depth at the structure increases.

The potential for sea level rise was incorporated in the project event tree simulation and life cycle analysis of the project. As directed by USACE (2009), three separate potential sea level curves were estimated placing the potential sea level change at the project site over the 50 year planning horizon somewhere between -0.05 ft to +1.6 ft. Each life cycle run for the project utilized one of the sea level change curves in order to factor in that potential change in project loading and its impact on maintenance requirements and effectiveness. With the slightly greater water level at the project site during these realizations, the incident wave height was also adjusted accordingly. So the future case scenarios incorporate both a higher water level as well as the impact of wave height.

1. **ADOPT NOW** by moving the sea level rise section of the report to the Main report for better clarity. In the analysis, the waves are currently estimated at three different potential water levels. The relative mildness of sea level change at the project site makes the inclusion of sea level change in the total loading environment less of a driving factor in a long-term maintenance strategy. In addition, due to the uncertainty of future sea level rise scenarios, the most likely approach for very large rubblemound structures for future maintenance would be to develop an adaptable maintenance strategy that could be modified as the gradual change is observed.

NWD Response (6/14/12): Comment resolved.

4. NWD Comment (5/31/12): Section 1.5.1, sect. 1.5.1.3, 1.5.1.4, 1.5.2 and elsewhere, the point is clearly demonstrated here and throughout that the loss of sand shoal material is a major contributor to the failing condition of the jetties. What isn't discussed is whether the significant reduction in sediment load in the Columbia system since the construction of the dams is potentially a contributing factor (loss of source material). The increase in active storage from 213KAF to 49MAF from 1910 to 1968 has had a tremendous impact on the hydrograph for the basin and correspondingly ability to transport sediment. How are we applying a watershed approach to the evaluation?

NWP Response (6/7/12): We are not applying a watershed approach to major rehab. It is outside the scope of a major rehab. That would need to be evaluated under general investigation study. The foundation concerns were addressed through IEPR. Additionally, the Corps and the region are investigating ways to place dredged material from the mouth of the Columbia River in near-shore areas north and south of both jetties respectively. This will also aid in reduction of the shoaling concern.

NWD Response (6/14/12): If the significant change in quantity of sediment supplied to the MCR doesn't affect the stability or plan evaluation to the jetties, then the report should so state. Not addressing this because this isn't a GI study isn't an adequate response.

Report modified to indicate change in sediment quantities not evaluated in report.

NWD Response (6/14/12): Comment resolved.

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5. NWD Comment (5/31/12): P 1-19. Here and elsewhere the concrete terminal of the south jetty is discussed. What impresses is that this south jetty head has remained functional and above water for over 70 years in this extremely violent environment. Referencing pg A2-3-66, assuming it will be above water for another 12-20 years will make it 90 year life. Recommend discussing if this was considered and if so, why eliminated as it seems to have performed incredibly well. Also, relate to assessment in 3.5.2.1.

NWP Response (6/7/12): The referenced paragraph states, "the entire cap has been severely damaged due to the severe wave climate – and is progressively failing." The cap is predicted to be non-existent within 12-20 years.

NWD Response (6/14/12): The point is that a 90-year life is really good survival in this violent environment. The question is "why wouldn't we 'consider' using a technique that has a demonstrated longevity of 70-years and a likely life of 90-years?"

IRC 6/14/12 comment closed: Agreed that all head stabilization options will be reviewed in DDR

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6. NWD Comment (5/31/12): Sect. 1.5.4.1 and elsewhere. There is an assumed near linear progression in the recession rates of the jetties. Is this realistic as the recession continues into progressively shallower water? Would this affect the alternative evaluation?

NWP Response (6/7/12): The overall assumption is that the North Jetty and Jetty A would be built back to a station certain and not allowed to recede back into shallow water. The South Jetty is not built back to a station certain in the selected plan, but the head will be stabilized when construction efforts are occurring at the end of the jetty. The predicted linear recession of the jetty was used for illustrative purposes. In Figures 1-24, -26 and -31, the linear portion was just used for simplicity. It represents two possibilities of recession as a constant if no action is taken. It is not meant to infer it is a linear regression.

NWD Response (6/14/12): If the linear progression was NOT used in the alternative analysis, so state.

NWP Response (6/14/12): Recession of jetty heads used in alternatives are based on the wave climate and structure response for the alternative being modeled.. Hold Head alternatives continue to re-construct to existing end-points. Those endpoints are: NJ-101+00, JA-89+00, SJ-head recession is assumed to reach 290+00 by 2020 for selected plan,

Comment Closed: IRC 6/14/12

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7. NWD Comment (5/31/12): Top of page 1-48 and throughout. The report repeatedly makes the point about the function, importance and performance of groins, but dismisses in the final evaluation without much discussion on why groins are no longer are that important/functional. Seems very inconsistent in terms of value of these engineering features.

NWP Response (6/7/12): Concur. The Corps began looking at applying a system approach to the MCR entrance in 1999. The following will be incorporated into Chapter 4 and the Executive Summary.

The Corps began looking at applying a system approach to the MCR entrance in 1999. Throughout FY 06-10, NWP considered where the end of each of three jetties should be at the mouth of the Columbia River and developed three jetty length options:

- rebuild the jetties to their authorized lengths
- rebuild the jetties to the midpoint between the authorized length and the existing jetty end station
- rehabilitating the jetty to the current end station

NWP has considered major alternatives to the authorized cross-section that included designs that stayed on the existing footprint and those that went off the existing footprint, including realigning the entire system.

Alternatives that extended the jetty lengths significantly beyond the existing end station or reconstructed the jetties off the existing footprint were deemed infeasible.

In FY 2010, a 90% draft of the MRR underwent District Quality Control (DQC) and Agency Technical Review (ATR). The underlying tenets of that report included a base condition involving a fix-as-fails approach where each jetty was allowed to degrade as low as 20% of the originally authorized cross-section remaining above MLLW -5, resulting in forecasted breaches. The hypothetical breaches would release material into the navigation channel, leading to emergency dredging. Breaches were forecasted to primarily occur in the winter, thus emergency dredging was very expensive, and reliability of the navigational channel became questionable. Moreover, breach volumes entering the navigation channel were difficult to quantify. In an attempt to model these effects, the SRB model code became more complex as the analysis was developed and the timing of the runs became very long and the economics was embedded within the model code. NWP also developed a qualitative numeric scoring of alternatives that included several factors beyond average annual cost.

The IEPR was conducted from December 2010 through April 2011. Concurrently, the SRB model underwent substantial review, including ATR approval and DDN-PCX model certification in January 2011. This documentation was then forwarded to HQUSACE for final approval where it was disapproved in June 2011 because the IEPR panel raised concerns about the frequency and severity of breaching and sediment transport in the base condition.

After consultation with NWD, it was decided that an MMR should be produced for the most critical portions of the North Jetty for inclusion in the FY 2014 budget submission. Therefore, the lagoon fill between STA 20 to 60 and critical repairs between STA 86 to 99 were removed from the MRR alternatives and included in the revised base condition.

NWP then decided to revise the SRB model, MRR and appendices per IEPR comments and hired Moffatt & Nichol, a coastal engineering consultant. Furthermore, the A/E task order emphasized improving the model code; showing compliance with current technology and Corps policy; providing additional documentation; improving practicality with data inputs and outputs; and user manual; clearly identifying the use and limitations of the model consistent with EC 1105-2-412.

Due to the level of construction and high mobilization costs, the revised FY 12 base condition—identified as an interim-repair approach—was developed to replace the FY 11 “fix-as-fails” approach. The new base condition allows the upper portion of the jetty is allowed to be degraded until approximately 40% of the cross-section is remaining prior to repair action being initiated. This change in the base condition allows for repair actions to take place prior to a breach event, and thereby eliminates breaching and sediment transport through the jetty, affecting the navigational channel and significantly reduces winter emergency dredging.

The economics analysis is now outside the model in a post-process spreadsheet. The code has been modularized and simplified so that there is one code for all three jetties. The user’s manual provides enough detail for a knowledgeable coastal engineer to run the model. These changes improved the transparency of the model's sub-routines, dependant and independent variables, and damage functions leading to the ultimate approval of the model on 27 April 2012.

The above series of events resulted in a change in the selected plans for the three jetties.

ER 1105-2-100, Appendix G (pp. 7-8), states: "Identification of the NED plan is to be based on consideration of the most effective plans for providing different levels of output or service. Where two cost-effective plans produce no significantly different levels of net benefits, the less costly plan is to be the NED plan, even though the level of outputs may be less."

It is important to note that the purpose of the authorized project is to maintain a reliable, functioning, deep-draft navigation channel through the Columbia River entrance. It is not to compare the structural components of each of the alternatives so that if two alternatives still result in no impact to the navigation channel, their benefit is treated as the same. Therefore, the alternatives were evaluated based on least cost as long as they still provided for a usable channel.

In addition, the price of jetty stone and the quantity needed to construct the spur groins proposed outweighed the predicted benefit of repeated maintenance. This assumption will be monitored in the recommended plan throughout time and if foundation conditions deteriorate, threatening or affecting the jetty's stability, this decision will be revisited in the future.

NWD Response (6/14/12): Comment resolved.

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8. NWD Comment (5/31/12): Sect 1.6 is kind of vague and really doesn't say much to convey the significance of the jetties. Suggest adding something to the effect of "While we do not have the methodology (technology/capability) to quantify impacts of continuing deterioration to deep draft navigation we can be sure that continued deterioration will result in reduced ability to maintain channel depths required for current traffic. If the channel becomes unstable or reverts back to a reduced depth the significant benefits of the Columbia/Snake River system will be at risk".

NWP Response (6/7/12): Concur. The following text will be added to Section 1.6: "While we do not have the methodology (technology/capability) to quantify impacts of continuing deterioration to deep-draft navigation, we can be sure that continued deterioration will result in reduced ability to maintain channel depths required for current traffic. If the channel becomes unstable or reverts back to a reduced depth, the significant benefits of the Columbia/Snake River system will be at risk."

NWD Response (6/8/12): Comment resolved.

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9. NWD Comment (5/31/12): Sect. 2.2. Here and elsewhere, a case is never made under what conditions jetty deterioration would result in failure to maintain navigation. This would seem critical to the evaluation.

NWP Response (6/7/12): Concur. The base condition will be rewritten to clearly explain the assumption that closure of the MCR will not be allowed to occur. The following language will be added to Sec. 2.3 and wherever necessary to make it clear that MRR base condition prevents a breach and therefore a potential failure to maintain the navigation channel. As stated in Section 4.2: "The base condition for this study is identified as an interim repair approach because the upper portion of the cross-section is allowed to be damaged to approximately ranges from 30-40 percent remaining prior to repair actions being taken. In this way, the jetty is maintained close to the margin of functional loss without breaching."

NWD Response (6/14/12): Comment resolved.

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10. NWD Comment (5/31/12): Unlabeled figure, top of p 2-3. There appears to be a notable drop in traffic at the MCR in 2009. This begs the question – why? Did this continue in 2010 and 2011? Was it an aberration? Also, the Columbia River Channel Improvement project is not discussed. The case was made that it is necessary to maintain commerce on the Columbia River. It would seem relevant to mention here.

NWP Response (6/7/12): NWP will add figure title on page 2-3. In 2007, the estimated annual value of shipping $17B; in 2010 it was $20B. There are many reasons that the total volume of traffic on a year-to-year basis through the Columbia River would be impacted; global trade, different users of the river, shifts in traffic between the Puget Sound and the Columbia River, and the needs of local industry. Although the traffic diminished in 2009 at $17 billion and 36 million short tons, there is still ample demonstrated need for navigation on the Columbia River. Additionally, since the completion of construction of the Columbia River Deepening Project in 2010, more than $200 million in infrastructure has been built in the Lower Columbia River to support growing needs for deep-draft navigation in the system.

NWD Response (6/14/12): Comment resolved.

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11. NWD Comment (5/31/12): Sect. 2.5. This is a very interesting fact that navigation has only been disrupted once, in 1929. Although it isn't clear exactly what that means. Have there not been any inbound or especially outbound delays during the history of the jetty system? It would seem that with the jetty system at its most deteriorated (minimal) condition since about 1913, with deeper draft vessels now plying the entrance and an environment of greater storms and wave heights, we might start expecting delays without repair. Was this assessed?

NWP Response (6/7/12): The following text has been added to Sec. 2.5: Transportation and delay benefits were not assessed because the assumption was the mouth of the Columbia River would remain open; would be maintained to the best of the Corps' ability based on available funding. To quantify transportation and delays is difficult in any entrance and specifically at the mouth of the Columbia River. There are closures at the MCR that are the decision of the US Coast Guard due to storm and wave conditions at the entrance. The offshore wave climate and the effects on the inlet and separating those effects to be dependent upon the jetty would be difficult; therefore the assumption was made that the Columbia River would remain open.

