US Army Corps of Engineers ®
Galveston District

Appendix A

Fish and Wildlife Coordination Act Compliance

for

Coastal Texas Protection and Restoration Feasibility Study

August 2021

United States Department of the Interior

FISH AND WILDLIFE SERVICE
Texas Coastal Ecological Services Field Office
17629 El Camino Real, Suite 211
Houston, Texas 77058
281/286-8282 / (FAX) 281/488-5882

In Reply Refer To:
FWS/02ETTX0-
2021-CPA-0021

January 29, 2021

Colonel Timothy R. Vail
District Commander
Galveston District, U.S. Army Corps of Engineers
Attention: Mr. Jeff Pinsky, Section Chief Environmental Branch
Regional Planning and Environmental Planning Center
P.O. Box 1229
Galveston, Texas 77553-1229

Re: Fish and Wildlife Coordination Act Report - United States Army Corps of Engineers, Coastal Texas Protection Restoration Feasibility Study

Dear Colonel Vail:

The Fish and Wildlife Coordination Act (FWCA) (Public Law 85-624; 16 U.S.C. 661 - 666) requires that the U.S. Army Corps of Engineers (Corps) coordinate with the Department of Interior - U.S. Fish and Wildlife Service (Service) where waters of any stream or other body of water are proposed or authorized, permitted or licensed to be impounded, diverted or otherwise controlled or modified to consult for the purpose of "preventing loss of and damage to wildlife resources." Please reference FWS/02ETTX00-2021-CPA-0021 in any future correspondence regarding this document.

This Fish and Wildlife Coordination Act Report (FWCAR) provides the Service's comments and recommendations to avoid adverse impacts to fish and wildlife resources that could occur due to construction of the proposed Coastal Texas Protection Restoration Feasibility Study (Study), while identifying planning constraints that may influence the Service's ability to fulfill our reporting responsibilities under Section 2(b) of the Fish and Wildlife Coordination Act (FWCA, 48 Stat. 401, as amended; 16 U.S.C. 661 et seq.). The FWCA requires that the Section 2 (b) report be made an integral part of any report (Environmental Impact Statement (EIS) No. 202000217) supporting further project authorization or administrative approval.

The proposed project is located along the Texas Gulf coast, from Bolivar Peninsula to South Padre Island, and includes the Gulf Intracoastal Waterway (GIWW), the Gulf of Mexico, adjacent tidal waters, barrier islands, coastal wetlands, rivers and streams, and adjacent habitats that make up the interrelated ecosystems along the coast of Texas. This FWCAR is prepared under the authority of the FWCA; and constitutes the final report of the Secretary of the Interior as required by Section 2(b) of the FWCA. The Service will provide copies of the FWCAR to the National Marine Fisheries Service and the Texas Parks and Wildlife Department. If any comments are received, they will be forwarded to the Corps. Comments in this report are also provided under the Endangered Species Act (Act) of 1973 and the Migratory Bird Treaty Act (MBTA) of 1918.

Previous Service involvement with the Study occurred by way of a Planning Aid Letter (PAL), dated November 20, 2017, and participation in Corps coordination meetings (Annex A of FWCAR). The PAL provided an initial analysis of the proposed project and made recommendations to avoid and minimize the proposed project impacts to important fish and wildlife trust resources.

The Service finds the six actionable Ecosystem Restoration (ER) measures meet the intent and purpose of the Study and provides opportunities for future collaboration with the National Wildlife Refuges and state wildlife management areas to refine the proposed plans to restore or protect existing habitats along the GIWW. In addition to providing hurricane storm surge protection in developed portions of the project area, implementation of the recommended plan (RP) would restore, enhance, and protect substantial areas of coastal wetlands, oyster reefs, bird rookery islands, and barrier island habitat.

The Service also finds that implementation of these six ER measures could result in some minor adverse impacts. Our recommendations are provided in the Service's Position and Recommendation Section of the FWCAR, which address ways to avoid such unintended impacts and to improve fish and wildlife habitat quality in these restoration areas. The Service supports implementation of the six ER measures in the RP provided the conservation measures in the Service's Position and Recommendation Section of the FWCAR are included as part of the RP in the EIS, and are implemented concurrently with construction of these measures.

The Service finds the Tier One Coastal Storm Risk Management measures collectively referenced as Galveston Bay Storm Surge Barrier System may create permanent disturbance to fish and wildlife species over such a large geographic area, with adverse effects on trust species and their breeding, nesting, and foraging areas along the Texas coast, nationally, and in other countries. Our concerns and recommendations for future coordination on the Galveston Bay Storm Surge Barrier are summarized below and further defined in the Recommendation Section of this Report.

Due to the uncertainties regarding the final project design, the project's complete impacts cannot be determined at the current stage of planning. Therefore, we cannot fully complete our evaluation of the Study's full effects on fish and wildlife resources at this time nor can we entirely fulfill our reporting responsibilities under Section 2(b) of the FWCA (48 Stat, 401, as amended; 16 U.S.C. 661 et seq.). We understand the next phase of the Study will produce more definitive project information and we recommend additional Service involvement to fulfil our reporting requirements and responsibilities under the FWCA.

We appreciate the opportunity to participate in the planning of the Study and look forward to working with your staff on this and future federal projects. If you have any questions or comments concerning this report, please contact staff biologist Jan Culbertson at 281-212-1516, or by email at jan_culbertson@fws.gov.

Sincerely,

Charles Ardizzone
Field Supervisor

Fish and Wildlife Coordination Act Report

on

Coastal Texas Protection and Restoration Feasibility Study

Prepared by:
Texas Coastal Texas Ecological Services
U.S. Fish and Wildlife Service
Region 2
Houston, TX

January 2021

EXECUTIVE SUMMARY

The Texas coast is subject to coastal erosion, relative sea level rise (RSLR), coastal storm surge, habitat loss, and water quality degradation. These coastal hazards are affecting the environmental and economic health of the coast, which negatively impacts the state and national economy. In addition, severe weather events such as Hurricane Rita, Hurricane Ike, Hurricane Dolly, and most recently Hurricane Harvey have caused further ecological and economic devastation to the Texas coast, emphasizing the need for enhanced resiliency of the coast to prevent future damage and loss.

The Coastal Texas Study (Study) is being performed under the standing authority of Section 4091, Water Resources Development Act of 2007, Public Law 110-114, which directed the Secretary of the Army, acting through the U.S. Army Corps of Engineers (Corps), in cooperation with the local sponsor, Texas General Land Office (GLO), to "develop a comprehensive plan to determine the feasibility of carrying out projects for flood damage reduction, hurricane and storm damage reduction, and ecosystem restoration in the coastal areas of the State of Texas." Further, the scope of the Study provides for the protection, conservation, and restoration of wetlands, barrier islands, shorelines, and related lands and features that protect critical resources, habitat, and infrastructure from the impacts of costal storms, hurricanes, erosion, and subsidence.

The recommended plan (RP) includes a combination of Coastal Storm Risk Management (CSRM) and Ecosystem Restoration (ER) measures that are designed to reduce the risk of coastal damages to natural and man-made infrastructure and to restore degraded coastal ecosystems across four regions. Multiple upper coast CSRM measures, specifically providing protection to the Galveston Bay area, are collectively referenced herein as the "Galveston Bay Storm Surge Barrier System." These upper coast CSRM measures consists of beach and dune nourishment along Bolivar Peninsula and Galveston Island, seawall improvements and ring levee around the City of Galveston, storm surge gates across Bolivar Roads, Dickinson Bayou and Clear Lake Channel, and non-structural improvements. An additional lower coast CSRM feature is proposed, which consists of beach and dune enhancement and sediment management on South Padre Island. Eight ER measures are also proposed along the coast in the four regions, which are designed to provide enhancement or restoration of existing bird rookery islands, oyster reefs, beach and dune, estuarine wetlands, breakwater protection for existing and restored wetland habitat, and to restore the hydrologic connection between the Gulf and the Lower Laguna Madre estuary.

The Study uses a tiered National Environmental Policy Act (NEPA) compliance approach, in accordance with the Council on Environmental Quality's (CEQ's) Regulations for Implementing the Procedural Provisions of the NEPA (40 CFR 1500—1508, specifically 1502.20). Using this approach, rather than preparing a single definitive Environmental Impact Statement (EIS) as the basis for approving the entire project, the Corps will conduct two or more rounds – or "tiers" – of environmental review of the RP. Six of the proposed ER measures were determined to be "actionable measures" which appear to have a sufficient level of site-specific detail to fully understand the context and intensity of the anticipated impacts and be considered consistent under NEPA. All proposed beach and dune restoration measures in addition to the Galveston Bay Storm Surge Barrier System were considered to be “Tier One” measures, which will be a broad environmental evaluation in the current NEPA assessment, with the understanding that a more detailed environmental evaluation will be provided during the next Tier Two NEPA assessment.

This Fish and Wildlife Coordination Act Report (FWCAR) provides the U.S. Fish and Wildlife Service’s (Service) comments and recommendations to avoid adverse impacts to fish and wildlife resources that could occur due to construction of the proposed project while identifying planning constraints that may influence the Service’s ability to fulfill our reporting responsibilities under Section 2(b) of the Fish and Wildlife Coordination Act (FWCA, 48 Stat. 401, as amended; 16 U.S.C. 661 et seq.). This FWCAR is prepared under the authority of the FWCA; and constitutes the final report of the Secretary of the Interior as required by Section 2(b) of the FWCA. The Service will provide copies of the FWCAR to the National Marine Fisheries Service and the Texas Parks and Wildlife Department. If any comments are received, they will be forwarded to the Corps. Comments in this report are also provided under the Endangered Species Act (Act) of 1973 and the Migratory Bird Treaty Act (MBTA) of 1918.

The recommendations of this FWCAR will specifically address in detail the six actionable ER measures, with the understanding that the Corps will provide future opportunities for Service to assist them with coordination and refinement of these measures during the planning and design phase (PED). The FWCAR will also give a general overview of our concerns and recommendations regarding the Tier One measures, with the understanding that the Corps will seek additional Service guidance under the FWCA to avoid and minimize adverse effects to trust resources in refining the beach and dune measures and the Galveston Bay Storm Surge Barrier.

The Service finds the six actionable ER measures meet the intent and purpose of the Study and provides opportunities for future collaboration with the National Wildlife Refuges (NWR) and state wildlife management areas (WMA) to refine the proposed plans to restore or protect existing habitats along the Gulf Intracoastal Waterway (GIWW). In addition to providing hurricane storm surge protection in developed portions of the project area, implementation of the RP would restore, enhance, and protect substantial areas of coastal wetlands, oyster reefs, bird rookery islands, and barrier island habitat.