NWD Response (6/14/12): The difficulty of the assessment is understood, but the critical question is whether it may have an impact or not. Is it fair to say the contribution to delays from the jetty condition above and beyond the base condition is not a significant contributor to delays?

NWP The Base condition states that the jetties will be maintained at a minimum level that prevents consequences to the navigability of the inlet. The statement "Is it fair to say the contribution to delays from the jetty condition above and beyond the base condition is not a significant contributor to delays?" is correct

NWD Response (6/14/12): Comment resolved.

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12. NWD Comment (5/31/12): Last paragraph sect. 2.5. "costs avoided" is not very descriptive. What does this include? Dredging? Maintenance? Rescues? Other?

NWP Response (6/7/12): Reference chart C-17. See Chapter 4 rewrite.

NWD Response (6/14/12): Comment resolved.

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13. NWD Comment (5/31/12): Is tectonic rebound accounted for (or significant) in this evaluation?

NWP Response (6/7/12): It is accounted for in the sea-level rise evaluation and is not considered to be significant.

NWD Response (6/14/12): Comment resolved.

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14. NWD Comment (5/31/12): Page 3-22, second paragraph discusses proposed spur groins. Are they in the recommended plan (part of scheduled repair)? It does not look like it but the descriptions in Sect 4.5 are pretty brief. Jumping back to 4.4.1 it looks like groins would be in "scheduled repair with engineering features" and the recommended plan is apparently "without engineering features" but it's not entirely clear.

NWP Response (6/7/12): Chapter 3 of the MRR discusses engineering considerations and is meant to fully describe the engineering approach and terminology, the base condition and alternatives. Chapter 4 will assess those alternatives and fully describe the selected plan. The following text will be added to 3-22 and potentially to 3.5.3.1.

In areas where foundation scour threatens the overall jetty stability, spur groins were considered in some alternatives. If constructed, the spur groins would be perpendicular to the jetty to facilitate stabilization via accumulation of sediment along the jetty foundation. Historical experience and numerical modeling were used to select the type, depth, and length of spur groin necessary to impact the processes causing increased scour at each jetty (e.g., rip currents, eddies). A range of information was utilized in developing recommended spur groin applications along the MCR jetties. The recommended plan was determined within the framework of trying to specify the lowest impact spur groin layouts (size and number of spurs) suitable to achieving the intended long-term stability purpose of the structures. Information utilized included knowledge of problem erosion areas along the three primary jetties, experience of spur groin application at the South Jetty and Yaquina South Jetty, observation of jetty relic stone wing impacts on shoreward sedimentation, other spur groin studies, and numerical hydrodynamic modeling. The effectiveness of the spur groins is evaluated in the model and compared using average annual costs to decide whether it's more effective to have higher up-front costs by constructing them, or repeated maintenance in those areas to secure the foundation on the jetty trunks without them.

NWD Response (6/7/2012): Chapter 3 information is resolved. NWD will be reviewing Chapter 4 rewrite.

NWD Response (6/14/12): Comment resolved.

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15. NWD Comment (5/31/12) **Brad**: Pg. 3-22, 3rd para. Similar except for jetty head feature. The discussion proposed ne w jetty head features 100 feet offshore form present above water terminus for north and south jetties and 400 feet for jetty A. This does not seem consistent with recommended plan for the jetties, especially the south jetty. The proposed plan needs to be consistent with the recommended. Perhaps it's a case of discussing one proposed option (ideal?) considered rather than the recommended plan but it should be made clear if that is the case. Also, Para 3.4.1 in particular makes a point how critical stabilization of the jetty head is, yet is dismissed in final alternative selection.

NWP Response (6/7/12): 3rd paragraph on pg. 3-22 is meant to discuss generically what jetty head capping would entail. It is not intended to represent the recommended plan. The last paragraph will be edited to say "would be" constructed instead of "will be". EDIT MADE.

NWD Response (6/14/12): Comment resolved.

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16. NWD Comment (5/31/12): Pg. 3-25. States jetty segment loses function when has been reduced to less than 15%+- 5% of original standard upper cross-section. Collaborate this with the 40% mention in the introduction and provide figure demonstrating what this means precisely, particularly as it relates to the "upper cross-section" piece.

NWP Response (6/7/12): The description given on page 3-25 of 15% upper cross-section remaining defines a breach condition. The 30-40% range defines the remaining cross-section of the damaged reach that triggers a repair action. These two ranges describe the remaining cross-section above -5 MLLW, except where -5 MLLW occurs below ground. The elevation is brought progressively up to remain just above ground in areas of the jetty root.

NWD Response (6/14/12): It would be helpful to show label both of these conditions on the figure being added to show the 40% (from a previous comment).

NWP Response (6/14/12): Concur. Labels added to graphs.

NWD Response (6/15/12): Comment resolved.

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17. NWD Comment (5/31/12): P. 3-28. 1st paragraph. Again, no mention of potential delays to navigation. State whether this is a concern.

NWP Response (6/7/12): The 1st paragraph will be modified in the following way: "A jetty breach at the MCR, if it occurred, would allow flow through the jetty and destabilize adjacent morphology. Elevated shoaling at the MCR would occur. Aggressive dredging may be required to maintain the MCR navigation channel and the jetty may require emergency repair. The distinction should be made between jetty damage and jetty failure and MCR project function failure. The primary function of the MCR project is to maintain the navigation channel for deep-draft shipping. The secondary function evaluated in the structure rehabilitation effort is to significantly extend the life and reliability of the jetties in order to reliably maintain the primary function. Subcategories addressed in order to accomplish the primary purpose included: prevention of a significant breach to the jetties, minimizing dredging of the channel, minimizing the frequency and magnitude of the required jetty repairs, and reducing the degradation rate of the jetties over time."

The 2nd paragraph will be modified in the following way: "If a jetty breach were to occur, it would likely occur during winter (October through March) in response to storm waves. Due to the typically severe weather conditions at the MCR during winter months, emergency jetty repairs (to fill the breach) and/or emergency dredging activities (to maintain the navigation channel) may not be possible or may only be possible at a reduced rate, with the end result likely being impacts to navigation until the actions can be completed. Jetty repairs are expensive and due to the sheer size of the structures usually include high costs of mobilization. Because these jetties are typically repaired from the top of the structure (especially during winter months), construction of a haul road is required for each jetty repair effort. In addition, there are some areas along the seaward half of the North and South jetties for which emergency jetty repairs during the winter months could not be conducted, due to the exposure of the construction site to overtopping wave conditions. Impacts to navigation would occur." EDITS MADE.

NWD Response (6/14/12): Comment resolved.

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18. NWD Comment (5/31/12): Page A2-3-77, Section 3.10, first paragraph discusses the potential for emergency dredging saying the contract dredges are typically working in warmer climates. The report should add that the contract dredges are typically working at projects on the east and gulf coast where work is limited to an environmental window and not expected to be

available to mobilize to the west coast. The dredge ESSAYONS is also generally in repair status and not likely to e available during the winter months.

In short, dredges are typically not available for dredging at the mouth during the winter months when a breach and sudden infill are likely to occur and the risks of dredging at the MCR during that period are very high so channel depths will likely be lost for an extended period. We typically have two dredges working at MCR for a total of 80-100 days per year to dredge 4-5MCY during favorable weather each year. The ability to dredge an additional 2-3MCY, (during the winter) is highly unlikely. Similar language should be added to Sect. 3.8.3.1 on page A2-3-65 where the report discusses some of the challenges with emergency dredging.

NWP Response (6/7/12): The 1st paragraph of section 3.10 will be edited to read: "The purpose of this rehabilitation study was to identify and recommend a course of action that would minimize future life-cycle costs and maintain deep-draft navigation for the MCR jetty system. While this was a least cost analysis, various additional elements including project reliability, constructability and access, and potential navigation risk were also considered in the alternative comparisons and rankings. The complexities of major jetty repair in challenging conditions, as well as the feasibility of emergency winter dredging at the MCR, were considered in the final evaluation. Only four contract dredges are capable of dredging at the MCR during winter conditions, and they are normally scheduled for work in milder climates during the winter months. Contract dredges are typically working at projects on the east and gulf coast where work is limited to an environmental window and not expected to be available to mobilize to the west coast. The Corps' dredge ESSAYONS is also generally in repair status and not likely to be available during the winter months.

In short, dredges are typically not available for dredging at the MCR during the winter months when a breach and sudden infill are likely to occur and the risks of dredging at the MCR during that period are very high, so channel depths will likely be lost for an extended period. We typically have two dredges working at MCR for a total of 80-100 days per year to dredge 4-5 MCY during favorable weather each year. The ability to dredge an additional 2-3 MCY (during the winter) is highly unlikely. The best-performing alternative for each jetty was selected by optimizing the initial cost of structure rehabilitation, optimizing future maintenance costs, and considering the time-varying reliability of the jetty."

NWD Response (6/8/2012): Comment resolved.

ALTERNATIVES ASSESSMENT

1. NWD Comment (5/31/12): There appears to be a considerable disconnect in the assessment of alternatives in terms of perceived accuracy of average annual costs (AAC) and the true accuracy of these numbers. In the selection of the NED plan the AAC numbers presented are treated as if they are discrete numbers, when in fact the considerable uncertainty in these numbers makes several alternatives (5 to 6 for both North and South jetty alternatives) virtually identical in terms of cost.   Any accuracy implied beyond two significant figures is completely unreasonable for values with this much uncertainty, anything beyond 5% accuracy is not likely to be supportable

either. More detailed analysis of the estimates was performed by Moffat and Nichol for north and south jetties – coasts are “very small and indistinguishable”. This is not true for Jetty A, where there is a much clearer NED plan – the recommended plan.

<u>NWP Response (6/7/12)</u>: ER 1105-2-100, Appendix G (pp. 7-8), states: “Identification of the NED plan is to be based on consideration of the most effective plans for providing different levels of output or service. Where two cost-effective plans produce no significantly different levels of net benefits, the less costly plan is to be the NED plan, even though the level of outputs may be less.”

<u>NWD Response (6/14/12)</u>: This comment is significantly addressed with major additions to chapter 4. The piece still under further review is the implied accuracy of the cost estimate - showing to 4 figures of accuracy when a case can easily be made that they could be shown to just two. One alternative at $10 million AAC and another at $10 million with the same benefits are both the NED plan. Chapter 4 writeup in particular for north and south jetty (telling the story) may make the case that base condition is the preferred alternative.

<u>NWP response (6/15/12)</u>: District decision to support selected plan in report.

<u>NWD Response (6/14/12)</u>: Comment resolved.

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2. <u>NWD Comment (5/31/12)</u>: It is stated in the executive summary and in the assessment of alternatives that alternatives are being assessed against several metrics (4, 5 or 6 depending on where you read), but determination of the recommended plan is based only on one of the listed metrics, the AAC. It is unclear if or how structural and functional reliability or constructability is included in these assessments.

<u>NWP Response (6/7/12)</u>: Our stochastic risk-based model (SRB) evaluates structural and functional reliability as related to damage and repair strategies and rehab alternatives. The output is converted to average annual cost outside the model as a simplistic way of combining all of these different factors into one type of metric. All of the evaluated plans are found to be acceptable when considered against the bulleted list in the executive summary.

Section 4-3 will be edited in the following way:

“The purpose of this rehabilitation study was to identify and recommend a course of action which minimizes the future life-cycle costs and maintain deep-draft navigation for the MCR jetty system. The starting point for this evaluation was to formulate alternatives that met the project purpose, and met acceptable levels of project reliability, constructability, and potential navigation risk. Alternatives varied by jetty geometry, including crest-width and -height, side slope, benching, and whether or not they included engineering features (spur groins and capping). The alternatives were further distinguished by holding the head location throughreconstruction of cross-section, or through capping. These alternatives were evaluated using the SRB model providing required repair volumes through time and by reach. The required repair volumes were converted to life-cycle cost and ultimately to an average annual cost for each alternative. The life-cycle costs included initial construction cost, repair cost, and their timing after rehab. The average annual cost of each alternative was put in ranked order and the recommended plan was chosen based on least-cost.

Alternatives including rebuilding submerged sections of each jetty were screened out in the early phases of the study. These alternatives included rebuilding up to the full authorized length, constructing jetty heads on currently submerged relic stone, rebuilding the cross-section off of the existing footprint, and realigning the jetties. Hence, these alternatives were unacceptable and eliminated from further consideration because they were either outside of the authorized project, or deemed unacceptable from a constructability standpoint. The current length of each jetty is generally deemed to result in an acceptable level of navigation access and maintenance dredging, meaning that rebuilding submerged sections of the jetty would have limited potential benefit. Although it was conclusively demonstrated that use of extremely large, dense stone in larger cross sections will reduce future maintenance costs, none of the rehabilitation alternatives proved to be cost effective.

The recommended plan will identify the optimum investment both in terms of proposed actions and timing of proposed actions, given the risk and uncertainty identified during the study. This plan will offer the greatest benefit to the project with respect to cost while still meeting the project goals."

NWD Response (6/14/2012): Further discussion is needed on this topic. This statement makes it sound like reliability IS included in the AAC. In appendix A, specifically page A2-4 and A2-7 it states "reliability is not used to simulate structure response and related consequences (life-cycle cost)." It is included in the AAC or it is not, please explain which.

Much improved language. However, this sounds like reliability was used as a screening criteria and not included in life-cycle cost.

NWP response (6/14/12) IRC: Reliability and damage simulated by the model share some parameters, slope, rock size etc, therefore both reliability and damage cannot be combined into the AAC or these parameters would be "double-counted". The alternatives brought forward are analyzed for functional reliability as a check to ensure that selected plan will perform.

NWD Response (6/14/12): Comment resolved.

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3. NWD Comment (5/31/12): There is only one number reported in the Plan Selection Tables (tables 4-1 through 4-3). That is average annual cost (AAC) . This is informative, but variance in the makeup of this single number would be extremely informative for comparison between alternatives. For instance a listing of the breakdown by the six categories making up this number: 1) repair activities; 2) rehabilitation activities; 3) additional fixed cost of activities; 4) Jetty head capping; 5) spur construction; and 6) normal dredging; would all be equally telling and informative on tradeoffs between alternatives.

NWP Response (6/7/12): Concur. We will insert table C-17 into Section 2.7.

NWD Response (6/14/12): Comment resolved.

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4. NWD Comment (5/31/12): In the executive summary and elsewhere the important point is made that there is $20 Billion in international trade annually passing through the protected area of the MCR jetties. Further, the report states that the project was authorized "to secure consistent navigation through the coastal inlet". However, in the alternative evaluation it isn't assessed how the various alternatives perform in relation to the authorized purpose nor if the project or lack thereof would impact the $20 billion in trade.

NWP Response (6/7/12): In our alternative formulation description, all plans met the authorized purpose. Text has been revised in both the executive and summary and chapter 4 to clarify that all evaluated plans met the authorized purpose.

NWD Response (6/14/2012): Comment resolved.

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5. NWD Comment (5/31/12) Pg. 3-37. Assessment is limited to 2:1 and 3:1 slopes, but all recommendations are steeper. What is the assessment of the steeper slopes.

NWP Response (6/7/12): Reference section is to the physical model and not alternatives being evaluated. The physical model used 2h:1v and 3h:1v slopes, but the alternatives analyzed by the SRB model used various sized slope ranging from 1.25h:1v to 3h:1v. The steeper slopes represent the historical repair design parameters and the current cross-section of each jetty. The flatter slopes were modeled in the physical wave tank to see if they would perform better than the existing design (see Tables 1-2, 3 & 4).

NWD Response (6/14/2012): As mentioned earlier, table c-17 is significantly better, however table as provided in draft of chapter 4 is even better yet.

NWD Response (6/14/12): Comment resolved.

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6. NWD Comment (5/31/12): Page 3-47, Sect, 3.5.3.2, paragraph 3 says the rebuild of the south jetty head was not considered a viable rehab option. Is that referring to technical viability (I read it that way) or the fact that it was not found economically justified? These are two different determinations and the meaning should be clear. The paragraph goes on to say it was proposed to be stabilized at approximately its current location, but that is not the recommended plan. Dropping consideration of rebuilding of the south jetty head is a major consideration; discuss briefly why it is not viable.

NWP Response (6/7/12): Holding the head at station 313 proved to be less cost-effective than continuing to allow the jetty to recede, per the model, with available information. All alternatives that involved rebuilding the south jetty head utilized existing relic stone as a foundation. Constructing the jetty head offshore from the current position of the end of the jetty to its authorized length was deemed infeasible due to the extensive scour hole and depth of water at the authorized south jetty terminus location.

Section 3.5.3.2 paragraph 3 will be revised to say:

"Based on the several constraints (see discussion in Section 11 of Appendix A1), the rebuild of the South Jetty head (presently located 1,500 feet inshore of the concrete monolith) was not considered a viable rehab option. Constructing the jetty head offshore from the current position of the end of the jetty to its authorized length was deemed infeasible due to the extensive scour hole and depth of water at the authorized south jetty terminus location. The head of the South Jetty was considered to be stabilized at approximately its current location (stations 313-315). Maximum viable rebuild of the North Jetty head was determined to be station 105, which would result in a re-established head position 1,700 feet inshore of the fully authorized length. Maximum viable re-extension of the head for Jetty A was determined to be station 93, which is 500 feet seaward of its current position and 400 feet landward of its full authorized length. Jetty A length is important to controlling erosion along the North Jetty foundation; however, the substantial scour hole south of the Jetty A head limits a cost-effective head rebuild." EDITS MADE.

NWD Response (6/14/12): Comment resolved.

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7. NWD Comment (5/31/12): 3.6.4 -- Here or somewhere it would be helpful to discuss very briefly the survey techniques used over the years to provide this good historical record. It could be meaningful if there was some opportunity for a systemic error sometime over the years.

NWP Response (6/7/12): This text was added to 3.3.2: Survey methods range from aerial LIDAR combined with bathymetric surveys to annual, on-the-ground surveys using GPS and hip-chain to locate station. The 2010 on-the-ground survey is included as Appendix A-4 in the report. Future surveys will use LIDAR/bathymetric methods and be compared biannually to track damage and jetty stone loss.

NWD Response (6/14/2012): Comment resolved.

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8. NWD Comment (5/31/12): Sect 3.10. This is an extremely meaningful evaluation yet seems to be widely ignored in the alternative plan selection. For instance it is pretty clear that the best alternatives are: North Jetty, Scheduled repairs w/Features and Scheduled repair w/Features (hold head); South Jetty, Scheduled repair w/head capping, scheduled repair w/features, scheduled repair (hold head) and scheduled repair w/features (hold head) are virtually the same and clearly the best; Jetty A, Small Template – Plan A, Small Template – Plan B, Small Template –plan A (hold Head), Small template – plan B (hold head) are virtually the same and clearly the best.

NWP Response (6/7/12): Please refer to previous responses regarding NED and least-cost plan.

NWD Response (6/14/2012): Changes to chapter 4 may resolve this comment.

NWP Response (6/14/12) IRC: District supports plan selected

NWD Response (6/14/12): Comment resolved.

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9. NWD Comment (5/31/12): Sect. 4.3 This is perhaps the most important section in the report, yet seems to be inconsistent with the story that is being told prior in the report. The metrics purported to be used don't seem to be used other than AAC in alternative screening. Additionally, paragraph states 5 metrics, but only lists 4. Is one missing? This is also inconsistent with the metrics mentioned in the executive summary which includes 6 metrics. Also states that none of the other metrics translated into the AAC. Paragraph is confusing and inconsistent with the report elsewhere. Are there several metrics or is AAC the only metric?

NWP Response (6/7/12): See NWP response for BLUF #2.

NWD Response (6/14/2012): Comment resolved.

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10. NWD Comment (5/31/12): A general documentation for computation of AAC should be included in the main report? It is very challenging to see by referencing between the engineering appendix and the economics appendix how these numbers were developed? This is absolutely critical and only provided cryptically. The story is not clearly told.

NWP Response (6/7/12): Table C-17 will be added into section 2.7.

NWD Response (6/14/2012): Updated chapter 4 largely answers this question. Still need to close out the issue on least cost. Although the updated chapter four is now reporting the AAC in thousands rather than down to the dollar, the report has still made a choice by cutting the line so thinly. It is completely reasonable to report these numbers in millions - for instance, the top three could be reported as $9.6 million AAC. Clearly the accuracy of these numbers over 50 years with all the uncertainties involved cannot be computed more precisely than this.

NWD Response, IRC (6/14/12): Comment resolved.

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11. NWD Comment (5/31/12): 4.4.1 North Jetty plan selection: Recommends Scheduled repair, holding the end station. This recommendation seems to be solely based on just one of the five (4 or 6?) metrics – AAC. It is noted that 5 of the other alternatives for the North Jetty are within 5% of the AAC for this option and 3 are within 3%. With the tremendous uncertainty in the future performance of the structure, large contingencies on cost estimates and other factors, these are all virtually the same costs and not sufficient variance to make a decision on. Ironically, the selected alternative, isn't even one of the clear best alternatives in terms of reliability. The

evidence in the report would suggest that either schedule repair w/features (BCR 1.06) or schedule repair w/features (hold head) would both be better alternatives (1.04).

NWP Response (6/7/12): See response for General Comment #2 and Alternative Assessment Comment #2.

NWD Response (6/14/2012): Updated chapter 4 largely answers this question.

NWD Response (6/14/12): Comment resolved.

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12. NWD Comment (5/31/12): 4.4.2 South Jetty. Although, accurately portrayed as none of the alternatives having a BCR greater than unity, five were virtually at unity and all gave much greater reliability than the selected alternative. One alternative was within 8/1000's of a percent, yet was dismissed as not being the NED. Ironically, although costing virtually the same, the selected alternative clearly has the lowest reliability. It would appear that three other alternatives would be better choices than the selected plan – scheduled repair (hold head) and scheduled repair w/head capping and spur groins (hold head) and scheduled repair w/spur groins only.

NWP Response (6/7/12): After initial screening, all alternatives brought forward into Chapter 4 were acceptable and least cost plan was selected.

NWD Response (6/14/2012): Updated chapter 4 largely answers this question. Still need to close out the issue on least cost. Although the updated chapter four is now reporting the AAC in thousands rather than down to the dollar, the report has still made a choice by cutting the line so thinly. It is completely reasonable to report these numbers in millions - for instance, the top three could be reported as $9.6 million AAC. Clearly the accuracy of these numbers over 50 years with all the uncertainties involved cannot be computed more precisely than this.

NWP Response (6/14/12) IRC: District supports plan selected

NWD Response (6/14/12): Comment resolved.

NAVIGATION BUDGETING

1. NWD Comment (5/31/12): The report needs to state very strongly in the Executive Summary and the conclusion that the BCR numbers for each of the jetty repair alternatives do not reflect or capture the benefits of the MCR system. The BCR numbers are at or near 1 and under the current budget climate are not likely to be supported for funding but they do not tell the full story of the importance of maintaining the jetties to provide a reliable navigation system on the Columbia River and its importance to national and regional economies. While we are not able to quantify those benefits and capture them, they are huge (as identified in the five bullets in the executive summary, e.g. 20 billion in international trade annually). The report does a good job of telling the story of the significance of maintaining the jetties from a technical standpoint but

some may not read past the apparently low BCRs to support funding requests of this magnitude. I could not find specific written documentation but believe I've heard a BCR below 2.5 is likely to be considered not worthwhile by OMB.

NWP Response (6/7/12): Noted. Detailed discussions will be occurring between NWD and NWP to present the best case possible for our FY 14 budget.

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2. NWD Comment (5/31/12): The report recommends a significant amount of habitat improvement projects as conservation measures under Section 7(a) (1). It is not clear how these actions would be funded if they are implemented. These types of actions should be conducted under the authority of Section 1135, 536 or other ecosystem restoration authorities. The navigation budget does not have funding for these actions and they should not be accomplished with MCR project funding.

NWP Response (6/7/12): NWP's reference to habitat improvement measures may have confused NWD. We are not trying to improve the habitat, we are trying to mitigate for impacts from the federal action. One exception to this is the establishment of the snowy plover habitat. The compensation for impacts to wetlands habitat is 2:1, and waters of the US impacts is 1.5:1.

NWD Response (6/8/2012): Tentatively resolved pending review of revised EA.

NWD Response (6/14/12): Comment resolved.

COST ESTIMATES & NED

XX1. NWD Comment (5/31/12): It is our understanding that the Cost Estimate has not completed appropriate review and currently is underway. This action is incomplete and the cost estimate could change.

NWP Response (6/7/12): Concur. We expect to have a certified cost estimate by 15 June. Early review of the effort indicates an increase to the total project cost of approximately 7%.

Comment resolved: PCX certified cost estimate in 13 June 2012.

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2. NWD Comment (5/31/12): The District should confirm cost terminology is consistent with the 25 August 2011 Corps of Engineers Civil Works Cost Definitions and Applicability guidance.

NWP Response (6/7/12): The district will confirm that cost terminology is consistent with 25 August 2011 Corps of Engineers Civil Works Cost Definitions and Applicability.

Comment resolved: PCX certified cost estimate in 13 June 2012.

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3. NWD Comment (5/31/12): Sect. 2.6, 3rd paragraph. Although planning level estimates are certainly appropriate here, that term requires further explanation as to how precise the cost estimates were in this study. Later when it comes to alternative comparison in section 4.2, the alternative selection seems to assume an extremely precise level of estimate (less than 1%).

NWP Response (6/7/12): These were generated using the best available data and the cost estimate is being ATR'ed and certified. All of the alternatives use the same cost assumptions.