All restoration measures planned within NWR lands are subject to a review for appropriateness and compatibility with the requirements of the National Wildlife Refuge System Improvement Act (NWRSA) of 1997 (PL 105-57). These reviews assure that the proposed actions will be consistent with the purposes and intent of the establishment of the refuge and the administration of the NWR System. However, the Service is not able to provide the financial commitment to complete the various elements of the ER measures on refuge lands. Although there may be statutory prohibitions for the Corps funding work on lands administered or owned by another federal agency, the non-federal sponsor of the RP, is not prohibited from funding support for these projects on federal land. The Service encourages the Corps and the non-federal sponsor to work with the respective refuge complex managers to explore potential funding opportunities to complete some of the proposed restoration work on refuge lands.

The Service also finds that implementation of these six ER measures could result in some minor adverse impacts. Our recommendations are provided in Service Position and Recommendation Section of the FWCAR, which address ways to avoid such unintended impacts and to improve fish and wildlife habitat quality in these restoration areas. The Service supports implementation of the six ER measures in the RP provided the conservation measures in the Service Position and Recommendation Section of the FWCAR are included as part of the RP in the EIS, and are implemented concurrently with construction of these measures.

The Service also supports the proposed beach and dune restoration measures in the RP, which could provide positive benefits to fish and wildlife habitats, based on the condition that there is an opportunity for the Service to provide additional input to the Corps through the tiered NEPA process. Although these beach and dune measures could result in some unintended minor adverse effects, the Service believes these measures will improve fish and wildlife habitat quality on Texas barrier islands, provided the conservation measures in the Service Position and Recommendation Section of the FWCAR, are included in the Tier Two Assessment and Final EIS, and are implemented concurrently with construction of these measures.

However, the Service finds the Tier One CSRM measure collectively referenced as Galveston Bay Storm Surge Barrier may create permanent disturbance to fish and wildlife species over such a large geographic area, with adverse effects on trust species and their breeding, nesting, and foraging areas along the Texas coast, nationally, and in other countries. Our concerns and recommendations for future coordination on the Galveston Bay Storm Surge Barrier are summarized below and further defined in the Recommendation Section of this Report.

1. The West Indian manatee (*Trichechus manatus*), federally listed species may be found within the Houston Ship Channel or Galveston Bay, which are found within the action area of the Galveston Bay Storm Surge Barrier. Although a rare visitor to the Texas coast, additional conservation measures to avoid adverse effects to West Indian manatees should be incorporated in the RP to be implemented during construction of the Bolivar Roads surge gates, interior bay surge gates, or ring levee around City of Galveston. See Recommendation Section for description of specific conservation measures for West Indian manatee.

2. The current design of the Bolivar Roads surge gates will likely cause increased retention times of floodwaters or seasonal high tides over the adjacent wetlands. The Service requests that the impacts of displacing migratory birds, or ground nesting birds such as the eastern black rail, due to retention of higher water levels in the wetlands surrounding Galveston Bay, is more fully evaluated in the Tier Two assessment for this CSRM measure.

3. The 3D Adaptive Hydraulics (AdH) model for the Galveston Bay Storm Surge Barrier System should extend to San Luis Pass to identify all potential impacts of constructing the gates on tidal flow, tidal amplitude, salinity, temperature, and sediment and organism movement within the Galveston Bay estuary and adjacent passes. The Service requests that additional AdH modeling be conducted to assess the environmental consequences of

the elevated tidal amplitude from the surge gates on land forms on either side of San Luis Pass resulting in potential loss of critical habitat for piping plover.

4. The combined structural (ring levee) and non-structural (dune and beach restoration) barriers proposed in the Galveston Bay Storm Surge Barrier System measures may prevent sediment overwash during storms, and interrupt natural wind driven transport of sediment to the bay sides of Bolivar Peninsula and Galveston Island, which are crucial in sediment accretion by tidal wetlands in prohibiting landward migration from relative sea level rise. The Service recommends the Corps conduct comprehensive bathymetric, hydrodynamic, and sediment transport studies to evaluate the short-and long-term impacts of sediment and nutrient losses caused by the proposed RP on the bay sides of Bolivar Peninsula and Galveston Island that may reduce the available nesting, breeding and foraging areas for migratory birds, and adversely affect endangered species.

5. The combined Galveston Bay Storm Surge Barrier System measures may also cause greater sediment deposition in San Luis Pass resulting in tidal restrictions into West Bay and Christmas Bay. Tidal exchange restrictions due to sediment accelerated accretion could also influence salinity gradients and water quality in the lower reaches of West Galveston Bay. These tidal restrictions could also result in limited fish migration or larvae transport into West Bay and Christmas Bay. The Service recommends the Corps evaluates the short-and long-term impacts of potential increased sediment accretion and tidal restrictions within the San Luis Pass on West Bay, Cold Pass, Moody's Island, Mud Island, and Christmas Bay.

6. The combined Galveston Bay Storm Surge Barrier System measures may also cause reduced tidal exchange, reduced circulation, increased nutrient levels, and increased retention times that will increase eutrophication and contaminant levels within Galveston Bay and its tributaries, which will adversely affect trust resources such as colonial waterbirds that forage on the fish and shellfish directly impacted by lower dissolved oxygen levels or contaminants. Reduced tidal exchanges may also cause longer bay retention times of freshwater inflows from floods, or Gulf waters from higher tides due to relative sea level rise. Longer retention of nutrient loaded waters may also promote toxic algal blooms (e.g., *Karenia brevis*) (Brand and Compton 2007), as well as promote the production of other pathogens which affect fish, shellfish, colonial waterbirds that forage on fish and shellfish, and the federally listed West Indian manatee (*Trichechus manatus*), which is susceptible to toxic algae blooms. Reduced tidal exchange and increased bay retention times may also lead to extended effects from oil or chemical spills on colonial waterbirds, West Indian manatee, and other marine mammals, and sea turtles.

7. The Galveston Bay Larvae Transport Model or particle transport model developed by Lackey and McAlpin (2020) does not provide an evaluation of the impacts to larvae movement restricted at the gates or transferred downstream of the Bolivar Roads surge gate along the shoreline of Galveston Island to San Luis Pass. The Service recommends that additional particle transport modeling be conducted to assess the environmental

consequences of surge gate's impact on tidal exchanges, fish migration, and larvae recruitment through Bolivar Roads and San Luis Pass.

8. The environmental consequences of the Bolivar Road surge gates on key species such as the blue crab (*Callinectes sapidus*) may be more likely to be affected by the Bolivar Roads surge gates than other species migrating through this pass. Blue crabs provide much needed nutrition and preferred food for the federally listed Whooping Cranes during their fall migration to Texas. Mature female blue crabs utilize the immediate lower Galveston Bay waters near Bolivar Roads pass during a critical stage in their egg incubation period and may be adversely affected by increased tidal velocities in the narrow deeper channel between the main surge gates. Water temperature related changes caused by tidal restrictions from the shallow water surge gates could also delay egg incubation periods resulting in greater mortalities to the eggs. An additional concern is any surviving larvae released into lower Galveston Bay may not be able to pass through the shallow water gate structures and concrete sills to reach the inner continental shelf for offshore growth, or the larvae's subsequent return to the estuary for growth and reproduction into mature adults. The Service recommends the Corps evaluate the direct and indirect impacts of changes in tidal velocities, tidal restrictions and water temperatures related to the Bolivar Roads surge gates on the mature female blue crab, her eggs, and larvae; and the overall consequences to trust species dependent on blue crabs in their diets.

9. Recommend the Corps fully compensate for any unavoidable losses of estuarine wetland, oyster, mud flat, submerged aquatic or open water habitat caused by project features as dictated by the Habitat Evaluation Procedure (HEP) model used for each habitat.

10. The Service encourages additional monitoring and adaptive management measures are incorporated at the mitigation sites (including preservation and rehabilitation of existing habitats) be included in the subsequent NEPA Tier Two analysis for all Tier One measures. Monitoring is an essential component of restoration and mitigation projects for understanding species use and composition of the newly rehabilitated sites and will provide a basis for future recommendations to ensure successful implementation and continued usage by all fish and wildlife species.

Transmittal of this document by Service and acceptance by Corps documents coordination between the agencies and compliance with the FWCA for the six ER actionable measures of the RP. Additional Service involvement is necessary for subsequent detailed planning, habitat analysis, engineering and design, and construction phases of each planning effort in order to fulfill our responsibilities under FWCA.

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INTRODUCTION

U.S. Fish and Wildlife Service (Service) is mandated to provide expertise during the planning and development of major federal projects, to ensure that fish and wildlife resources are conserved, and that impacts to these resources are avoided or minimized. The Fish and Wildlife Coordination Act (FWCA) (16 U.S.C. 661-667e; the Act of March 10, 1934; Ch. 55; 48 Stat. 401), requires consultation with the Service and State fish and wildlife agencies where the "waters of any stream or other body of water are proposed or authorized, permitted or licensed to be impounded, diverted or otherwise controlled or modified" by any agency under a Federal permit or license. Consultation is to be undertaken for the purpose of "preventing loss of and damage to wildlife resources." Second, The Rivers and Harbors Act of 1938 (33 U.S.C. 540, and other U.S.C. sections; Chapter 535, June 20, 1938; 52 Stat. 802), provides for wildlife conservation to be given "due regard" in planning federally authorized water resource projects.

The FWCA provides a basic procedural framework for the orderly consideration of fish and wildlife conservation measures to be incorporated into Federal and federally permitted or licensed water development projects. The principle provisions of the FWCA include:

1. A statement of Congressional purpose that fish and wildlife conservation shall receive equal consideration with other project features;

2. Mandatory consultation with wildlife agencies to achieve such conservation;

3. Full consideration by action agencies of the recommendations resulting from consultations;

4. Authority for action agencies to implement such recommendations as they find acceptable.

This Coastal Texas Fish and Wildlife Coordination Act Report (FWCAR) is presented for the Coastal Texas Protection and Restoration Feasibility Study (Study) to provide the Service's comments and recommendations while identifying planning constraints that may influence the Service's ability to fulfill reporting responsibilities under Section 2(b) of the Fish and Wildlife Coordination Act (FWCA, 48 Stat. 401, as amended; 16 U.S.C. 661 et seq.). This FWCAR is prepared under the authority of the FWCA; and constitutes the final report of the Secretary of the Interior as required by Section 2(b) of the FWCA. The Service will provide copies of the FWCAR to the National Marine Fisheries Service and the Texas Parks and Wildlife Department; if any comments are received they will be forwarded under a separate cover. Comments in this letter are also provided under the Endangered Species Act of 1973 and the Migratory Bird Treaty Act of 1918.

The Services' evaluation in this report is based on current data, modeling, and analyses made available by the Corps and Service files. The Service understands construction of the project is subject to Congressional approval and funding of the Recommended Plan (RP), which will occur sometime in the future. Any measures not considered for review in this report will undergo subsequent NEPA and require additional FWCA coordination, including the Service's involvement in additional habitat analysis and design considerations, once funding is provided and additional design level details have been determined. Service involvement will also be required for subsequent detailed planning, habitat analysis, engineering design, and construction phases of each planning effort to fulfill responsibilities under the FWCA.