The terminology planning level estimates is being used in this paragraph to represent existing data. It is not to do a complete design and independent government estimate.

NWD Response (6/14/2012): Comment resolved.

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4. NWD Comment (5/31/12): Sect. 2.7 This paragraph seems too critical to the report to be hidden in an appendix. Suggest the summary table be beefed up in the main report to provide somewhat of a breakdown of benefits (annual savings in dredging, maintenance, safety, etc.).

NWP Response (6/7/12): Concur. We will insert Table C-17 into Section 2.7 of the main report.

NWD Response (6/14/2012): Comment resolved.

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5. NWD Comment (5/31/12): Section 4 (page A2-4-1) There is not an adequate description of the type, magnitude, and timing of the costs assumed for all alternatives. Without more details I cannot determine whether the economic costs/benefits are reasonable. Please provide some example simulations that describe and show the type of costs (ie dredging, repairs, rehab, spurs, head capping), the magnitude of these costs over time. The basis of this concern is ER1105-2-100 paragraph E-3.

NWP Response (6/7/12): Concur. The outputs will be added to the report.

NWD Response (6/14/12): Comment resolved.

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6. NWD Comment (5/31/12): Section 3.5.4 Structural and functional reliability should be represented in the economics evaluation not as separate engineering criteria. This direction was included in the 30 June 2010 NWD Issue Resolution Conference guidance - comment 1c.

NWP Response (6/7/12): See NWP response under BLUF #3.

NWD Response (6/14/2012): Comment resolved.

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7. NWD Comment (5/31/12): Section 4.5, third paragraph states that the NED plan and plans that do not limit the recession of the jetty head are "not statistically different". This Section seems to be arguing that the NED cost differences between some plans are not significant. This is a significant concern because it has the potential to result in a different NED plan. Please define what you mean by "not statistically different".

NWP Response (6/7/12): "Not statistically different" has been deleted. Added text to Section 4.5, South Jetty that reads: Although the base condition is the NED plan, the interim repair, hold head alternative is very close in AAC, differing by $85,000 or 0.9 percent.

NWD Response (6/14/2012): Comment resolved.

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8. NWD Comment (5/31/12): The breakdown of the costs did not include required mitigation action or habitat improvement features. These are important to the overall project costs and required to be included in total project costs and alternatives consideration to determine BCR. Additionally, a CEICA of the habitat features was not included.

NWP Response (6/7/12): They are included in the cost analysis in the selected plan and are applied consistently across all alternatives.

NWD Response (6/14/12): Comment resolved.

HABITAT IMPROVEMENTS

1. NWD Comment (5/31/12): The project concluded that MCR work would result in no significant impact and thus, prepared the environmental assessment. Additionally, the ESA consultation process concluded with NMFS determination of Not Likely to Adversely Affect salmon and steelhead species, and specifically stated, "For Pacific salmon and steelhead, green sturgeon, and eulachon, NMFS expects construction-related effects on water quality, hydraulic and hydrological processes and estuarine, marine, and upland habitats to be insignificant or discountable." There is a discretionary conservation measure to carry out management actions as identified in the Columbia River Estuary ESA Recovery Plan Module. Additionally, there are some recommended conservation measures for snowy plover in the USFWS consultation letter. However, the described habitat measures (chapter 5) potentially commit the project to what could be viewed as excessive measures such as levees breaching, land preservation, and large scaled restoration actions. It also proposes to establish an interagency adaptive management team, and acknowledges a need for future NEPA and ESA documentation in addition to the project development of the habitat action (s). Our concern is the scope of actions presented are 1) not required, 2) are disproportionate to the scope of short and long term impacts, and 3) are, in many cases, based on provided Table 5-5 of the Evaluation Report, not within the MCR navigation project authority, would require additional authority to complete, and as stated, would require quite a bit of additional work. The Section 7(a)(1) proposals additionally have a potential fiscal law violation if the expenditures are not attributed to the proper authority. Additionally, 4) the work is 100% federal, dedicating obligations to the future O&M of the habitat projects. Our

recommendation is to pull all reference of additional habitat features from the document prior to public release, especially the FONSI, 404(b)1 analysis, and all information used for permitting purposes. The revised FONSI could include a statement such as "Habitat features were proposed in earlier documents as additional work the Corps could perform; however, they are not required or proposed as part of the MCR jetties MRR. They could be considered in the future under the appropriate authorities".

It is important to distinguish that regarding the habitat improvement measures, NMFS states: "These habitat improvement projects will require additional consultations, and the proposed AMT likely will be of assistance in this process. Furthermore, NMFS did not consider the beneficial effects of the habitat improvement projects in making our jeopardy/adverse modification determinations." This clarifies that NMFS is not viewing these measures as offsets to any anticipated impacts, nor have they adopted them into any RPAs.

NWP Response (6/7/12): Your assessment highlights an omission in the NWP documents NWP gave you to review, and we apologize for not clarifying. Except for the establishment of the snowy plover, the habitat improvement methods (HIM) are also compensatory impacts to aquatic resources that require mitigation under the CWA and as clarified under 33 CFR 332. NWP proposes to compensate for the aquatic impacts at a 1.5:1 ratio and compensate to the wetlands impacted at a 2:1 ratio. The wetland mitigation is identified in the 2012 EA and FONSI. The Section 7(a) (1) HIM complements the mitigation to compensate for impacts to waters of the US (aquatic resources). Since the contractor may or may not use the sites NWP has identified and analyzed in the 2012 EA and FONSI, an AMT will help the NWP identify what actual in-water impacts really need compensation. The AMT will be composed of federal and state agencies that have authority in regards to the mitigation. The 2012 EA and FONSI will be revised to make this clarification. This AMT process will allow NWP to compensate accordingly.

The report and the EA will be clarified to not include habitat improvement language. The Corps will rename the 7a1 actions to reflect that they are compensatory mitigation for impacts to aquatic resources.

The Corps coordinated with the States, USFWS, and NMFS to determine appropriate mitigation ratios based on functions and typical compliance requirements. Proposed wetland mitigation is at a 2:1 ratio and mitigation for waters other than wetlands is at a 1.5:1 ratio. Though WQCs have not yet been obtained, the Corps has been working closely with the Certifying agencies to ~~ensure~~ ensure meeting our legal responsibilities. compliance with anticipated clearance documents. The BA was based on and the BiOp evaluated a larger suite of actions so that a larger acreage of mitigation was proposed for impacts to aquatic resources. It is anticipated that through meetings and discussions with the AMT the total for proposed mitigation will decrease to reflect the reduced project footprint.

NWP will need to continue to work with NWD and FWS on the snowy plover issue. This is truly a Section 7(a)(1) mitigation as U.S. Fish and Wildlife Service (FWS) adopted the biological opinion (BiOp) that NMFS issued. A larger suite of actions was assessed in order to allow maximum flexibility in the execution of the contract, and still meet the intent of reducing environmental impacts.

NWD Response (6/14/12): Comment resolved.

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2. NWD Comment (5/31/12): The report reiterates in section 5.4 that habitat improvement measures are not mitigation or to compensate for any project related impacts. While the report states further analysis would be required and discussions will take place in the AMT, it establishes expectations that the MCR project will evaluate the Table 5-5 projects and take an action. Additionally, the AMT is not described in the report, and conclusions as to the team purpose and composition is drawn from the NMFS Biological Opinion. It is unclear how this team has the responsibility and authority to be established, make decisions for Corps projects, or how its' activities would be funded.

NWP Response (6/7/12): Description of the AMT's purpose is described on pp 88 of the EA and will be added to the Report. The team will be comprised of regular government agency resource agency participants that have regulatory authority over various components of the project, including compliance monitoring. Annual or more frequent meetings as required would establish a regular venue for the Corps to present monitoring results; to ensure regular coordination with resource agencies under dynamic project conditions and changing species status; and to vet yet to be determined details on proposed mitigation actions. The Corps would retain decision-making authority. The list of potential mitigation actions was presented as examples of possibilities that could be considered for mitigation rather than commitments to specific project.

This descriptive language was included as such in the original final EA and on pp 88 of the revised EA. This passage states, "Due to the dynamic conditions at MCR and the long duration of the MCR Jetty Rehabilitation schedule, the Corps proposes formation of a modified Adaptive Management Team (AMT). The Corps suggests annual meetings to discuss relevant design and construction challenges and modifications, technical data, new species listings or critical habitat designations, evolving environmental conditions, and adaptive management practices as needed. The primary purpose of the proposed AMT and its implementation is to ensure construction, operation, and maintenance actions have no greater impacts than those described in the Biological Assessments and Environmental Assessment, and that Corps obligations and terms and conditions are being met. This will also allow confirmation that any necessary construction or design refinements remain within the range and scope of effects described during Consultations are being met and efforts are being made to adjust mitigation once final impacts are fully understood. These adjustments could result in a reduction in mitigation based on actual impacts occurring. This forum will provide an opportunity for periodic evaluation as to whether or not the proposed actions, ESA listings, or environmental conditions result in any re-initiation triggers. It will also facilitate continued coordination and updating and allow the Corps to inform agency partners when unforeseen changes arise. Results regarding marine mammal and fish monitoring, wetland mitigation and habitat improvement monitoring, as well as water quality monitoring will also be made available to the AMT in order to fulfill reporting requirements and to address any unexpected field observations. Results of jetty monitoring surveys will also inform the AMT of the repair schedule and design refinements that may become necessary as the system evolves over time. This venue will provide greater transparency and allow opportunities for additional agency input. Final selection and design of the habitat improvement and wetland mitigation proposal will be vetted through this forum to facilitate obtaining final environmental clearance documents for this component of the MCR proposed action. Potential principal partners include federal (National Marine Fisheries Service, U.S. Fish and Wildlife Service) and State (Washington and Oregon) resource management agencies." Further agency consultation will be required when mitigation details for waters other than wetlands are proposed. NEPA, ESA, and CWA compliance documents may need to be supplemented.

An AMT approach has been successfully utilized on the Columbia River Channel Improvements Project (CRCIP). This proposed AMT would be expected to perform a similar function.

NWD Response (6/14/12): Comment resolved.

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3. NWD Comment (5/31/12): Note: The efforts of this future work have not been provided a cost estimate or included in the project evaluation and BCR. This is not an issue if habitat features and the AMT are pulled from the report. If a specific project(s) is pursued, it would have to be included in the cost estimate and evaluated with CEICA, and included in the BCR for the project.

NWP Response (6/7/12): Cost estimates were developed for compensatory mitigation based on a combination of costs of per acre of previous mitigation work at Lois Island, potential mitigation costs to purchase wetland bank credits, and based on estimates to complete various components of the mitigation actions. These were estimated for the MMR and MRR project as a whole and were included as such in both reports.

Because the mitigation sites have not been identified yet, a representative site (Lois Island) was used for costing purposes. It should be noted that this is intended to be a maximum cost and therefore, cost effectiveness and incremental cost analysis was not performed. The cost estimate is being certified by the NWW cost center of expertise. The district proposes to compensate for the aquatic impacts ranging from 1.5:1 to 2:1 ratio.

NWD Response (6/14/12): Comment resolved.

MITIGATION

1. NWD Comment (5/31/12): Chapter 5 of the report and NEPA document did a good job covering the environmental resources and potential impacts of the project. The design also appears successful in avoiding and minimizing any impacts to wetland resources in the project area. There still remains some unavoidable impacts to wetlands regulated under the Clean Water Act that require mitigation. In regards to the assessment of impacts in the North Jetty, a low quality lagoon of 8.02 acres would be filled. It is unclear if this lagoon is the same area evaluated and permitted as a MCR disposal site in 1999. A map would be helpful, however, I am looking for District confirmation we are not mitigating for something previously permitted.

Additionally, it should be clarified under what authority the mitigation is required, specifically, if this is classified as a wetland, or other waters of the U.S., as meeting the definitions in the CWA.

NWP Response (6/7/12): The district is confirming that the mitigation areas were not previously impacts, nor mitigation through a prior Corps action. Compensatory mitigation for impacts to aquatic resources is required under the Clean Water Act. A complete delineation is available for your review if required.

NWD Response (6/14/12): Comment resolved.

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2. NWD Comment (5/31/12): Section 5.4, the proposed mitigation plan does not include an incremental cost / cost effectiveness analysis. The basis of my concern is ER 1105-2-100 paragraph 7-35h.. Cost of mitigation measures are part of total project costs and are included in the benefit-cost analysis of alternative plans. ER 1105-2-100 2-3 c (6) & 2-4 k (NED analysis). Additionally, mitigation measures require Incremental Cost Analysis. ER 1105-2-100 Appendix C, C-3 e. "An incremental cost analysis shall be performed for all recommended mitigation plans. The purpose of incremental cost analysis is to discover and display variation in costs, and to identify and describe the least cost plan. Mitigation analysis shall be presented in an analytical framework commensurate with other project benefits and costs so that rational decisions regarding mitigation can be made. The least cost mitigation plan that provides full mitigation of losses specified in mitigation planning objectives, and which is unconstrained except for required legal and technical constraints, shall always be identified and displayed." Note: Appendix E places mitigation costs at $6,548,886. Mitigation requirements are for CWA impacted wetlands comprised of 4.7 acres of wetlands and 11.52 acres of other waters of the U.S. The analysis is inconsistent with policy and ICA/CE should be completed.

NWP Response (6/7/12): Because the exact mitigation lands have not been identified yet, a representative site (Lois Island) was used for costing purposes. It should be noted that this is intended to be a maximum cost and therefore, cost effectiveness and incremental cost analysis was not performed. The cost estimate is being certified by the NWW cost center of expertise. The district proposes to compensate for the aquatic impacts ranging from 1.5:1 to 2:1 ratio.

NWD Response (6/14/12): Comment resolved.

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3. NWD Comment (5/31/12): Per WRDA 2036, all mitigation requires a monitoring plan that includes monitoring until completion and adaptive management thresholds. This information was not supplied with the project documentation. The plan should be submitted and costs of mitigation and ongoing monitoring included in the project cost summary.

NWP Response (6/7/12): This will be drafted and included in the EA and Report. It will reflect intent to monitor prior, during, and 3 years after completion of project construction to meet all environmental compliance obligations and ensure successful establishment of compensatory mitigation actions. Monitoring was also discussed in the section describing the AMT function in the EA.

NWD Response (6/14/12): Comment resolved.

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4. NWD Comment (5/31/12): Table 5-5. The first project needs to be differentiated from the mitigation project required for CWA compliance described in A2-5-17.

NWP Response (6/7/12): This will be clarified in both the EA and Report so that it is consistent with the descriptions of compensatory mitigation.

NWD Response (6/14/12): Comment resolved.

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5. NWD Comment (5/31/12): Note. Table 5-5 is a comprehensive list of estuary projects. Some are familiar from earlier discussions on potential FCRPS BiOp compliance projects. This list should be evaluated for potential project to complete under the Section 536, 206, or 1135 for consideration of meeting estuary habitat restoration targets in the FCRPS BiOp.

NWP Response (6/7/12): These projects were also intentionally shared with the Estuary Program because though they had potential as MCR mitigation, the Corps would not be completing most of them for MCR actions.

The Corps will review the list to exclude federal levee removal or acquiring private properties. Any private lands and levee breaches will be removed from the report.

NWD Response (6/14/12): Comment resolved.

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6. NWD Comment (5/31/12): The proposed mitigation seems excessive for maintenance of existing structures that have been in place for over 100 years. Most in-water impact will occur within the footprint of the existing structure and have only short term, minor impacts. There is not a clear description of the habitat value of the lagoon adjacent to the north jetty (or other wetlands for that matter) but it appears to be an area where sand washed and washes out during high waves and does not appear to be high value habitat or serve as rearing habitat for ocean or riverine species. The environmental write up discusses impacts of features such as groins that do not appear to be part of the recommended plan. Any mitigation should be commensurate with the value of those unavoidable impacts and only for areas beyond the limits of the existing project impacts/footprint.

NWP Response (6/7/12): See NWP response to Habitat Improvements comments 1 and 2. The report will be corrected to reflect the discussion in the EA. This is a continuation of the above comments and will be further clarified to reflect compensatory mitigation obligations under 33 CFR 332. Impacts include both a temporal and geographical scale and were described in the EA, and the functions and values assessments of the wetlands were included in the EA. Spur groins were evaluated in the EA but were not part of the preferred alternative. Ratios and amounts were justified in earlier comment responses. Cumulative impacts and effects to low-value wetlands and waters must still be considered. Wetland impacts were considered permanent ~~in nature~~

because they would be in place for over a year and mostly into perpetuity of the project. Ratios for wetlands were based on the delineations and functional assessments along with COE Regulatory practices, resource agency input, and WA and OR mitigation ratio guidance. Inwater habitat improvement/offsetting actions/waters other than wetlands ratios were set at 1.5 to 1. The Corps was revising the final EA when the report was submitted, and the original EA had the old proposed action in it, which included spur groins.

NWD Response (6/14/12): Comment resolved.

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7. NWD Comment (5/31/12): This report and all future reports, BA's FONSIs, etc, should clearly distinguish mitigation verses environmental features. This report blends them, including in the FONSI, making it difficult to distinguish the project impacts and responsibilities, verses other things we would like to do. Additionally, mitigation has very specific reporting requirements, which must be clear upfront to DOI and typically, agencies who issued the mitigation.

NWP Response (6/7/12): As mentioned, the EA and FONSI are being revised to better clarify and describe compensatory mitigation actions. See NWP responses to Habitat Improvements comments 1 and 2.
A generic monitoring plan will be developed and included in both the EA and Report. Monitoring was also discussed in the section describing the AMT function in the EA. Bob has forwarded the mitigation database link into which the District must enter our mitigation actions. This information will also inform development of generic monitoring plan descriptions.

NWD Response (6/14/12): Comment resolved.

NEPA/ENVIRONMETNAL ASSESSMENT

1. NWD Comment (5/31/12): A comprehensive list of comments on the 2011 draft EA was included. The draft 2012 EA is listed as released, with no dates given. An indication of the comments on the revised project, and their resolution has not been provided. Additionally, the FONSI was not included in the review package. A review for legal and policy compliance could not be determined. Note, the FONSI is required to be circulated with the draft EA. The District has indicated that they have not completed the FONSI. As indicated by the District, the report has not been circulated consistent with policy to implement NEPA.

NWP Response (6/7/12): The EA and FONSI are both under revision pending resolution of Division and District comments, and a draft FONSI was provided to Division. The original Final EA had a response to comments from 2006 and 2011 PN periods and has been posted on the Corps' public website for over a year (See EA Section 7 beginning on approximately p 204 of the Revised EA). The MMR FONSI has also been posted publically for over a year, though it did not cover the full suite of MRR actions. Per 33 CFR 230.11 the draft FONSI for an O&M action does not need to be circulated for comment, but a Public Notice will be issued regarding availability of both the EA and FONSI. This project has also been reviewed under an

Independent External Peer Review process, the results of which have been posted on the Corps' public website.

Division verbally indicated (mtg 5/31/12) that District does not need to re-circulate the FONSI given the multiple opportunities for public comment.

NWD Response (6/14/12): Comment resolved.

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2. NWD Comment (5/31/12): Page 5-1 & 5-2 discuss offsite mitigation opportunities. This is in conflict with mitigation identified earlier in the report. If onsite or adjacent mitigation areas are available, please provide justification for offsite mitigation sites.

NWP Response (6/7/12): The MRR will be revised to be consistent with the environmental documentation and commitments. Compensatory mitigation requirements for both MMR and MRR actions and potential mitigation sites are described in EA Section 5.6. Onsite or adjacent mitigation to address impacts is preferred, and a suite of possible mitigation measures were also included since adequate details regarding site potential were unavailable. Specific project selection and design will also be vetted through the AMT to ensure compliance and appropriateness. Details describing wetland mitigation indicated there are adjacent and onsite opportunities (see Section 5.6 pp 145-154). The list will be modified to not include private property.

NWD Response (6/14/12): Comment resolved.

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3. NWD Comment (5/31/12): Page 5-2 recommends additional research studies, projects, and partnerships. Please clarify how these fit the scope and authority of the MCR jetties project.

NWP Response (6/7/12): These are collaborative efforts not specifically attached to the O&M responsibility of MCR. For instance, ongoing RM&E efforts funded through the Columbia River Fish Mitigation program will be shared with the adaptive management team and resource agencies to further their understanding of the species and their habitat use in the estuaries. It is not the intent that this project fund research actions.

4. NWD Comment (5/31/12): The EA was very thorough and well written. However, we recommend for future documents to limit information to relevant resources and discussions of impacts of the proposed project. For instance, while good information, the wetland scoring sheets, proposed mitigation site detailed analysis, etc, are not information needed in the report, but can be relegated to the project files and available for review should someone wish to see them.

NWP Response (6/7/12): Noted.

NWD Response (6/14/12): Comment resolved.

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5. NWD Comment (5/31/12): The EA is currently being revised based on the revised proposed action, but there does not appear to be a public review period. The last time the EA was revised (in 2010) there was a 30-day public review period (see page a2-5-27). NEPA does not require public comment in this instance, but the last time the project changed the public did have an opportunity to comment. This may be viewed as a change in practice and could be troubling.

NWP Response (6/7/12): District Management and Counsel discussed re-distribution for public comment and determined that this was unnecessary. The decision was based on the following reasoning: there have been multiple opportunities for comment (2 Public Notice Comment periods and 3 public meetings); the final EA and the MMR FONSI have been publically available for over 1 year; the project footprint and schedule duration under the newly revised preferred alternative is smaller than previously proposed; the FONSI will be stated as Provisional, and therefore may require additional revisions based on the CZMA and CWA compliance documents; and the FONSI and final EA will be posted publically on the website and a PN will be sent announcing availability per 33 CFR 230.11. The comments from the IEPR are available on our public website.

NWD Response (6/14/12): Comment resolved.

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6. NWD Comment (5/31/12): The draft FONSI is not concise and difficult to determine what the MCR final action will be, what are the specific mitigation requirements verses habitat features, and what the final conclusion is on compliance. The FONSI is written in such a way that its intended purposes are lost in the details that are covered in the EA, and should not be re-written here. Suggest revising the FONSI to a clear and concise findings. See 33 CFR 230.11.

NWP Response (6/7/12): Noted.

NWD Response (6/14/12): Comment resolved.

DATA GAPS

1. NWD Comment (5/31/12): Please provide a signed copy of the review plan.

NWP Response (6/7/12): DDN-PCX approved review plan was sent to NWD on 5 June.

NWD Response (6/14/12): Comment resolved.

QUALITY CONTROL/EDITORIAL

1. NWD Comment (5/31/12): The document has not undergone adequate DQC. The basis of the concern is EC 1105-2-410. Contradicting assumptions, erroneous references, and missing

graphics leads to a lack of credibility. The document needs to have a thorough DQC. Specific comments below.

NWP Response (6/7/12): The district will thoroughly check the entire document again.

Closed DQC: Revisions and QA of printed document is complete.

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2. NWD Comment (5/31/12): Many references to other sections of the documents are incorrect. For example Section 2.3 references a description of the base condition in Section 3.15. The report does not have a section 3.15. Section 3.5.1.1 references to graphs and table are incorrect. Section 3.5.1.3 references to graphs and tables are incorrect. Figures 3-22 labels for figures are incomplete. Figure 3-23 labels for figure are incomplete. Section 4.2 last sentence refers to the Base Condition as described in Section 3.10.2. The Base Condition is not described in Section 3.10.2.

NWP Response (6/7/12): All references will be verified.

NWD Response (6/14/12): Comment resolved.

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3. NWD Comment (5/31/12): At least 3 figures in the Evaluation Report are completely black (1-16, Table 1-2, Table 1-3, on page 1-22, Table 3-2, page 3-31) . Figure 3-16 is missing photo. Additionally, page numbering switches throughout the document (3-2, to A2-4-6, etc).

NWP Response (6/7/12): The electronic versions did not print properly. The following tables have been corrected: 1-2, 1-3, 1-4, 3-2, 3-3, 3-4.

NWD Response (6/14/12): Comment resolved.

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4. NWD Comment (5/31/12): Section 1.5.4.4. is titled "Summary of repairs and modifications to the MCR Jetties", but the text of the section does not include such a summary. For example I don't believe the total cost of historical repairs is summarized here or elsewhere in the project history section.

NWP Response (6/7/12): Title changed to “Damage and repair trends for MCR Jetties”.

NWD Response (6/14/12): Comment resolved.

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5. NWD Comment (5/31/12): The title for Figure 1-4 should say shoaling (typo).

NWP Response (6/7/12): This has been updated.

NWD Response (6/8/2012): Comment resolved.

6. NWD Comment (5/31/12): Figure 1-16, the label on the bottom line does not look correct (MCR bathymetry and dm disposal sites).

NWP Response (6/7/12): Labels have been corrected.

NWD Response (6/8/2012): Comment resolved.

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7. NWD Comment (5/31/12): Section 2.1, last sentence should state "Benefits and costs are converted to average annual equivalents" not average annual cost equivalents.

NWP Response (6/7/12): This has been updated.

NWD Response (6/14/12): Comment resolved.

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8. NWD Comment (5/31/12): Section 3.10.1 paragraph 5, this sentence states that "The top economic performing alternatives are presented in figure 3-41 in terms of functional and structural reliability". Structural and functional reliability are not economic performance.

NWP Response (6/7/12): Sentence has been rewritten to say:

The functional and structural reliability scores of the top economic performing alternatives are presented in figure 3-41.