Since there may be a significant time lag between the Study and construction phases, the Service recommends the Corps reinitiate coordination under a separate FWCA agreement when the pre-construction, engineering, and design (PED) phase begins and when subsequent design and analysis begins for measures that are not reviewed in this report. This will allow the Service to conduct a comprehensive review of the project footprint, impacts, and update recommendations based on environmental conditions at the time of construction.

Study Authority

The Study is being performed under the standing authority of Section 4091, Water Resources Development Act of 2007, Public Law 110-114, which directed the Secretary of the Army, acting through the U.S. Army Corps of Engineers (Corps), to "develop a comprehensive plan to determine the feasibility of carrying out projects for flood damage reduction, hurricane and storm damage reduction, and ecosystem restoration in the coastal areas of the State of Texas." Further, the scope of the Study provides for the protection, conservation, and restoration of wetlands, barrier islands, shorelines, and related lands and features that protect critical resources, habitat, and infrastructure from the impacts of costal storms, hurricanes, erosion, and subsidence.

As a result, the non-Federal sponsor, the Texas General Land Office (GLO), signed a Feasibility Cost Share Agreement in November of 2015. The Study is following the Corps guideline of SMART Planning, with the exception of the cost of the study and time allotted. SMART Planning encourages risk-informed decision making and the appropriate levels of detail for conducting investigations, so that recommendations can be captured and succinctly documented and completed in a target goal of 3 years and for less than $3 million in compliance with the 3x3x3 rule. It reorients the planning process away from simply collecting data or completing tasks and refocuses it on doing the work required to reduce uncertainty to the point where the PDT can make an iterative sequence of planning decisions required to complete a quality study in full compliance with environmental laws and statutes. Because of the scale of the study area, complexity of the problems, and dual purpose scope (CSRM and ER), the Study has an exemption for the time and money aspect, but has still maintained the risk-informed decision making aspect.

Study Purpose

This Study is being conducted to determine the feasibility of constructing a large-scale, comprehensive CSRM and ER plan to restore and enhance the resiliency of the Texas' ecologic coastal features and reduce the risk of coastal storm damage. The Study will specifically investigate two purposes, CSRM and ER, to achieve the mission:

- Develop and evaluate coastal storm damage risk reduction measures (CSRM) for Texas residents, industries, and businesses, which are critical to the Nation's economy.

- Increase the net quantity and quality of coastal ecosystem resources by maintaining and restoring coastal Texas ecosystems and fish and wildlife habitat (ER).

The intent of the CSRM and ER structural and nonstructural features is to provide coastal communities with a multiple-lines-of-defense strategy to become more resilient and less vulnerable to coastal hazards. This would help protect the vital coastal ecosystem, the health and safety of residents and visitors in the coastal communities, and the industries within those communities, all of which are critical to the economic wellbeing of the State and the Nation.

Study Need

Along the Texas coast, critical resources vital to the social, economic, and environmental welfare of the nation are at risk. Historically and currently, the Texas coast is vulnerable to tropical storms and hurricanes that take human life, flood homes and businesses, and damage coastal ecosystems. The damages from hurricanes and tropical storms could become more severe as wind speed is projected to increase with higher sea levels and rising ocean temperatures. When tropical disturbances negatively impact the Texas coast, the immediate damage and the continued aftermath affect more than the people who live in these coastal counties. The Texas coast is an important economic area for ports, oil and gas refineries, corporate headquarters, military bases, petrochemical facilities and numerous other enterprises. The shutdown of even a single Texas port can impact State and national economies for a significant period of time as experienced in 2008 when Hurricane Ike came ashore near Houston and Galveston, or Hurricane Harvey impacted the entire coast in 2017.

Texas ranks among the top states in at-risk property value, historic storm damages, and historic number of direct hurricane hits. Over recent history, significant hurricane storm surge events have impacted every region of the Texas coast, including every major bay system. Without additional protection, the risk associated with hurricane storm surge is anticipated to increase over time for multiple reasons including: continued population growth and economic expansion within at-risk coastal areas, forecasted increases in storm intensity due to changes in climate patterns, and forecasted increases in relative sea level.

Shoreline erosion is also a significant threat to the Texas coast. On average, the Texas shoreline is retreating 4 feet per year with some areas experiencing losses greater than 30 feet per year making these rates some of the highest in the Nation. Shoreline erosion threatens coastal habitats, recreational amenities, and residential, transportation, and industrial infrastructure. Absent the protection or restoration of these critical coastal features, the risks associated with coastal erosion are anticipated to increase. As the shoreline retreats, sensitive ecosystems are destroyed and the ability of the natural coastline to defend against hurricane surge is diminished, which will be exacerbated by projected future conditions.

Relative sea level rise, which is a combination of land subsidence and sea level rise, exacerbates the existing vulnerabilities associated with coastal living and is expected to increase the potential for coast flooding, shoreline erosion, saltwater intrusion, and loss of wetland and barrier island habitats in the future. Current forecasts indicate that relative sea levels could rise by 1 to 6 feet over the next 50 years. Depending on the severity and rate of sea level change, there could be significant impacts on communities along the Texas coast. For example, a 4-foot increase in sea level could affect a quarter of interstates and arterials and nearly 75% of port facilities on the Gulf coast (Climate Change Science Program, 2008). Furthermore, relative sea level rise degrades the primary lines of defense and exacerbate storm surge concerns. Without a comprehensive plan to protect, restore and maintain a diverse coastal ecosystem and reduce the risks of storm damage to homes and businesses, the nation's economy and the health and welfare of the coastal communities will continue to be at risk from coastal storms.

Without a comprehensive plan to protect, restore and maintain a diverse coastal ecosystem and reduce the risks of storm damage to homes and businesses, the nation's economy and the health and welfare of the coastal communities will continue to be at risk from coastal storms.

The Corps identified the following problems, which directly reflects the need, within the Study area:

- Coastal communities, including residential populations and the petrochemical industry, are becoming increasingly vulnerable to life safety and economic risks due to coastal storm events;
- Critical infrastructure throughout the region, including hurricane evacuation routes, nationally significant medical centers, government facilities, universities, and schools are becoming more at risk for damage from coastal storm events;
- Existing Hurricane Flood Protection Systems (HFPS), including systems at Port Arthur, Texas City, and Freeport that do not meet current design standards for resiliency and redundancy will be increasingly at risk from storm damages due to relative sea level rise and climate change;
- Degradation of nationally significant migratory waterfowl and fisheries habitats, oyster reefs, and bird rookery islands within the study area is occurring and increasing due to relative sea level rise, habitat fragmentation, and erosion; and
- Water supply shortages are occurring due to increasing conflicts between municipal and industrial water demand and the ecological needs of coastal estuaries and ecosystems.

The Corps defined the following objectives for the Study:

<u>Coastal Storm Risk Management (CSRM) Objectives</u>

- Reduce economic damage from coastal storm surge to business, residents, and infrastructure along coastal Texas;
- Reduce risk to human life from storm surge impacts along coastal Texas;
- Enhance energy security and reduce economic impacts of petrochemical supply-related interruption due to storm surge impacts;
- Reduce risks to critical infrastructure (e.g., medical centers, ship channels, schools, transportation, etc.) from storm surge impact;

- Manage regional sediment, including beneficial use of dredged material from navigation and other operations so it contributes to storm surge attenuation where feasible;
- Increase the resilience of existing hurricane risk reduction systems from sea level rise (SLR) and storm surge impacts; and
- Enhance and restore coastal geomorphic landforms that contribute to storm surge attenuation where feasible.

Ecosystem Restoration (ER) Objectives:

- Restore size and quality of fish and wildlife habitats such as coastal wetlands, bird rookery islands, oyster reefs, and beaches and dunes;
- Improve hydrologic connectivity into sensitive estuarine systems;
- Reduce erosion to barrier islands and shorelines of interior bays, and channels;
- Create, restore, and nourish oyster reefs to benefit coastal and marine resources; and
- Manage regional sediment so it contributes to improving and sustaining diverse fish and wildlife habitat.

DESCRIPTION OF THE STUDY AREA

The enabling legislation for this Study defines the study area as the "coastal areas of the State of Texas from the Sabine River on the east to the Rio Grande River on the west and includes tidal waters, barrier islands, coastal wetlands, rivers and streams, and adjacent areas". This includes all 18 of Texas coastal counties, which for study purposes have been subdivided into four areas: the Upper Texas Coast, the Mid to Upper Texas Coast, the Mid Texas Coast, and the Lower Texas Coast (Figure 1).

Texas has 367 miles of coastline within which 21 major river basins terminate, bringing fresh water into the individual bays and estuaries which dominate the Texas coast. The Texas shoreline itself is characterized by seven barrier islands: Galveston, Follet's, Matagorda, St. Joseph's (San José), Mustang, North and South Padre. Bolivar Peninsula also acts like a barrier island due to its location along the Gulf shoreline. These barrier islands serve as the backbone of the Texas Gulf coast. Another key feature in the study area is the Gulf Intracoastal Waterway (GIWW), which parallels the Texas coast and is protected behind the seven barrier islands.

For the purposes of this Study, the location of potential improvements or other alternative plans were limited to areas within the Texas Coastal Zone Boundary. The coastal zone is defined as "coastal waters and adjacent shorelands extending inland only to the extent necessary to control shorelands where the uses of which have a direct and significant impact on the coastal waters". Gulf and tidal waters, barrier islands, estuaries, coastal wetlands, rivers and streams, and adjacent developed lands are all included.