NWD Response (6/14/12): Comment resolved.

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9. NWD Comment (5/31/12): P. 1-20, 1st paragraph. Here and elsewhere, it isn't clear how you could have equal proportion of stone placed on both sides of the jetty when they are placed at different slopes.

NWP Response (6/7/12): The stone was placed where it was needed. The following sentence has been deleted:

"An equal proportion of stone was placed on the north and south sides of the jetty."

NWD Response (6/14/12): Comment resolved.

---

10. NWD Comment (5/31/12): Editorial: top of page 1-45 says concrete cap was 500 feet long, pg. 3-19 says 300 feet. Also, based on figure 1-27 it appears to have settled around 17', but this isn't discussed.

NWP Response (6/7/12): The precise dimensions of the concrete terminus given that it is 70 years old ranges between 300 and 500 feet with numerous repairs across time. Historical records are not consistent. In the 1930s a 400' asphaltic cap was constructed to seal the jetty head at stations 340-344 at elevation 23-26'. In 1941-42, the south jetty head was further repaired with 76,000 tons of stone and 14,000 cubic yards of concrete.

The concrete terminal is not intact and is indeed disintegrating and settling.

NWD Response (6/14/12): Comment resolved.

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11. NWD Comment (5/31/12): Sect. 3.2.4. This reference needs to be update to the EC. Date is 1 October 2011.

NWP Response (6/7/12): This has been updated.

NWD Response (6/14/12): Comment resolved.

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12. NWD Comment (5/31/12): Sect. 3.3.2. The point seems to be of deficient maintenance has significantly contributed to the near failure of the jetties "…more maintenance stone would have been expected.." This could also be read to mean that not as much maintenance was needed as expected. Suggest rewording to clarify the point.

NWP Response (6/7/12): The intent of this section is to describe the predicted maintenance levels to maintain the jetty structure at or near a constructed cross-section. The first method using .7x the construction volume per year of structure life is a rough estimate that could be used to predict required maintenance in the future. The second method, surveying the structure and measuring the volume of stone missing is a method of calculating how much stone would be required and using it to check the assumptions made by the first method. The SRB model represents a third method of predicting required maintenance to maintain the jetty structure. It is unclear to the comment evaluator how this section is attempting to make a point that "deficient maintenance has significantly contributed to the near failure of the jetties."

Sentence will be changed to: "In extreme exposure of the structure, the expected maintenance requirements described above would predict more stone would be required to maintain the cross-section integrity." EDIT MADE.

NWD Response (6/14/12): Comment resolved.

---

13. NWD Comment (5/31/12): Figure 3-21. A plan view would be extremely informative for the jetty head templates.

NWP Response (6/7/12): A graphical depiction would be helpful to illustrate those alternatives that included jetty head construction; however the jetty heads are not in the selected plans. Complete drawings will be generated when and if head stabilization occurs.

NWD Response (6/14/12): Comment resolved.

---

14. NWD Comment (5/31/12): 3.5.3.2. last paragraph. This explanation is extremely confusing. Suggest rewording.

NWP Response (6/7/12): This will be rewritten to read: Figures 1-24, 1-26, and 1-31 illustrate the original length modeled by USGS and the lengths and head positions of the authorized project. The loss of littoral sediment can be reduced by stabilizing the jetty heads which maintains the overall morphology of the inlet. Because the recommended jetty lengths for the considered alternatives are about the same as existing jetty head locations, it is not expected that the proposed project will have a negative impact on the hydrodynamics or sedimentation processes of the MCR inlet. EDIT MADE.

NWD Response (6/14/12): Comment resolved.

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15. NWD Comment (5/31/12): Figures 3-22 and 3-23. Labels for templates aren't clear or are missing.

NWP Response (6/7/12): These have been corrected.

NWD Response (6/14/12): Comment resolved.

---

16. NWD Comment (5/31/12): Figures 3-34 through 3-36. Why is major jetty breach, emergency repairs not showing on graph?

NWP Response (6/7/12): The Major Jetty Breach Emergency Repairs are shown on the graph. They are located at "0" on the x-axis. This is because they do not occur under the new base condition where actions are taken to prevent a jetty breach, review of the base condition figures showing repair frequency indicates the Monte-Carlo likelihood of a breach in any given year is less than one (max of 0.5).

NWD Response (6/14/12): Comment resolved.

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Attachment

(Appendix H)

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EC 1165-2-209
31 Jan 10

Attachment C-1

COMPLETION OF AGENCY TECHNICAL REVIEW

The Agency Technical Review (ATR) has been completed for the Major Rehabilitation Report of the Mouth of the Columbia River (MCR) Jetty System. The ATR was conducted as defined in the project's Review Plan to comply with the requirements of EC 1165-2-209. During the ATR, compliance with established policy principles and procedures, utilizing justified and valid assumptions, was verified. This included review of: assumptions, methods, procedures, and material used in analyses, alternatives evaluated, the appropriateness of data used and level obtained, and reasonableness of the results, including whether the product meets the customer's needs consistent with law and existing US Army Corps of Engineers policy. The ATR also assessed the District Quality Control (DQC) documentation and made the determination that the DQC activities employed appear to be appropriate and effective. All comments resulting from the ATR have been resolved and the comments have been closed in DrChecks[sm]

Robert Patev
ATR Team Leader
CEIWR-RMC-ED

22 Jun 2012
Date

for Eric Bluhm
Project Manager – Portland District
CENWP-PM-FP

22 Jun 12
Date

CERTIFICATION OF AGENCY TECHNICAL REVIEW

Significant concerns and the explanation of the resolution are as follows: the Stochastic Risk Based model and its documentation. The model code was modularized and further documented, revised as a single code for all three jetties, and the User's Guide completely rewritten. This was all reviewed again by the ATR team leader. All concerns resulting from the ATR of the project have been fully resolved.

for Lance Helwig, P.E.
Chief, Engineering and Construction Division – Portland District
CENWP-EC

6/22/2012
Date

for Laura Hicks, PMP
Chief, Planning and Project Management Branch – Portland District
CENWP-PM-F

6/22/12
Date

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Comment Report: All Comments
Project: MCR 2010 Jetties Rehab Report
Review: Revised ATR
Displaying 24 comments for the criteria specified in this report.

Id	Discipline	DocType	Spec	Sheet	Detail
4659300	Hydraulics	Major Rehabilitation Report	n/a'	n/a	n/a

(Document Reference: Appendix H)

Para. 2(a) Recommend clarifying that the revised base condition: interim repair, with jetty head recession applies to all three jetties. Also, add to the base condition description that the spur groins are no longer included. Resolve with Para. 4 table which implies that the North Jetty and Jetty A NED plans include capping by the term "hold head". Para. 5 table indicates that only Jetty A will be reassessed during DDR with respect to hold head alternative. Should this apply to the North Jetty also, and the South Jetty?evaluated

Submitted By: alan jeffries (907-753-2740). Submitted On: 08-Jun-12

1-0 Evaluation **Concurred**

Section 3.8 of the main report has been edited to describe the FY 2011 base condition, the revised base condition and the events that resulted in the revision. Please refer to the revised report 12 June. Jetty A and North Jetty will be maintained so that head recession is prevented. In the hold head alternatives, although the large bull nose is not constructed, the jetty terminous are rebuilt and the required cross section to stabilize them (North and Jetty A) will be designed in DDR. South Jetty will be evaluated prior to 2019, when repairs are scheduled to reach the end of the jetty. It is not certain that the South Jetty terminous is in the most optimal location, as the model evaluation did not show a measurable benefit in arresting the recession. The discussion to evaluate the South Jetty head location is in the recomendations and description of selected plan. The increased monitoring identified in the report will assit the district in tracking the changes in foundation erosion, and morphology changes due to S. Jetty head recession and, if necessary be able to adaptively manage the design.

Submitted By: Mark Brodesser (503-808-4914) Submitted On: 12-Jun-12

1-1 Backcheck Recommendation **Close Comment**

Closed without comment.

Submitted By: alan jeffries (907-753-2740) Submitted On: 12-Jun-12

Current Comment Status: **Comment Closed**

Id	Discipline	DocType	Spec	Sheet	Detail
4661912	Hydraulics	Major Rehabilitation Report	n/a'	n/a	n/a

(Document Reference: Main Report)

Executive Summary: The NED plans described in the bullet items for each jetty state that "head stabilization" is included for the North Jetty and Jetty A. This appears to conflict with the base condition described elsewhere (Appendix A1 part 16.f.) in which head capping is not included. It isn't clear if the term "head stabilization" is the same as "head capping". Also, recommend that that the spur groins be identified as features which will not be included in the base condition if that is the intent. Part 4.5: Same as above.

Submitted By: alan jeffries (907-753-2740). Submitted On: 11-Jun-12

1-0 Evaluation **Concurred**

Base condition does not include the re-capitalization of constructing the engineering features. See Exec summary, chapter 4 and chapter 7 for revised descriptions of the plans. The selected plans for North Jetty and Jetty A are scheduled repair (without the engineering features of spurs and the head capping previously designed). However, the model indicated that an economical advantage could be attained by reconstructing the failing cross-sections at the jetty ends instead of allowing them to recede without re-construction. This indicated to the team that some form of stabilization will be beneficial for the North jetty and Jetty A, but the large bull nose would not pay for itself over the 50 year life. Description of the South Jetty plan (base condition) describes the adaptive management that will be used with the increased monitoring to inform future maintenance decisions.

Submitted By: Mark Brodesser (503-808-4914) Submitted On: 12-Jun-12

1-1 Backcheck Recommendation **Close Comment**

Closed without comment.

Submitted By: alan jeffries (907-753-2740) Submitted On: 12-Jun-12

Current Comment Status: **Comment Closed**

4661936	Hydraulics	Major Rehabilitation Report	n/a'	n/a	n/a

(Document Reference: Main Report)

Part 4.5: The NED plan for the South Jetty calls for evaluating head stabilization during the DDR and P&S stage. It is stated that if a haul road on the crest of the jetty is placed to allow for other repairs, then the stabilization of the head could be evaluated. However, the June 2010 MRR draft report appeared to base the South Jetty head capping construction on the assumption that a jack-up barge would be used. This would then not necessarily require the placement of a haul road on the crest for access to the end of the jetty for head capping. If a jack-up bagre is still potentially a viable and cost effective means of construction for jetty head capping, recommend adding this in a sentence to the NED plan bullet for the South Jetty.

Submitted By: alan jeffries (907-753-2740). Submitted On: 11-Jun-12

1-0 Evaluation **Non-concurred**

Unlike the 2011 report, the 2012 report has a construction schedule that works from the Jetty roots seaward. The EA allows for barge delivery and the contractor is not precluded from using a jack-up barge, the selected plan will not discuss contractor's means and methods as it may limit competition.

Submitted By: Mark Brodesser (503-808-4914) Submitted On: 12-Jun-12

1-1 Backcheck Recommendation **Close Comment**

Closed without comment.

Submitted By: alan jeffries (907-753-2740) Submitted On: 12-Jun-12

Current Comment Status: **Comment Closed**

4661982	Hydraulics	Major Rehabilitation Report	n/a'	n/a	n/a

(Document Reference: Main Report)

Parts 4.5 and 4.6: It is not clear why omitting the South Jetty head capping and allowing head recession was selected for the NED if the cost is not statistically/significantly different. Also, in Part 4.6 the proposed South Jetty head station that will be considered for potential capping is 313+00, however, 315+00 was the station per the June 2010 MRR report. At that time also the North Jetty was recommended for capping at Sta 105+00 instead of the revised Sta 101+00. Recommend adding rationale for the revised head capping station (possibly more apropriately in Appendix A1).

Submitted By: alan jeffries (907-753-2740). Submitted On: 11-Jun-12

Revised 11-Jun-12.

1-0 Evaluation **Concurred**

The revised report has a much improved plan selection description. For the S. Jetty, even though the costs are close, the NED plan was chosen by the PDT and the decision is supported by NWD. The following excerpt from 4.6: "While the South Jetty NED plan is the base condition--allowing head recession--it's not statistically different from the base condition alternative holding at STA 313." Report has been revised to clarify districts intentions. The correct language is in the revised plan in section 4.5 under the description of the selected plan for South Jetty. Section 4.6 will be revised to match. Basically instead of indicating that "not significantly different" it says that the AAC's are very close, varying by .9 % (thanks we missed that text in 4.6 when we revised in 4.5) 313 is the station that is used in all the "hold head" alternatives. This is not the base condition for comparing alternatives. The name is misleading, however all alternatives, including base condition hold head were compared against the base condition that allows the jetty to recede. In the hold head alternatives the model would repair stations out to 313, instead of ignoring the degradation of the outer reaches in the alternatives that did not include head capping or "hold head" by repair. While this option proved economically viable for the Jetty A and North Jetty, the consequences of recession for South Jetty do not outweigh the costs of repairing to that station. The selected plan construction schedule indicates repair of South Jetty stations 258-290 in 2020, prior to that time it is anticipated by the district that the affects of shallow water disposal (recently approved and implemented) as well as an increased understanding of the inlet morphology derived from enhanced monitoring (multi-beam/photogrametric or LIDAR) will allow the district to track the changes in the jetties and inlet in a 3d model. This additional information will be used to inform the decision discussed in the revised selected plan for S. Jetty. In short, the head capping cannot be justified at this time but the district is confident that additional information will make for an informed decision in the future. We put that in the report so we won't be precluded from taking actions that modify our plan should we begin to see consequences to the stability of the inlet.