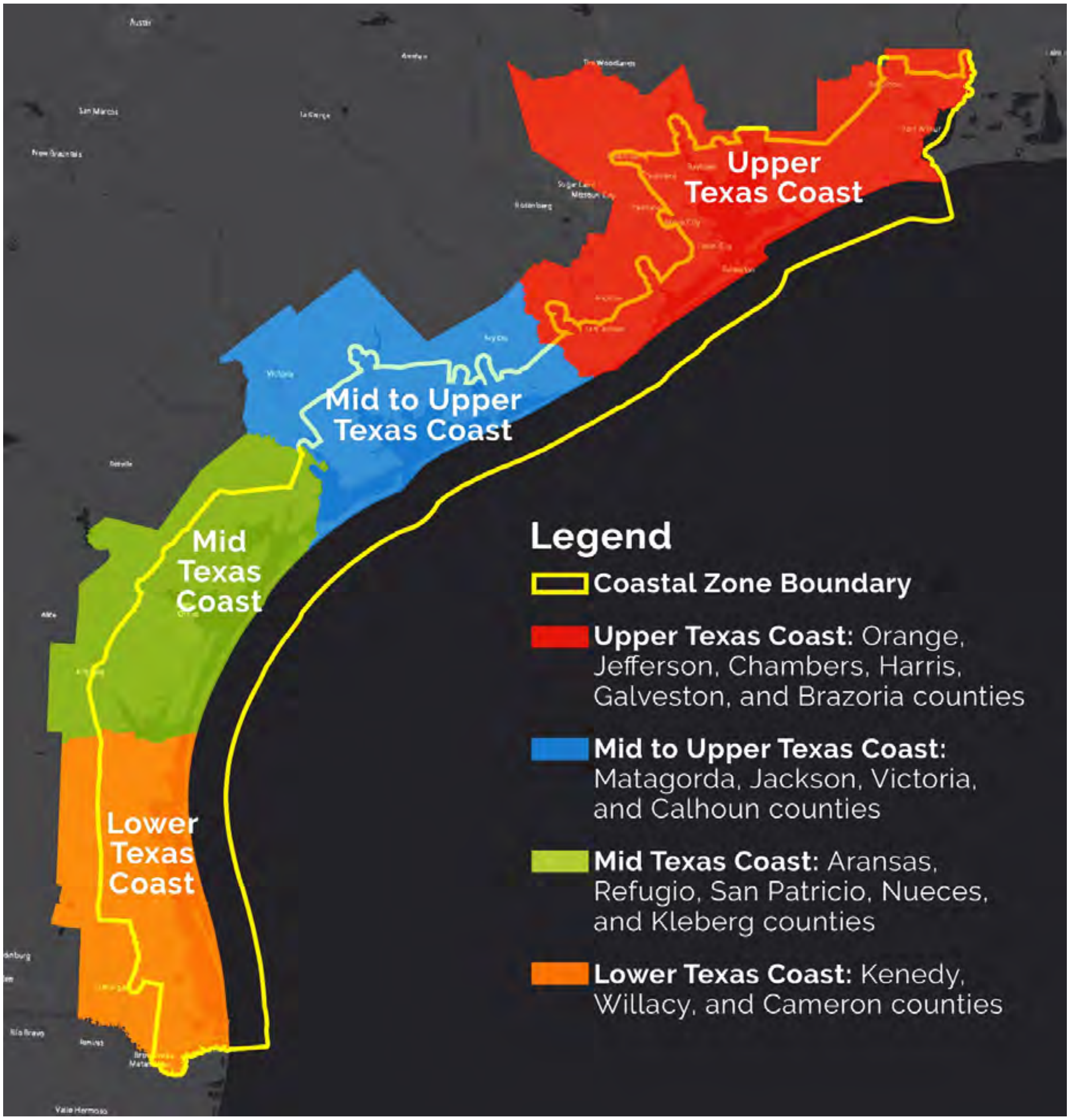

Figure 1. Coastal Texas Study Area

Climate

Within the study area, average temperatures along the Texas Coast vary. Rainfall is the main form of precipitation along the coast and tends to occur most frequently and in greatest amounts in the spring and late summer/early fall. Rainfall rates decrease, and temperatures increase moving south along the coast. Coastal relative humidity averages slightly more than 60% over the year (Nielsen-Gammon, 2016).

During El Niño periods, when Pacific waters are warmer than normal, the Texas coast is typically wetter and cooler than average conditions in the winter. Freshwater inflows to estuaries may increase and bay salinities may decrease during these time periods. When Pacific waters are cooler than average conditions, the La Niña pattern is in place, and winters are warmer and dryer than normal resulting in droughts, reduced freshwater inflows, and increased bay salinities (Tolan, 2007).

Prevailing southerly and southeasterly winds blow warm, humid air from the Gulf onshore much of the year. High temperatures in the 80- and 90-degrees Fahrenheit (°F) occur in the summer along the coast (Nielsen-Gammon, 2016). However, during the winter months rapid drops in bay water levels and temperatures occur many times a year along the Texas coast with the passage of fast-moving cold fronts. These rapid water temperature drops, sometimes to below freezing, have caused massive fish and sea turtle mortality events along the coast (Shaver et al., 2017b). In some instances, dolphins have been affected. Although freezing temperatures were previously reported as relatively uncommon along the Texas coast (Martin and McEachron, 1996), this type of cold water temperature event has become more frequent on the lower and mid-coasts between 2007 and 2015 (Shaver et al., 2017b). Hypothermic or cold-stunning sea turtle events have occurred state-wide with 4,529 green sea turtles recovered between 1980 and 2015 (Shaver et al., 2017b). An additional 203 hypothermic stunned green turtles were found incidentally captured due to power plant water intake entrapment. Overall, 63.9% of the 4,529 hypothermic stunned turtles were found alive, and 92% of those survived rehabilitation and were released. The largest hypothermic stunning events (with more than 450 turtles documented) occurred during the winters of 2009±2010, 2010±2011, 2013±2014, and 2014±2015, with most turtles affected in the Laguna Madre. More recently when temperatures dropped along the mid-coast of Texas on January 13-15, 2021, there were 92 cold stunned green sea turtles recovered from East Matagorda Bay and Upper Laguna Madre.

Although most low pressure systems generate tropical storms or hurricanes during the summer and fall seasons, low pressure systems can also form in the Gulf during the winter causing long periods of steady rains and flooding along the coast. In rare cases, these winter systems can strengthen, generating high winds and water levels substantially above high tide (Contreras 2003). However, the probability of summer – fall hurricane landfalls on the Texas Coast is currently occurring about one in every 6 years between May and November (Roth, 2010). The most active area for hurricanes over the past 160 years is the upper Texas coast with 28 landfalls, followed by the mid Texas coast with 25 landfalls, and the lower Texas coast with 15 landfalls. Although Hurricane Ike in 2008 had a direct landfall in Galveston Bay causing over $29.5 billion worth of damage, there have been more recent storms with greater impact to the Texas coast. Hurricane Harvey, a Category 4 storm, made initial landfall on the Texas mid-coast near Aransas Bay on August 25, 2017, with 130 miles per hour winds and storm surge of up to 10 feet above ground level. Hurricane Harvey continued up the coast causing over $125 billion in damages according to the National Hurricane Center. Hurricane Harvey endured for 117 hours, stalling over the Texas coast for four days, and releasing 60.58 inches or 53.4 million acre-feet of water, the highest record for a single storm event in the continental United States. The majority of that rainfall fell on the Houston metro area, which is the nation's fourth-largest city with 6.6 million residents. The flood damages from this storm affected over 32,000 residents, 300,000 structures, 500,000 cars, 61 drinking water facilities, and 40 wastewater treatment facilities. This storm was also responsible for causing 266 hazardous material spills, 150 million gallons of sewage overflows, and 13 million cubic yard of debris that needed to be removed. Approximately 25% of oil and gas production was shut down in this region, affecting 55 per cent of the nation's production. In addition, Arkema's chemical plant in Crosby (northeast side of Houston), Texas ignited when the storm disabled the refrigeration system required to maintain these chemicals in an inert state. The impact of extinguishing a chemical fire with foam during extreme flooding conditions on the surrounding habitats has not been fully assessed. Climatologist reviewing the precursors to Hurricane Harvey determined that the Gulf's air temperatures were hotter than normal conditions in 2017 allowing it to hold more moisture, but once released, dense sheets of water descended without interruption for a longer period of time. According to the Massachusetts Institute of Technology models, increased warming of the Arctic and temperature contrasts with the rest of the earth slows down the jet stream, and increases the likelihood for greater numbers and strengths of hurricanes along the Texas coast in the future (https://www.thebalance.com/hurricane-harvey-facts-damage-costs-4150087).

Relative Sea Level Rise

Relative sea level rise (RSLR) and erosion threaten coastal ecosystems. Sea level has risen more than 0.17 inch per year (inch/year) along the upper and middle Texas coast from 1957 to 2011 (NOAA, 2016d). The highest rate of RSLR, 0.26 inch/year, was measured at the Galveston Pleasure Pier (tide gauge 8771510) and the lowest was at Port Mansfield at 0.08 inch/year (tide gauge 8778490). Higher rates of RSLR along the upper coast are generally attributed to higher rates of subsidence, ranging up to 10 feet from 1906 to 2000, with the highest rates occurring in the Houston-Galveston area. Through increased groundwater regulation, reduced rates of groundwater withdrawal have considerably reduced the rate of subsidence in the upper coast region, but have not restored the former elevations of wetland and land surrounding Galveston Bay.

As sea levels rise on the upper coast of Texas, the shorelines along Galveston Bay and Gulf are more exposed to erosion from wind and wave forces. Coastal erosion contributes to these shorelines retreating an average of 4 feet per year, with some areas experiencing losses greater than 30 feet per year. Disrupted sediment supply, coastal development, and relative sea level rise (RSLR) also amplify shoreline retreat (BEG 2020). Sediments supplies are notably deficient along the Texas coast, mainly due to ship channel dredging, damned upstream rivers, and the presence of jetties. These factors have collectively contributed to the increasing loss of coastal wetlands converted to open water habitat, which has reduced the amount of available foraging, nesting and breeding habitat for many migratory birds and threatened and endangered species.

Fish and Wildlife Habitats

General Overview

The study area encompasses the Texas Gulf coast from the mouth of the Sabine River to the mouth of the Rio Grande and includes the Gulf of Mexico (Gulf) and open bay bottom waters, seagrass beds, tidal mud flats, oyster reef complexes, barrier islands, beach and dune habitat, coastal wetlands, rivers and streams, and adjacent coastal prairie depressional wetlands. These habitats are characteristic of those found within the Gulf Prairie and Marsh ecological region along the coast of Texas (Gould et al., 1960). The Gulf Intracoastal Waterway (GIWW), a man-made navigable waterway, bisects these habitats but also provides hydrological connectivity between the upper coast and lower coast. The study area has been separated into four regions to further describe the geographic differences of these habitats found along the coast (Figure 1). Important trust resources are found within all four regions, which include multiple National Wildlife Refuges (NWR), Wildlife Management Areas (WMAs), state protected coastal preserves, and non-profit land trusts (Figure 2; Table 1). Only the NWRs directly or indirectly affected by the Coastal Study's proposed projects will be discussed in detail in the FWCAR.

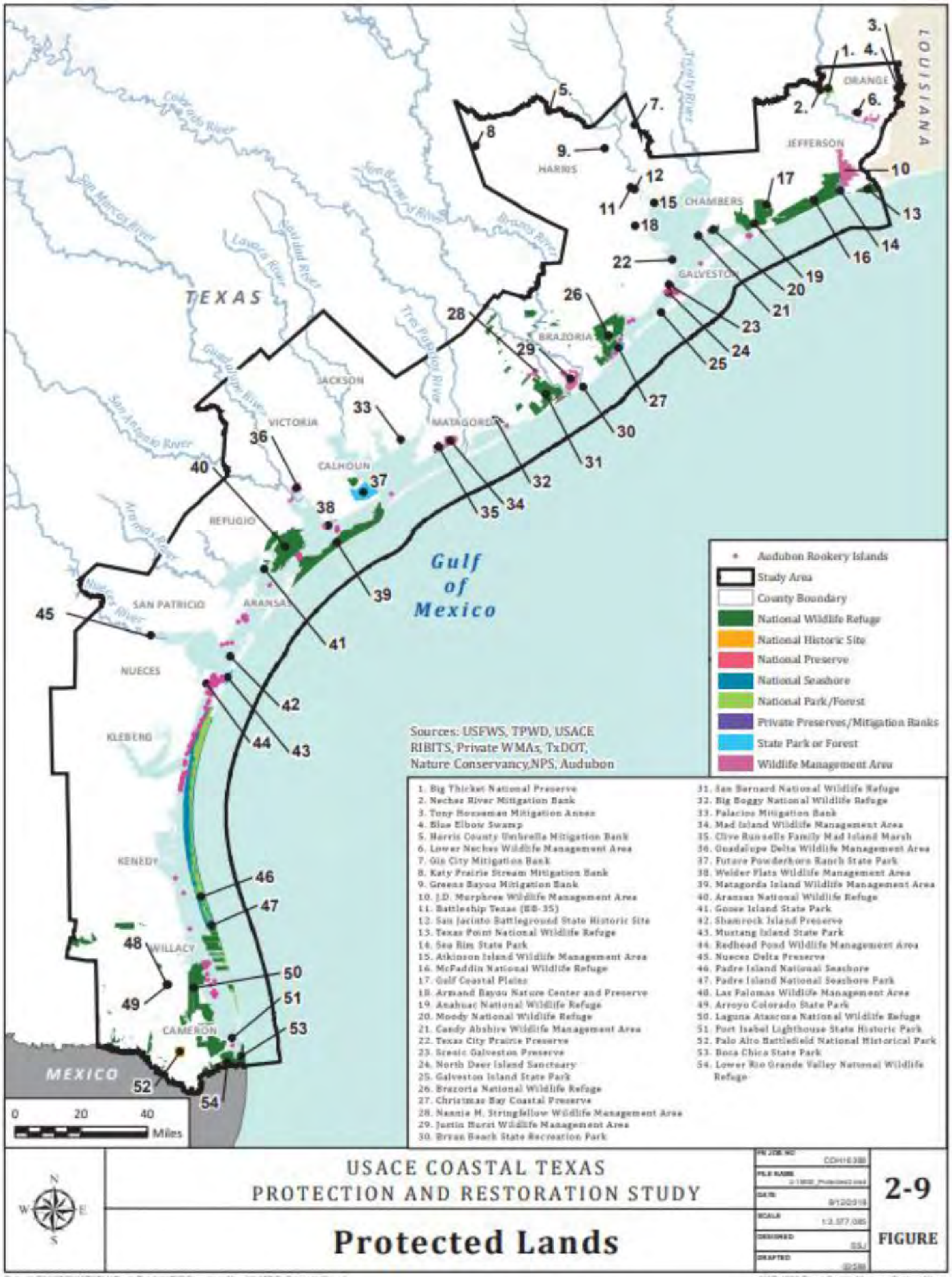

Figure 2. Protected Lands within the Coastal Texas Study Area.

*Table 1. Protected Land within the Coastal Texas Study Area**

Land Owner Protected Land	Breakwaters (acres)	Bird Island Restoration (acres)	Wetland Restoration (acres)	Oyster Reef Creation (acres)	Dune/ Beach Restoration (acres)
USFWS Anahuac NWR	29	0	34	0	212
USFWS Brazoria NWR	106	0	308	2	0
USFWS—San Bernard NWR	64	0	130	0	0
USFWS—Big Boggy NWR	25	23	8	0	0
USFWS—McFaddin NWR	0	0	0	0	19
NPS Padre Island National Seashore	0	0	0	0	1,333
TPWD—Justin Hurst WMA	10	0	13	0	0
TPWD—Galveston Island State Park	0	0	0	0	64
TNC—Muddy Marsh Bird Sanctuary	4	0	2	0	0
TNC—McFarlane Marsh	0	0	0	0	0
HAS—Bolivar Flats Shorebird Sanctuary	0	0	0	0	**78

** Acreage is based on information received from Corps of Engineers prior to January 29, 2021.*
***Bolivar Flats will require 78 acres of mitigation for impacts from Bolivar Roads Levee Tie In.*

Upper Coast Region

The upper coast region of the study area occurs in Chambers, Galveston, Harris, and Brazoria counties, and includes the Galveston Bay complex (Trinity Bay, East Bay, West Bay, and upper and lower Galveston Bay, Christmas Bay, Bastrop Bay, Chocolate Bay, and Drum Bay). The study area also receives freshwater inflows from several large watersheds (Trinity, San Jacinto, Brazos Rivers, and Chocolate Bayou). The Galveston Bay area is recognized as nationally significant by Federal designation of the Galveston Bay National Estuary Program. The broad range of salinities and flat topography of this upper coast region support a wide variety of habitats, including beach and dune habitats; tidal and freshwater coastal wetlands; shallow bay waters, which support seagrass beds; oyster reef complexes; tidal mud flats; coastal prairies; and forested riparian corridors along streams and bayous. Submerged and intertidal reefs in Galveston Bay complex, that previously suffered severe storm damages from Hurricanes Ike and Harvey, are currently being restored through extensive shell recovery efforts by Texas Parks and Wildlife Department (TPWD) and Galveston Bay Foundation (GBR). The barrier peninsula (Bolivar) and island (Galveston) separate Galveston Bay from the Gulf of Mexico. The remainder of the upper coast is protected by Follet's Island, which separates Christmas Bay from the Gulf of Mexico. Three major deep water navigation channels in this region include the Sabine-Neches Waterway, Houston Ship Channel, and the Freeport Harbor Channel. However, the Study action area only includes the Houston Ship Channel, Galveston Bay complex, and the GIWW.

Upper Coast Region Protected Lands

Important trust resources on the upper coast include multiple National Wildlife Refuges (NWR), Wildlife Management Areas (WMAs), state protected coastal preserves, and non-profit land trusts: Texas Chenier Plains NWR Complex (McFaddin NWR, Anahuac NWR, and Moody NWR), Texas Mid-Coast NWR Complex (Brazoria NWR), Houston Audubon Society (HAS) Sanctuaries (Bolivar Flats Shorebird Sanctuary, Horseshoe Marsh Bird Sanctuary, Boy Scout Woods Bird Sanctuary, and High Island Bird Sanctuaries), TPWD's Christmas Bay Coastal Preserve, Galveston Island State Park, and Justin Hurst WMA. Many other protected lands occur on the upper coast but are further discussed in the EIS.

Anahuac National Wildlife Refuge

The Anahuac NWR, in the Texas Chenier Plains Refuge Complex was established in 1963, and conserves and manages 38,948.15-acres of fresh, intermediate, brackish and tidal wetland in Chambers County for migrating, wintering, and breeding waterfowl, shorebirds, and waterbirds. It also provides strategic and crucial resting areas for the Neotropical migratory songbirds on their route across the Gulf of Mexico. Additional lands have been recently donated or purchased within the approved refuge acquisition boundaries along both sides of the GIWW, west of High Island that are within the footprint of the Study's proposed breakwaters and wetland creation projects (ER measure). Anahuac NWR also owns undeveloped beach habitat along State Highway (SH) 87, west of High Island, in Galveston County that are located within the footprint of the proposed beach and dune restoration measures of the Galveston Bay Barrier System (CSRM measure). Any work planned within refuge lands requires prior compatibility coordination with the Texas Chenier Plains Refuge Complex manager. Contact information for this refuge is: Texas Chenier Plain Refuge Complex, P.O. BOX 278, Anahuac, Texas 77514; Phone Number: 409-267-3337; Fax Number: 409-267-4314.

McFaddin National Wildlife Refuge

This 67,057.38-acre NWR was established in 1980 and contains the largest tracts of coastal freshwater wetlands remaining in Texas. The 5,400-acre White Marsh tract was added in 2000. Salt water intrusion following the GIWW construction in the 1940's, and subsequent erosion and subsidence in the 1970's has converted much of the former palustrine emergent wetlands into brackish wetlands. However, large freshwater areas still exist within interior areas west of Clam Lake. This refuge also contains important beach and dune habitat, back-dune wetlands (coastal dune swales), coastal prairie, and freshwater wetlands that are important resources for supporting spring neotropic migrant songbird and waterbirds during their migration stop across the Gulf. However, the degradation of State Highway 87 from previous hurricanes, RSLR, and coastal erosion have contributed to loss of beach and dune protection for the interior wetland habitat within the McFaddin NWR. Currently the NWR and GLO are in process of restoring beach and dunes within the refuge on Bolivar Peninsula. Only a small portion of the proposed beach and dune restoration measures of the Coastal Texas Galveston Bay Barrier System (CSRM measure) are planned to tie into the existing dune restoration project on Bolivar Peninsula. Any planned work within refuge lands requires prior compatibility coordination with the McFaddin NWR manager. Contact information for this refuge is McFaddin NWR, P.O. Box 358, Sabine Pass, Texas 77655; Phone Number: 409-971-2909; Fax Number: 409-971-2104.

Brazoria National Wildlife Refuge

Established in 1966, this 44,413-acre refuge serves as an important wintering grounds for ducks and geese migrating south along the Central Flyway. The diverse habitats of this refuge are comprised of freshwater sloughs, brackish wetlands, coastal prairies, and woody thickets. More than 300 species of resident or migratory birds benefit from the current fire management and wetland restoration projects underway within the NWR. The Brazoria NWR and its companion refuges, San Bernard and Big Boggy, were designated an Internationally Significant Shorebird Site by the Western Hemisphere Shorebird Reserve Network. The Coastal Texas proposed breakwaters and wetland creation projects planned along both sides of the GIWW (ER measure) are within the footprint of the Brazoria NWR and directly affect wetlands associated with Big Slough and Oyster Lake. Any planned work within refuge lands requires prior compatibility coordination with the Texas Mid-Coast Refuge Complex manager. Contact information for this refuge is: Texas Mid-Coast Refuge Complex, 2547 CR 316, Brazoria, TX 77422; Phone number: 979-964-4011; Fax Number: 979-964-4021.

Mid to Upper Coast Region

Matagorda, Jackson, Victoria, and Calhoun counties occur in the mid to upper Texas coast and include several bay systems (East and West Matagorda Bay, Lavaca Bay, Espiritu Santo Bay, San Antonio Bay, and Mesquite Bay). Primary watersheds feeding these bays include the Caney Creek, and San Bernard, Colorado, Lavaca, and Guadalupe Rivers, which form the boundaries of this region. West Matagorda Bay is the largest of the bay systems in the mid to upper coast region and includes numerous minor estuaries. Important deep water navigation channels in this region include the Matagorda Ship Channel and the Victoria Barge Canal. Pass Cavallo separates Matagorda Peninsula from Matagorda Island but is not the main deep water navigation channel between the Gulf and West Matagorda Bay.

Notable oyster restoration has occurred on existing or historic relic reefs in the mid to upper coast including Half Moon Reef, Mad Island Reef, Sammy's Reef, and Shell Island Reef. Additional oyster shell recovery efforts have been managed by TPWD in Lavaca Bay.