Submitted By: Mark Brodesser (503-808-4914) Submitted On: 12-Jun-12

1-1 Backcheck Recommendation **Close Comment**

Closed without comment.

Submitted By: alan jeffries (907-753-2740) Submitted On: 12-Jun-12

Current Comment Status: **Comment Closed**

4662326	Hydraulics	Major Rehabilitation Report	n/a'	n/a	n/a

(Document Reference: Appendix A2)

Part 4.b (pg 78): This section discusses four parameters that are not represented in the SRB model: Vertical Deflation of Morphology, Littoral Sediment Inflow, and Impacts to Inlet Stability, and Impacts to Navigation. Residual risks of underestimating costs and potential compromises to funtional performance of the MCR Inlet are discussed. These four are all important factors which will be impacted by the revised base condition for the project (with no head capping) and should probably be mentioned in the main report. Recommend adding this same discussion to the Main Report (possibly to Part 3.6) and/or a brief discussion of residual risk to Part 4.3.

Submitted By: alan jeffries (907-753-2740). Submitted On: 11-Jun-12

1-0 Evaluation **Non-concurred**

Please refer to chapter 4 and 7 of the main report for discussion on head recession stabilization. The risk factors structural risk and functional risk are discussed and included in the final plan selection. A2 is considered a part of the report, other review comments previously recieved have indicated that thie information is appropriate in the appendix.

Submitted By: Mark Brodesser (503-808-4914) Submitted On: 12-Jun-12

1-1 Backcheck Recommendation **Close Comment**

Closed without comment.

Submitted By: alan jeffries (907-753-2740) Submitted On: 12-Jun-12

Current Comment Status: **Comment Closed**

4674641	Economics	Other	n/a'	n/a	n/a

(Document Reference: Economic Appendix, Page 14 and Section 5a)

Assume that all base conditions have a minimum BCR of 1.0. Need to add caveat/note as it is not clear that this is the condition. Also, need to discuss that this is a "relative BCR" and if quantified that the BCR could be substantially greater than 1.0 as the minimum case.

Submitted By: Robert Patev (9783188394). Submitted On: 17-Jun-12

1-0 Evaluation **For Information Only**

The base condition is the scenario used to compare all other alternatives. Our guidance essentially assumes that the base condition has a 1:1 benefit-cost ratio. As for a discussion on the relative BCR, see Section 2.12.

Submitted By: Mark Brodesser (503-808-4914) Submitted On: 18-Jun-12

1-1 Backcheck Recommendation **Close Comment**

This fact should be clearly stated in Section 2.12.

Submitted By: Robert Patev (9783188394) Submitted On: 22-Jun-12

2-0 Evaluation **Check and Resolve**
Revisions in 2.12 2nd para: Revisions begin at "If None The MRR base condition (discussed in Sections 2.3 and 3.84) consists of a reasonably efficient plan in which thorough annual jetty inspections are used to initiate repairs when significant degradation is observed. Given the efficacy of the base condition, it is difficult for any alternative that includes large initial expenditures to reduce total present value costs. If none of the alternatives evaluated provide cost savings over the base condition, then the base conditions for all three jetties would become the least cost plan, this would result in an overall BCR of 1:1, indicating that the base condition was the most efficient plan for each jetty.

Submitted By: Mark Brodesser (503-808-4914) Submitted On: 20-Jun-12

Backcheck not conducted

Current Comment Status: **Comment Closed**

4674643	Economics	Other	n/a'	n/a	n/a

(Document Reference: Economic Appendix, Page 14)

The year 2015 seems early in terms of the base year given the funding will not start to then if this gets in the MR cue and it will still take a year plus for E&D and DRR before full construction funding would begin. Explain the effect/sensitivity of using a later base year of say 2017 or 2018 on the economics?

Submitted By: Robert Patev (9783188394). Submitted On: 17-Jun-12

1-0 Evaluation **For Information Only**
Using a later base year is inconsequential to the economics--it will have no affect on alternative ranking

Submitted By: Mark Brodesser (503-808-4914) Submitted On: 18-Jun-12

1-1 Backcheck Recommendation **Close Comment**
Response is sufficient and comment is closed.

Submitted By: Robert Patev (9783188394) Submitted On: 19-Jun-12

Current Comment Status: **Comment Closed**

4674645	Economics	Other	n/a'	n/a	n/a

(Document Reference: Main report, Exec Summary, Pg 4)

Please explain how the combined BCR of 1.1 was obtained. Suggest adding the explanation to the report.

Submitted By: Robert Patev (9783188394). Submitted On: 17-Jun-12

1-0 Evaluation **Concurred**

It was calculated using a weighted average for net benefits. An explanation will be added to Chapter 2.

Submitted By: Mark Brodesser (503-808-4914) Submitted On: 18-Jun-12

1-1 Backcheck Recommendation **Open Comment**

Please send verbiage to be added to report before comment can be closed out.

Submitted By: Robert Patev (9783188394) Submitted On: 19-Jun-12

1-2 Backcheck Recommendation **Close Comment**

Response is sufficent and comment is closed.

Submitted By: Robert Patev (9783188394) Submitted On: 22-Jun-12

2-0 Evaluation **Check and Resolve**

The following has been included in 2.12 For the North Jetty the incremental benefits are achieved by lowering overall repair costs through enacting a more pro-active maintenance plan which reduces expedited repairs by increasing scheduled repairs (see table 2.6 highlighted plan for North Jetty). A similar efficiency was found for Jetty A, and therefore both the North Jetty and Jetty A have positive BCRs reflecting the lower costs of the recommended plans when compared to the base condition. The South Jetty recommended plan is the base condition, therefore the individual BCR for the South Jetty is 1:1, (recommended plan divided by base plan). The South Jetty is also the most expensive of the three jetties to maintain, followed by the North Jetty (BCR (1.09). In order to calculate a combined BCR, the BCRs for each jetty are weighted by the cost of the recommended plan for that jetty. When the weighted average is calculated the least expensive Jetty, Jetty A (BCR 1.42) has less influence on the overall combined BCR than the North and South Jetties and a combined BCR of 1.1 results.

Submitted By: Mark Brodesser (503-808-4914) Submitted On: 20-Jun-12

Backcheck not conducted

Current Comment Status: **Comment Closed**

4674646	Hydraulics	Other	n/a'	n/a	n/a

(Document Reference: Main report, pg 52)

South Jetty has had significantly more repairs that either NJ or JA....however, the structure is being left off any advanced maintenance like NJ and JA. Please explain reason as it is not clear in report.

Submitted By: Robert Patev (9783188394). Submitted On: 17-Jun-12

1-0 Evaluation **For Information Only**

The last jetty rock maintenance on the Jetty system was on the South Jetty in 2006. NWP believed that the most critical repairs at this time are: 1) Dune augmentation to secure South Jetty Root. 2) Lagoon fill to protect North Jetty root/beachside trunk from being undermined. 3) North Jetty Trunk stations 86-99 These are captured as advance actions by either direct submission in the PBUD (dune augmentation) and a previously approved MMR.

Submitted By: Mark Brodesser (503-808-4914) Submitted On: 18-Jun-12

1-1 Backcheck Recommendation **Close Comment**

Response is sufficient and comment is closed out.

Submitted By: Robert Patev (9783188394) Submitted On: 19-Jun-12

Current Comment Status: **Comment Closed**

4674647	Economics	Other	n/a'	n/a	n/a

(Document Reference: Main report, pg 70 , Section 2.5)

Assumptions in this section cannot be guaranteed given the current USACE funding and budget constraints. What is the uncertainity if the required funding for these are not available to maintain these assumptions? How would these effect the economic results in this chapter?

Submitted By: Robert Patev (9783188394). Submitted On: 17-Jun-12

1-0 Evaluation **For Information Only**

The major rehab guidelines do not address this problem. The base repair strategy used to evaluate alternatives matches the guidance and was strongly suggested by the IEPR team in 2011. It is the belief of the district that USACE will react in time to ensure Navigation continues at the MCR, and this is reflected in the base condition.

Submitted By: Mark Brodesser (503-808-4914) Submitted On: 18-Jun-12

1-1 Backcheck Recommendation **Close Comment**

Response is sufficient and comment is closed out.

Submitted By: Robert Patev (9783188394) Submitted On: 19-Jun-12

Current Comment Status: **Comment Closed**

4674648	Economics	Other	n/a'	n/a	n/a

(Document Reference: Main report, pg 70 , Section 2.5)

Regarding assumptions, were any of the costs accounted for in the economic model? that is were there any "navigivational service performance" maintenance costs? If so, how much and what level now and in the future were accounted for? Same issue goes for transportation service benefits did not increase? Why?

Submitted By: Robert Patev (9783188394). Submitted On: 17-Jun-12

1-0 Evaluation **For Information Only**

The base condition precludes impacts to navigation; therefore, there are no navigational costs included in the analysis

Submitted By: Mark Brodesser (503-808-4914) Submitted On: 18-Jun-12

1-1 Backcheck Recommendation **Open Comment**

If base condition precludes impacts to navigation then why do you have to make these assumptions? Maybe a better definition of the terms would be useful.

Submitted By: Robert Patev (9783188394) Submitted On: 19-Jun-12

1-2 Backcheck Recommendation **Close Comment**

Response is sufficent and comment is closed.

Submitted By: Robert Patev (9783188394) Submitted On: 22-Jun-12

2-0 Evaluation **Concurred**

The terms used to describe the benefits in 2.5 have been editied, confusing terms have been changed and the following has been added for clarity. The specific navigation costs considered in this report are the costs of maintenance activities for the three jetty system, these costs can be summarized as the cost of repairing or rehabilitating the structure and the increase in dredging costs relative to the alternative being considered. The direct costs for maintaining the jetties are summarized in table 2.6 by alternative. The costs are differentiated by type of repair; a planned rehabilitation cost, a scheduled O&M cost and an expedited repair cost. Because the alternatives vary in the timing and scope of repair activity, the total costs for an alternative can be compared against the base condition to identify the most cost efficient maintenance strategy. If no efficiency in repair timing and scope can be found that is superior to the base condition, the base condition is identified as the most efficient means of maintaining the jetties, and therefore the most efficient means of maintaining navigation at the MCR. A more efficient means of maintaining the MCR jetties lowers the costs of maintaining navigation at MCR, therefore increasing the BCR even if the navigation benefits themselves do not increase.

Submitted By: Mark Brodesser (503-808-4914) Submitted On: 20-Jun-12

Backcheck not conducted

Current Comment Status: **Comment Closed**

4674650	Economics	Other	n/a'	n/a	n/a

(Document Reference: Main report, pg 78 Section 2.12)

NWP has decided to ignore a plausible event that should have been included in the SRB simulation model and event tree. It was highly recommend that this be included from the previous ATR as it should NOT have had significant impact on the life-cycle cost estimates but would of been good to document that it was part of the simulation process and the final results.

Submitted By: Robert Patev (9783188394). Submitted On: 17-Jun-12

1-0 Evaluation **For Information Only**

The base condition was revised to prevent a breach in response to two IEPR comments: one in regards to the SRB model's efficacy and another questioning the sediment transport estimates for a breach. Those subroutines, while still part of the model, are turned off.

Submitted By: Mark Brodesser (503-808-4914) Submitted On: 18-Jun-12

1-1 Backcheck Recommendation **Close Comment**

Question validity of IEPR reviiewers comments but response is sufficent and comment will be closed.

Submitted By: Robert Patev (9783188394) Submitted On: 19-Jun-12

Current Comment Status: **Comment Closed**

4674652	Economics	Other	n/a'	n/a	n/a

(Document Reference: Main report, pg 78 Section 2.12)

Agreed that the BCR of 1.1 (see previous comment) is very misleading given all the current investments of the MCR system is substantial. However, this project still is a critical structure to permit the MCR navigation system to operate at full capacity. Any slowdown of incoming traffic either due to substanital breaching and inflows of sediments or a catasphrophic failure of one of the jetties should be reflected in final economic estimates.

Submitted By: Robert Patev (9783188394). Submitted On: 17-Jun-12

1-0 Evaluation **Non-concurred**

The discussion and presentation of BCR for this report has been discussed between NWP and NWD planning, economics and leadership. The report as written, represents the outcome of those discussions. The importance of MCR navigation and the benefits not identified in the BCR are discussed in the exec summary, chapter 2, chapter 4 and recommendations chapter 7.