Like many areas in the upper coast, the broad range of salinities and flat topography allows the region to support a wide spectrum of habitats, including barrier islands with beach and dune habitats, tidal and freshwater coastal wetlands; shallow bay waters that support seagrass beds, tidal flats, and reef complexes; coastal prairie with small wetland depressions; and forested riparian corridors. Extensive seagrass habitat occurs in East and West Matagorda Bays immediately adjacent to Matagorda Peninsula and Matagorda Island, respectively, and also in Espiritu Santo Bay, near Pass Cavallo. Mangroves also intersperse *Spartina* wetlands surrounding Espiritu Santo Bay.

Mid to Upper Coast Region Protected Lands

There are multiple federal, state, and non-profit organization land trust resources found within the study area including: the Texas Mid-Coast Refuge Complex (San Bernard NWR and Big Boggy NWR), Aransas/Matagorda Island Refuge Complex adjacent to Powderhorn Lake, Mad Island Preserve (The Nature Conservancy (TNC)), TPWD's Mad Island WMA, Matagorda Island WMA/State Park, Matagorda Peninsula Coastal Preserve, and the Powderhorn Ranch WMA/State Park.

San Bernard National Wildlife Refuge

Established in 1966, this refuge is home to one of the largest tracts of old growth forest in Texas. The Dance Bayou tract (1,271 acres) is comprised of bottomland hardwoods, riparian wetlands, and fluvial woodlands. San Bernard NWR was designated as an "Internationally Significant Shorebird Site" by the Western Hemisphere Shorebird Reserve Network due to its importance to waterfowl and migratory birds. This 63,601.92 acre refuge also includes beach habitat, fresh and brackish wetlands, tidal bayous, freshwater ponds, Columbia Bottomland Hardwood forests, and native coastal prairie habitats. Due to the significant loss of wetlands within the refuge, wetland restoration and management remains a top priority. The Coastal Texas proposed breakwaters and wetland creation projects planned along both sides of the GIWW (ER measure) are within the San Bernard NWR property and directly affect wetlands associated Cow Trap Lake, Cedar Lake, and refuge lands adjacent to the GIWW. The San Bernard NWR is part of the Texas Mid-Coast Refuge Complex. Any planned work within refuge lands requires prior compatibility coordination with the Texas Mid-Coast Refuge Complex manager. Contact information for this refuge is: Texas Mid-Coast Refuge Complex, 2547 CR 316, Brazoria, TX 77422; Phone number: 979-964-4011; Fax Number: 979-964-4021.

Big Boggy National Wildlife Refuge

Established in 1983, this 4,526-acre refuge provides protection for coastal wetlands and one of the most prominent bird rookeries at Dressing Point. It also conserves key coastal wetlands for

Neotropical migratory birds and shorebirds in spring and fall, as well as for wintering waterfowl and year-round wildlife. The Coastal Texas proposed breakwaters and wetland restoration planned along the GIWW adjacent to East Matagorda Bay (ER measure) are within the Big Boggy NWR property. The Big Boggy NWR is part of the Texas Mid-Coast Refuge Complex. Any planned work within refuge lands requires prior compatibility coordination with the Texas Mid-Coast Refuge Complex manager. Contact information for this refuge is: Texas Mid-Coast Refuge Complex, 2547 CR 316, Brazoria, TX 77422; Phone number: 979-964-4011; Fax Number: 979-964-4021.

Aransas/Matagorda Island National Wildlife Refuge Complex

Although the Coastal Texas's proposed breakwaters and wetland restoration project is planned to enhance TPWD's Powderhorn Ranch (ER measure), these restoration projects are not directly within the north unit of Aransas NWR. However, as this refuge is located within the Mid to Upper Coast Region and is located directly adjacent to Powderhorn Lake, federally listed species utilizing this area may be disturbed or affect by construction activities. The majority of the Aransas/Matagorda Island NWR Complex is located further south and adjacent to the GIWW, San Antonio Bay, Mesquite Bay, Aransas Bay, and includes portions of Matagorda Island in the Coastal Texas' Mid Coast region. Established in 1937, this 116,885.19-acre refuge serves as an important wintering grounds for the federally listed whooping crane (*Grus americana*), and multiple species of ducks and geese migrating south along the Central Flyway. The diverse habitats of this refuge are comprised of freshwater sloughs and ponds, seagrass beds, tidal and brackish wetlands, coastal prairies, and woody thickets. Contact information for this refuge is: Aransas NWR, 1 Wildlife Circle, Austwell, Texas 77950; Phone Number: 361-286-3559; Fax Number: 361-286-3722.

Mid Coast Region

The Mid Coast Region of the Study area occurs within Aransas, Refugio, San Patricio, Nueces, and Kleberg counties, and includes several bay systems (portions of San Antonio Bay, Aransas Bay, Copano Bay, Redfish Bay, Corpus Christi Bay, Nueces Bay, and the Upper Laguna Madre, including Baffin Bay). Primary watersheds feeding these bays include the Mission River, Aransas River, Nueces River, and Los Olmos Creek which forms the southern boundary between the mid coast region and the lower coast). Important deep water navigation channels in this region include the Corpus Christi Ship Channel and the La Quinta Channel.

This region has many barrier islands that protect wetlands, bird rookery islands, and seagrass habitat including Matagorda Island, Mustang Island, San Jośe Island, and North Padre Island. The Nueces River Delta is a unique resource found in the area that has many interest groups working to restore and conserve it and its ecological functions (Lloyd, 2016). Extensive seagrasses occur throughout the area, and unique remnant beach rock, or fossilized serpulid worm tube reefs occur within Baffin Bay. The Upper Laguna Madre is also a defining feature of the Texas mid coast as it is the northernmost portions of a hypersaline lagoon, described further below (Tunnell and Judd, 2002).

Mid Coast Region Protected Lands

Trust resources found within the region are Aransas/Matagorda Island National Wildlife Refuge Complex, Redfish Bay Scientific Area, and TPWD' Dagger Island Bird Rookery Island, Padre Island National Seashore (PAIS) and Red Head Pond WMA. PAIS is owned and managed by the National Parks Service (NPS) and is the longest stretch of undeveloped barrier island in the world (NPS, 2016). The Study proposes to create wetlands, construct breakwater protection for existing wetland, and enhance existing bird rookery islands adjacent to the Dagger Island Bird Rookery Island (ER measures).

Lower Coast Region

The southernmost portions of the Texas coast occur within Kennedy, Willacy, and Cameron counties and are dominated by the Lower Laguna Madre, which is one of five hypersaline lagoons in the world. High overall temperatures and evaporation rates, combined with low rainfall and freshwater input, contribute to these higher salinity levels (Tunnel and Judd, 2002). Average salinity along the Laguna Madre is 36 parts per thousand (ppt) (EPA, 1999). Main watersheds that flow into the Lower Laguna Madre include Arroyo Colorado and the Rio Grande. The Laguna Madre is shallow estuary, averaging approximately 3.3 feet deep, and, including the South Bay and the Bahia Grande complex, contains approximately 180,000 acres of tidal mud and sand flats (Tunnel and Judd, 2002). The Port Mansfield Channel provides a Gulf outlet between the Lower Laguna Madre and the Gulf of Mexico that separates North and South Padre Islands. However, the main outlet into the Gulf for the southern reach of the Lower Laguna Madre is Brazos Santiago Pass, which provides deep water access to the Brazos Island Harbor and Brownsville navigation channels.

Abundant wind tidal flats in this region provide important habitat for a variety of coastal wildlife from migratory waterfowl, shorebirds (like the Federally listed piping plover (*Charadrius melodus)* and rufa red knot (*Calidris canutus rufa*), wading birds, and other estuarine-dependent species like shrimp and various finfish (White et al., 1986). These wind tidal flats are usually barren except for large areas colonized by blue-green algae mats called algal flats. The unique processes that result in algal flat formations only exist in a few locations worldwide, including the Persian Sea, Red Sea, and Eastern Mediterranean Sea (Morton and Holmes, 2009).

Lower Coast Region Protected Lands

Protected lands for trust resources in the Lower Coast region include: Padre Island National Seashore (PAIS), and the South Texas Refuge Complex (Laguna Atascosa NWR and the Lower Rio Grande NWR). The Study proposes beach and dune habitat restoration within PAIS on the north side of the Port Mansfield Channel, in addition to future enhancement of the recently restored Port Mansfield Bird Islands. The Laguna Atascosa NWR is located on South Padre Island, side of the Port Mansfield Channel, which separates the Laguna Madre from the Gulf of Mexico. Although this refuge's lands are not specifically within the footprint of the proposed ER measures for this region, the federally listed species that utilize this area may be indirectly affected by disturbances from dredging activities in the Port Mansfield Channel and by beach and dune construction on PAIS lands.

Ecologically Significant Habitats in the Study Area

Several habitat types have been identified as ecologically significant along the Texas coast. These habitats include: estuarine emergent wetlands, palustrine emergent wetlands, beaches and dunes, bird rookery islands, open bay bottoms/inland open water, submerged aquatic vegetation (seagrass), and oyster reefs. Although coastal prairies, bottomland hardwood forests and Tamaulipan thornscrub habitat that the Service believes is ecologically important biotic communities found within the study area, these habitats were described in the 2017 PAL, and are only incorporated by reference in the FWCAR. Due to the scope of the Study, these habitats were not considered for restoration in the Study and are therefore not described further.

Estuarine Wetlands

Estuarine wetlands (tidal or saline) are found either in dense continuous stands or in fringing narrow stands along bay shorelines and directly inland of beaches, dunes, and barrier islands within the study area. Estuarine plant communities vary geographically between the upper coast in the Texas Chenier Plain to the lower coast in the Coastal Bend and Laguna Madre based on the type of hydric soil present, amount and duration of tidal fluctuations, proximity to Gulf waters, and the amount of rainfall or freshwater inflows received in that region of the coast. These estuarine wetland plant communities have flexible stems, which slows tidal water exchanges, allowing sediments to settle out, and ultimately provides more substrate for plants to grow upward as sea level rises. The stem density and flexibility of these estuarine wetland plant communities can also attenuate wind and waves to provide coastal protection from storm surge (Koch et al., 2009). Estuarine wetlands along the Texas coast also serve as important breeding, feeding, and nesting habitat for a diverse range of fish and wildlife species including migratory birds and threatened and endangered species.

Estuarine wetlands (tidal or saline), frequently flooded by tidal inundations, are able to tolerate a wide range of salinity gradients between 5 to 30 parts per thousand (ppt), with an average of 18 ppt. These tidal wetland plant communities are typically dominated by smooth cordgrass/oystergrass (*Spartina alterniflora*) at lower elevations, and surrounded by higher elevation plants, including marshhay cordgrass (*Spartina patens*), seashore saltgrass (*Distichlis spicata*), black needlerush (*Juncus romerianus*), saline marsh aster (*Aster tenuifolius*), and Gulf cordgrass (*Spartina spartinae*). Tidal wetland communities located at higher elevations or on less vegetated tidal mud flats are more exposed to evapotranspiration processes, and are often dominated by more salt tolerant plants such as glasswort (*Salicornia spp.*) and sea oxeye daisy (*Borrichia frutescens*). Within Espiritu Santo Bay, Mesquite Bay and South of the Coastal Bend, black mangrove (*Avicennia germinans*) is often found interspersed with smooth cordgrass in these frequently flooded tidal wetland plant communities.

Estuarine wetlands, located further inland and less frequently flooded with tidal inundations, and receive more freshwater influence are characterized as brackish wetlands. Brackish wetlands salinities typically range between 5.0 to 18.0 ppt, with an average salinity of 8.0 ppt. Brackish wetland species often include saltmarsh bulrush (*Scirpus robustus*), seashore saltgrass and marshhay cordgrass. Brackish wetlands have the highest rates of habitat loss on the upper Texas coast due to subsidence, loss of organic materials, and salt water intrusion from development of canals and navigable waterways.

Intermediate wetlands is located further from the Gulf, between brackish and freshwater (non-tidal) wetland with year-round lower salinities ranging from 3 to 4 ppt. However, hydrologic changes to intermediate wetland communities may shift to either fresh or brackish if salinities rise or fall due to weather related events such as droughts, excessive rainfall, or influxes of sea water during hurricanes. Intermediate wetlands are dominated by marshhay cordgrass, with the additional diversity from seashore paspalum (*Paspalum vaginatum*), Olney bulrush (*S. americanus*), California bulrush/giant bulrush (*S. californicus*), common reedgrass/Roseau cane (*Phragmites australis*), bulltongue (*Sagittari lancifolia*), and sand spikerush (*Eleocharis montevidensis*). Submerged aquatics such as pondweeds (*Potamogeton spp.*) and southern water nymph (*Najas guadalupensis*) are also found within intermediate wetland communities.

The ecological function of all estuarine wetlands (tidal, brackish and intermediate wetland) within the study area have been significantly altered and degraded as a result of a long history of land development from oil and gas related groundwater withdraw and construction of navigation channels. The GIWW, in particular, divided the once-contiguous freshwater and intermediate wetlands in the study area and severed the natural freshwater inflows that maintained these diverse plant communities. The effects of this disruption has created artificial barriers between wetland plant communities and freshwater inflows, reduced the available supply of sediment, and reduced their ability to trap sediments needed for maintaining target elevations, as an adaptation to RSLR. The GIWW has also introduced tidal influences into historically non-tidal or intermediate wetlands (salt water intrusion), which has resulted in decreased plant productivity, plant mortality, peat collapse, loss of organic soils, and conversion of diverse plant communities to open water habitat. Changes to or loss of these plant communities ultimately affects the spatial distribution of fish and wildlife species including trust species (threatened and endangered species) that depend on these habitats. An additional loss of these plant communities has occurred due to barge traffic causing wave induced erosion of the wetlands along the shoreline. Cumulatively these effects have contributed to the current degradation of the estuarine wetlands within the action area. Continued altered hydrologic regimes, lack of sediment input, subsidence and salt water intrusion will continue the trend of wetland conversion to less productive, saline habitats or open water. Under the current conditions, rising sea levels will exacerbate the existing decline in estuarine wetlands over time. Although many Texas NWRs were established to conserve and mange wetland habitats specifically for the benefit of migratory waterfowl, additional protection and preservation measures are needed to reestablish hydrologic connectivity and reduce erosion of existing estuarine habitats along the coast.

Palustrine Wetlands

Palustrine emergent wetlands are heterogeneous, with local species composition governed by frequency and duration of flooding, micro-topography, substrate, current flow and salinity. This type of freshwater wetland is typically dominated by maidencane, duck potato, spikerushes, pennywort, elephant-ear and alligatorweed. Other common plants are California bulrush, giant cutgrass, beggarticks and cattail. Palustrine wetlands are often support very diverse assemblage of species of grasses and broad-leaved annuals, waxing and waning throughout the growing season. Freshwater wetlands salinity rarely exceeds 2 ppt, with a year-round range of approximately 0.5-1.0 parts per thousand (ppt).

According to the Galveston Bay Estuary Program's (GBEP) Galveston Bay Status and Trends Report and other studies the majority of wetland losses in the Lower Galveston Bay area during the last 50 years can be attributed to the loss of palustrine or freshwater wetlands (White et al., 1993; Jacob and Lopez, 2005; Lester and Gonzalez, 2008). White et al. (1993) estimated that of the 35,120 acres of emergent wetlands lost during the 1950 to 1989 time period, 73 percent (25,640 acres) were freshwater wetlands. This equates to a loss of nearly 641 acres per year. White et al. (2004) also found that freshwater wetlands decreased by 1,082 acres on Galveston and Follet's Island and Bolivar Peninsula between the 1950s and 2002.

GPEP's Galveston Bay Status and Trends Report also evaluated the NOAA C-CAP land cover data for the five counties surrounding Galveston Bay and within the study area (Brazoria, Chambers, Galveston, Harris, and Liberty), which showed net losses of freshwater wetlands totaled 25,787 acres, representing a loss of 1,826 acres per year. Of that amount 15,823 acres of freshwater wetlands were lost to development. The other losses were due to the conversion of freshwater wetlands to non-wetland classifications. Some losses were due to changes in hydrology or saltwater intrusion, which converted the freshwater wetland to upland vegetation suitable for grazing.

Work by Jacob and Lopez (2005) estimated that the Lower Galveston Bay watershed lost approximately 3% of its freshwater wetlands to development between 1992 and 2002 (9,052 acres of freshwater emergent, forested, and scrub/shrub classes). The NOAA C-CAP study (1996-2005) also estimated an annual rate of loss of 2,599 acres of freshwater wetlands or 0.3% per year (NOAA, 2006).

Freshwater wetlands support extremely high densities of migratory waterfowl and other wildlife. Continued loss without restoration or protection of this declining habitat will have devastating impacts to migratory waterfowl and other wildlife species in the Galveston Bay ecosystem.

<u>Beaches and Dunes</u>

Beaches are a transition habitat on barrier islands or peninsulas between the land and sea. Benthic aquatic organisms (polychaetes and mollusks) may thrive in the lower portion of the beach (forebeach) where sediments are frequently inundated by Gulf waters. However, in areas at and just above the high tide zone (supratidal zone), conditions are more difficult for benthic aquatic or terrestrial species to survive. Although dry sand above the high tide zone in front of the dunes (foredunes) is easy to heat and cool, resulting in strong shifts in temperature in this area of the beach. The foredunes also experiences strong shifts in salinity, from highly saline conditions during dry weather caused by salt spray being concentrated by evaporation on the sand, to being diluted of salt during intense rains. As a consequence, very few animals or plants can live in these higher elevated zones in front of the dunes.

In the wrack zone (at base of supratidal zone), there a small oasis in the otherwise dry and barren sand. Here, the debris (e.g. seashells, animal remains, decomposing seaweed and sea grasses, and other materials) left by the high tide forms a narrow band of rich organic content, which provides a reservoir of water and food for the animals found within this zone. Cryptic species in this zone only emerge from the sand at night or when the tide is high, which includes: polychaete worms and arthropods such as crabs, sand hoppers/beach fleas, beetles, spiders, and flies.

Because of the abundance of polychaetes and arthropods in the wrack zone, this area of the beach is prime foraging habitat for shorebirds and threatened and endangered species (piping plover and rufa red knot). The most abundant species observed in the wrack zone are typically American avocet (*Recurvirostra americana*), western sandpiper (*Calidris mauri*), long-billed and short-billed dowitchers (*Limnodromus scolopaceus* and *L. griseus*, respectively), semipalmated sandpiper (*C. pusilla*), pectoral sandpiper (*C. melanotos*), black-bellied plover (*Pluvialis squatarola*), dunlin (*C. alpine*), sanderling (*C. alba*), willet (*Catoptrophorus semipalmatus*), semi-palmated plover (*Charadrius semipalmatus*), least sandpiper (*C. minutilla*), and snowy plover (*Charadrius alexandrines*). Common nesting shorebird species include the willet, killdeer (*Charadrius vociferous*) and black-necked stilt (*Himantopus mexicanus*). Colonies of nesting birds also include least terns (*Sterna antillarum*) and black skimmers (*Rynchops niger*) on beaches and wash-over terraces.

The back-beach and dunes are more productive habitat than the forebeach area, and contains a mosaic of salt-tolerant plants, which are adapted to shifting sands, high winds, and rising waters. These salt-tolerant plants help form dunes by trapping wind-blown sand, while their roots help stabilize the sand and protect the dune from erosion. Species found growing here include seapurslane (*Sesuvium portulacastrum*), saltmeadow cordgrass/ marshhay cordgrass, (*Spartina patens*), bitter panicum (*Panicum amarum*), Virginia dropseed (*Sporobolus virginicus*), white morninglory (*Ipomoea stolonifera*), camphor daisy (*Rayjacksonia phyllocephala*) goat-foot morninglory (*I. pes-caprae*), glassworts (*Salicornia spp*.), sea-lavender (*Limonium carolinianum*), and sea-ox-eye daisy (*Borrichia frutescens*).

Texas beaches change shape regularly and move landward (retreat) or seaward (advance) in response to wind, waves, currents, the short and long-term relative sea level rise, and the supply of sand. The availability of sediment in many areas along the coast is hampered by natural and anthropogenic means such as increased frequency of hurricane leveling events, recurring dredging activities, and the presence of jetties, dykes, and groins, which change the spatial distribution of sediments deposited downstream of these structures. Most sediments are either permanently removed from the system or transported far enough offshore that smaller waves are unable to carry the material back to the beach resulting in sand-starved beaches.

While short-term weather related changes from hurricanes and unseasonably high tides can be variable, the long-term changes due to sea level rise, combined with lack of coarse-grained sand supply, and annual erosion have contributed to increased shoreline retreat of the beach and dune systems along the Texas coast. Shoreline retreat has been observed to average three to four feet per year since the 1930s in many areas along the coast. These natural and anthropogenic changes have degraded, lowered or completely removed beach and dune systems, which has negatively impacted the available habitat for wildlife species. These changes have also resulted in compromised dune structures so they can no longer deter Gulf waters from directly flowing into historically freshwater wetland areas, thereby resulting in conversion to tidal wetlands or to open water habitat, and potentially displacing fish and wildlife species from these habitats. The reduction and loss of shoreline habitat can also be directly correlated with the status of seven Federally-threatened and endangered species including the piping plover, red knot, and nesting sea turtles. Continuing loss of critical habitat for piping along some portions of the coast may result in changes to piping plover spatial distributions and eventually affect the recovery plan for this species.