Submitted By: Mark Brodesser (503-808-4914) Submitted On: 18-Jun-12

1-1 Backcheck Recommendation **Close Comment**

Agree that report does document the benefits not claimed by the BCR. Response is sufficient and comment is closed.

Submitted By: Robert Patev (9783188394) Submitted On: 19-Jun-12

Current Comment Status: **Comment Closed**

4674663	Hydraulics	Other	n/a'	n/a	n/a

(Document Reference: Main report, Figures 3-40 and beyond)

It appears from these life-cylce diagrams that the structural and functional reliability end back up to the same values after 50 years and after we spend $300M for the repairs in 2015. Why is there no similiar investment planned in the system to increase reliability in 20-25 years and beyond?

Submitted By: Robert Patev (9783188394). Submitted On: 17-Jun-12

1-0 Evaluation **For Information Only**

The base condition and all alternatives were developed to maintain channel navigability. Functional reliability was a secondary calculation, to ensure alternatives are providing a minimum level of functional reliability for the MCR inlet. The selected plans all meet the minimum level. While the report supports interim repairs on the South Jetty, those plans are based on model repair volume estimates. The actual repairs to the South Jetty, and the others, will be tied to damage measured per the biennial bathymetric, photogrammetric and LIDAR surveys.

Submitted By: Mark Brodesser (503-808-4914) Submitted On: 18-Jun-12

1-1 Backcheck Recommendation **Close Comment**

Response is sufficient and comment is closed.

Submitted By: Robert Patev (9783188394) Submitted On: 19-Jun-12

Current Comment Status: **Comment Closed**

4675609	Economics	Major Rehabilitation Report	n/a'	n/a	n/a

Coordinating Discipline(s): Economics

test

Submitted By: Kevin Knight ((415) 977-8597). Submitted On: 18-Jun-12

1-0 Evaluation **Concurred**

success

Submitted By: Mark Brodesser (503-808-4914) Submitted On: 18-Jun-12

1-1 Backcheck Recommendation **Close Comment**

Closed without comment.

Submitted By: Kevin Knight ((415) 977-8597) Submitted On: 19-Jun-12

Current Comment Status: **Comment Closed**

4676922	Economics	Major Rehabilitation Report	n/a'	n/a	n/a

Coordinating Discipline(s): Economics

During the previous review, the major concern had been the lack of defense of the Federal interest. This version is a vast improvement. You may still want to consider the following which may strengthen the case for "obvious Federal interest": * Using more recent vessel traffic or commodity values. The year 2009, as in the appendix, was a poor data point due to the economic downturn. * Page C-3, provide additional details on the present Columbia River deepening (cost, date of completion, etc). * Figure C-1 is great at showing the widespread reach and extension of the hinterland, but caution about showing the map w/ the containers. Many evidence suggests a shift in vessel deployments away from the West Coast once the Panama Canal is enlarged in 2014. * Provide a blurb on MARADs Marine Highway initiative and National Export Initiative, of which the Pacific Northwest is a key artery. * Besides stating that "only once has the jetty system been disrputed", emphasize the serious consequences of a breached jetty. Tremendous economic losses, thousands of vessels being rerouted, safety issues, long term emergency clean-up costs, etc. It may not need to be quantified, but discussed as a means of putting the Federal interest issue to rest. * Love the fact that you quantified the RED impacts--do you happen to know the increased tax revenues? (some I/O models can calculate those in addition to the jobs and income).

Submitted By: Kevin Knight ((415) 977-8597). Submitted On: 18-Jun-12

1-0 Evaluation **Concurred**

PDT will add information regarding MARAD in the exec summary "The Columbia River comprises the M-84 Corridor for the Marine Highway Program. It is noted by the US Department of Transportation as a truck bottleneck resulting in up to 750,000 truck delay hours and an area of major rail congestion. The marine highway serves to reduce the congestion."

Submitted By: Mark Brodesser (503-808-4914) Submitted On: 18-Jun-12

1-1 Backcheck Recommendation **Close Comment**

Closed without comment.

Submitted By: Kevin Knight ((415) 977-8597) Submitted On: 19-Jun-12

Current Comment Status: **Comment Closed**

4676932	Economics	Major Rehabilitation Report	n/a'	n/a	n/a

Coordinating Discipline(s): Economics

Curiously, why was the Deep Draft PCX contacted to review the model? (The model appears to be more like a Coastal Storm Damage Reduction).

Submitted By: Kevin Knight ((415) 977-8597). Submitted On: 18-Jun-12

1-0 Evaluation **For Information Only**
The MCR is a deep draft navigation project authorized for the sole purpose of navigation.

Submitted By: Mark Brodesser (503-808-4914) Submitted On: 18-Jun-12

1-1 Backcheck Recommendation **Close Comment**
Closed without comment.

Submitted By: Kevin Knight ((415) 977-8597) Submitted On: 19-Jun-12

Current Comment Status: **Comment Closed**

4676947	Economics	Major Rehabilitation Report	n/a'	n/a	n/a

Coordinating Discipline(s): Economics

Page C-7, "Base Year and IDC" Section: Sentence..."In general, the more the benefits vary through time and the longer the time to implementation....the stronger the effect will be". This statement is confusing--how so? Makes the AAE costs higher?

Submitted By: Kevin Knight ((415) 977-8597). Submitted On: 18-Jun-12

1-0 Evaluation **Concurred**
The paragraph is a direct quote from 1105-2-100 2.4 (o), agree that it may be confusing but the PDT is unclear on how it can be written better.

Submitted By: Mark Brodesser (503-808-4914) Submitted On: 18-Jun-12

1-1 Backcheck Recommendation **Close Comment**
Closed without comment.

Submitted By: Kevin Knight ((415) 977-8597) Submitted On: 19-Jun-12

Current Comment Status: **Comment Closed**

4676969	Economics	Major Rehabilitation Report	n/a'	n/a	n/a

Coordinating Discipline(s): Economics

Brian answered my question about"fix as fail" repair vs. "scheduled repair" but other readers might also be surprised to see "fix as fail" unit costs lower than a scheduled repair. The term "fix as fail" implies an expedited or unplanned action.

Submitted By: Kevin Knight ((415) 977-8597). Submitted On: 18-Jun-12

1-0 Evaluation **Concurred**
Fix as fails unit costs are based on less durable, locally available, smaller jetty stone. Scheduled repair assumes we have the time to develop quarry stone that is more suitable for the site, larger, denser but not locally available and therefore more expensive.

Submitted By: Mark Brodesser (503-808-4914) Submitted On: 18-Jun-12

1-1 Backcheck Recommendation **Close Comment**
Closed without comment.

Submitted By: Kevin Knight ((415) 977-8597) Submitted On: 19-Jun-12
Current Comment Status: **Comment Closed**

4676979	Economics	Major Rehabilitation Report	n/a'	n/a	n/a

Coordinating Discipline(s): Economics

Consider expanding the discussion on the "Without Project" Base Condition assumption and how the team derived this assumption (Brian explained the history to me over the phone).

Submitted By: Kevin Knight ((415) 977-8597). Submitted On: 18-Jun-12

1-0 Evaluation **For Information Only**
Please see 3.8.3 for a description of the development of the base condition.

Submitted By: Mark Brodesser (503-808-4914) Submitted On: 18-Jun-12

1-1 Backcheck Recommendation **Close Comment**
Closed without comment.

Submitted By: Kevin Knight ((415) 977-8597) Submitted On: 19-Jun-12
Current Comment Status: **Comment Closed**

4676989	Economics	Major Rehabilitation Report	n/a'	n/a	n/a

Coordinating Discipline(s): Economics

Figure C-4: Example of Life Cycle Cost Spreadsheet. Shouldn't we be compounding costs for the years 2008 through 2014 to the Base Year? (future years were correctly discounted).

Submitted By: Kevin Knight ((415) 977-8597). Submitted On: 18-Jun-12

1-0 Evaluation **For Information Only**
See South Jetty Base condition C-17 added into the appendix C.

Submitted By: Mark Brodesser (503-808-4914) Submitted On: 18-Jun-12

1-1 Backcheck Recommendation **Close Comment**
Closed without comment.

Submitted By: Kevin Knight ((415) 977-8597) Submitted On: 19-Jun-12
Current Comment Status: **Comment Closed**

4677008	Economics	Major Rehabilitation Report	n/a'	n/a	n/a

Coordinating Discipline(s): Economics

Tables C-5 through C-16 are hard to follow. Consider tracing one alternative fully, then providing the alternate data at the end or simplifying the display.

Submitted By: Kevin Knight ((415) 977-8597). Submitted On: 18-Jun-12

1-0 Evaluation **Concurred**
See South Jetty Base condition C-17 added into the appendix C.

Submitted By: Mark Brodesser (503-808-4914) Submitted On: 18-Jun-12

1-1 Backcheck Recommendation **Close Comment**
Closed without comment.

Submitted By: Kevin Knight ((415) 977-8597) Submitted On: 19-Jun-12
Current Comment Status: **Comment Closed**

4677036	Economics	Major Rehabilitation Report	n/a'	n/a	n/a

Coordinating Discipline(s): Economics

Perhaps the biggest lingering concern is with the formulation (Brian said this is mainly because of the without project baseline assumption). Indeed, there are 71 alternatives and only a handful are actually cost effective. Even among the cost effective plans, there is enough margin of error to make them non-cost effective. Was there a possibility of reformulation? (modifying repair schedules, etc)? I'm aware that this study was delegated to the MSC, but understand that this type of analysis is precedent-setting as the Corps will be undertaking these much more frequently in the future.

Submitted By: Kevin Knight ((415) 977-8597). Submitted On: 18-Jun-12

1-0 Evaluation **For Information Only**
Cheaper alternatives all represent a level of maintenance that is "less than" the base condition and does not provide the minimum level of protection for the Navigation entrance. This is a result of the base condition being the minimally acceptable level of maintenance, therefore by definition, it's going to be the most efficient or nearly the most efficient means of maintaining navigation.

Submitted By: Mark Brodesser (503-808-4914) Submitted On: 18-Jun-12

1-1 Backcheck Recommendation **Close Comment**
Closed without comment.

Submitted By: Kevin Knight ((415) 977-8597) Submitted On: 19-Jun-12

Current Comment Status: **Comment Closed**

4677048	Economics	Major Rehabilitation Report	n/a'	n/a	n/a

Coordinating Discipline(s): Economics

We had resolved this issue over the phone, but it may be worthwhile to explain the nomenclature in the Econ appendix: rehab, emergency repair, interim repair, etc.

Submitted By: Kevin Knight ((415) 977-8597). Submitted On: 18-Jun-12

1-0 Evaluation **Non-concurred**
The information is available in A2, while the PDT agrees that the information would be beneficial in Appendix C we are trying not to repeat information over and over. We will add a reference to it in App. C.

Submitted By: Mark Brodesser (503-808-4914) Submitted On: 18-Jun-12

1-1 Backcheck Recommendation **Close Comment**
Closed without comment.

Submitted By: Kevin Knight ((415) 977-8597) Submitted On: 19-Jun-12

Current Comment Status: **Comment Closed**

Attachment 9

(Appendix H)

Attachment C-1

COMPLETION OF AGENCY TECHNICAL REVIEW

The Agency Technical Review (ATR) has been completed for the Major Rehabilitation Report of the Mouth of the Columbia River (MCR) Jetty System. The ATR was conducted as defined in the project's Review Plan to comply with the requirements of EC 1165-2-209. During the ATR, compliance with established policy principles and procedures, utilizing justified and valid assumptions, was verified. This included review of: assumptions, methods, procedures, and material used in analyses, alternatives evaluated, the appropriateness of data used and level obtained, and reasonableness of the results, including whether the product meets the customer's needs consistent with law and existing US Army Corps of Engineers policy. The ATR also assessed the District Quality Control (DQC) documentation and made the determination that the DQC activities employed appear to be appropriate and effective. All comments resulting from the ATR have been resolved and the comments have been closed in DrChecks[sm]

Robert Patev
ATR Team Leader
CEIWR-RMC-ED

22 June 2012
Date

for Eric Bluhm
Project Manager – Portland District
CENWP-PM-FP

22 Jun 12
Date

CERTIFICATION OF AGENCY TECHNICAL REVIEW

Significant concerns and the explanation of the resolution are as follows: the Stochastic Risk Based model and its documentation. The model code was modularized and further documented, revised as a single code for all three jetties, and the User's Guide completely rewritten. This was all reviewed again by the ATR team leader. All concerns resulting from the ATR of the project have been fully resolved.

for Lance Helwig, P.E.
Chief, Engineering and Construction Division – Portland District
CENWP-EC

6/22/2012
Date

for Laura Hicks, PMP
Chief, Planning and Project Management Branch – Portland District
CENWP-PM-F

6/22/12
Date