Although much of the Texas coast has become severely eroded, beach nourishment projects are being conducted in critical areas to protect the forebeach, back-dune wetlands (dune swales), and create additional nesting, resting, and foraging opportunities for listed and non-listed migratory shorebirds, sea turtles, and fish species of commercial and recreational importance. Beach and dune restoration projects are also an effective way of protecting coastal communities without constructing hardened structures that could alter the sediment supply and hydrology of an area.

Bird Rookery Islands

Since 1973, the Service along with other Federal, State, local non-governmental agencies and private citizens have monitored several hundred coastal colonial waterbird sites along the Texas coast. Most rookery islands are small – only a few acres or less in size – and while some naturally formed most were created through the placement of dredged material or fragmentation of land features during construction or maintenance of navigation channels, particularly the GIWW.

In general, spoil islands provide suitable bare ground nesting habitat and subsequent vegetation succession can create shrub and tree habitat for other colonial nesters. Rookery islands are isolated from the mainland and are too small to sustain predator populations, thereby providing optimal foraging, roosting, breeding, nesting, and rearing habitats for migratory birds and a wide variety of colonial waterbirds and coastal shorebirds, including herons, terns, pelicans, egrets and cormorants. Colonial waterbirds rely on open water, mud flats, estuarine wetlands and seagrass for foraging, which is abundant near the islands. Rookery islands provide areas for birdwatching, ecotourism, and recreational fishing. Nesting pairs on rookery islands can range from a few pairs to thousands of birds depending on the island size.

In addition to providing quality bird habitat, the islands have been noted as providing suitable habitat for establishment and growth of seagrass meadows through modification of tides and currents and the increase in nutrients from bird defecation.

The importance of coastal rookeries to bay ecosystems is well documented in terms of enhancing fisheries production, recreational bird watching opportunities, and photography. Rookery islands on the back side of the barrier islands and adjacent bays also provide natural wave attenuation and erosion protection for bay shorelines and wetlands along navigation channels.

Audubon Texas conducted studies to quantify erosion along Texas rookery islands and project future land loss. Fourteen islands were rated as the highest priority in need of protection and eight of those islands are predicted to experience a complete land loss within 50 years (Hackney et al, 2016).

Rookery islands in the action area are currently severely degraded due to erosion, which averages 2.7 feet of loss per year, or are no longer present. Deepening of adjacent water for navigation channels, increased ship traffic, loss of oyster reef structure due to commercial harvesting, and relative sea level rise have resulted in increased wave energy battering rookery island shorelines, resulting in a net loss of island habitat. Where remnant islands remain within the action area, only a small portion of the islands remains dry and provide minimal suitable habitat to serve as a rookery for colonial nesting birds. Existing rookery islands are expected to be lost under future conditions of continued erosion and RSLR.

Some Texas bay systems appear to be more resilient in terms of bird nesting on rookery islands, which may be associated with the frequency of dredge events and placement options, presence of predators, exposure to wind and wave related erosion, or invasive species controlling available ground nesting space. Galveston Bay rookeries have experienced high rates of erosion and predator presence at most nesting sites including: Jigsaw, Rollover Pass, Struvey Lucy, Marker 52, Vingt-et-un, and Smith Point islands. Chocolate Bay in Brazoria County supports several colonial waterbird nesting sites including Alligator Point, West Bay Mooring, and several Corps Beneficial Use Placement sites, which currently need additional material to counter RSLR. East Matagorda Bay has few spoil islands suitable for colonial nesters but Dressing Point Island within the Big Boggy NWR has maintained successful colonial water bird nesting colonies due to active management efforts. Chester Island in West Matagorda Bay) and Lavaca Bay Spoil Islands (63-77) in Lavaca Bay are located adjacent to the Matagorda Ship Channel and are both eroding rookery islands that provide the only nesting habitat for a small portion of the West Matagorda Bay complex. The spoil islands at the mouth of Chocolate Bayou, Lavaca Bay Islands (51-63), Point Comfort-ALCOA, mouth of Lavaca River, and Matagorda Bay Islands (39-51) adjacent to the Matagorda Ship Channel lack sufficient elevation to support nesting birds. Although the Laguna Madre historically supported 42 colonial waterbird islands, mainly constructed during the original dredging of the GIWW, these islands now lack suitable elevations to support colonial nesters. (USFWS, 2017). Recent navigation maintenance dredging needs for the Port Mansfield Channel have prompted the Corps to restore the Port Mansfield bird rookery island using beneficial use dredged materials.

The Texas Colonial Waterbird Society (2017) reported a declining trend for colonial waterbird populations where habitat availability and predator presence may be limiting factors. While some of the existing islands receive periodic dredge maintenance material, others have not. Many islands have and continue to erode warranting additional protection measures.

Audubon Texas (Hackney et al. 2017) authored a comprehensive Texas Coastal Rookery Conservation Plan that identified all current and historical colonial waterbird islands as well as birds commonly found breeding at each site. However, more recently, Harte Research Institute for Gulf of Mexico Studies (HRI) at Texas A&M University at Corpus Christi developed a Gulf of Mexico Research Initiative Information and Data Cooperative (GRIIDC) web portal in ArcGIS to facilitate data sharing through the Gulf of Mexico Research Initiative (GoMRI). This web portal provides mapping information and tracks historic and current use of every rookery island along the Texas Coast. The Service recommends the Corps work with the HRI to ensure the most up to date information for active rookery islands is evaluated prior to designing and planning restoration measures in in the final EIS

Open Bay Bottom/Inland Open Water

Open bay bottom is one of the most abundant and productive habitats found in estuaries because it interacts with other systems including seagrass meadows, tidal flats, wetlands, etc. Open bay bottom is made up of soft sediments, home to many infauna (organisms that live in the sediments). These benthic invertebrates, mostly bivalves and polycheates, are vital to the system, converting energy from detritus and the sediments back into the water column, making it available for phytoplankton. Phytoplankton are the base of the food web and are important to having a productive bay system. Between 30 to 100% of nutrients used by these phytoplankton are recycled, making this process essential for aquatic organism that feed on them, and in turn provide an important food source for higher trophic level organisms.

A significant portion of the action areas where open bay bottom will be affected is routinely dredged in order to maintain the authorized navigational channel depth. The frequency of dredging disturbance is dependent on the shoaling rates in a particular area and can occur as frequently as every year to every ten or more years. After the disturbance occurs, there is a temporary loss of benthic invertebrates, which is recolonized after the dredging has been completed.

Seagrass Meadows

One of the most biologically productive and recreationally and economically valuable habitats is seagrass meadows, also sometimes referred to as seagrass beds. This habitat type provides difficult to replace ecological functions such as foraging and nursery habitat for waterfowl, fish, shrimp, crabs, and other economically important estuarine species as well as sea turtles, manatees, and countless invertebrates that are produced within, or migrate to seagrasses (USFWS 2017). Aquatic organisms' abundance is seagrass meadows is 10 to 100 times greater than in open bay bottom areas. Almost 40,000 fish and one thousand times as many small invertebrates are supported by a single acre of seagrass (TPWD 1999).

Seagrass meadows are comprised of submerged aquatic vegetation (SAV) which includes salt tolerant aquatic grasses (seagrasses) and attached macro-algae. Seagrasses are usually found in calm, shallow gulf waters where higher salinities, light, and nutrients are plentiful. Excessive freshwater inflows into a bay system can decrease salinities to near brackish conditions, and depending on the duration of the fresh conditions, some seagrass species are not physiologically capable of tolerating these extreme conditions and may die. Bare spaces are often recolonized with less favorable species for foraging waterfowl or fish.

The most common species of seagrass in Texas coastal waters are shoal grass (*Halodule beaudettei*), manatee grass (*Cymodocea filiformis*), widgeon grass (*Ruppia maritime*), clover grass (*Halophila engelmanni*), and turtle grass (*Thalassia testudinum*). Shoal grass is the most common of the five species of seagrass, followed by widgeon grass and manatee grass. Shoal grass and widgeon grass are pioneer specie that can grow quickly in areas of little productivity. Clover grass can also colonize in areas of bare or algae-covered substrate or as an understory within the other four species of grass beds. As the substrate becomes more stable, turtle grass begins to appear last, initiating the climax of succession. It is important to note this because the ecological niche of each species determines the order of succession. As these climax species begin to increase in abundance, the structure of the seagrass community becomes more complex, involving the increase of leaf surface area. This allows for epiphytic growth on the blades which provides food to grazing organisms that control the growth of the epiphytes. (TPWD 1999).

Open bay bottom and seagrass meadows have an inverse relationship, meaning that if one of these habitats is decreased, then the other increases. If enough light and nutrients are available and environmental factors are right, seagrass can take root in open bay bottom. This was seen after the GIWW was dredged in the late 1940s, as the exchange with the Gulf of Mexico increased causing salinities to decrease, making it possible for more seagrasses to become established. More recently, the opposite has been observed, as decreased freshwater input, brown tide and prop scarring have all caused decreases in seagrass meadows. Once the Seagrasses die and area gone, the areas will return to open bay bottom. (TPWD 1999)

Seagrass meadows provide many benefits to the ecosystem. One important aspect is that seagrass meadows help to dampen the effects of strong currents, prevent erosion, enhance water clarity, provide protection to fish and invertebrates, and prevent scouring of bay bottoms. Seagrasses help to reduce wave action with their above ground leaf structure and erosion with their below ground root and rhizome structure, thus keeping the substrate firm and maintaining water clarity. (TPWD 1999)

Seagrass also help to increase bottom surface areas, allowing for larger and more diverse communities of organisms to exist. Seagrasses provide substrate on which many other organisms can grow especially smaller attached algae and filter-feeing animals including sponges, bryozoans, and tunicates. Filter-feeders clear the water of particles and algae that compete for light and in turn serve as food for baitfish and juvenile fish. For larger organisms, seagrass meadows serve as nurseries and provide shelter. Commercially and recreationally important, federally-managed fisheries and many other species are dependent on seagrasses for all or part of their life history including: spotted sea trout (*Cynoscion nebulosus*), red drum (*Sciaenops ocellatus*), black drum (*Pogonias cromis*), blue crabs, and shrimp. (TPWD 1999)

The majority of Texas seagrass meadows occur along the middle to lower Texas coast where waters are warm, clear, and have higher salinities. Almost 80% of the remaining seagrass habitat in Texas is located in the Laguna Madre System and although considered abundant, this resource remains threatened by decreased clarity of the water and salinity changes. The seagrass meadows here are the winter home to 80% of the continental population of redhead ducks and are now confined to wintering areas on the Gulf of Mexico due to declining abundance of seagrasses along the Atlantic Coast. Ducks Unlimited (2017) estimates the decline of shoalgrass, the preferred forage of redheads, is more than 40% in the Laguna Madre since 1965, which can be attributed to salinities changes and dredging activities for navigation projects.

Aerial photographs from the 1950s indicate seagrasses were once present in Galveston Bay and ranged from 2,500 to 5,000 acres; however, they were completely eliminated by 1989. Restoration efforts in West Galveston Bay have included transplanting and seed broadcasting and so far have been successful in establishment and spreading of seagrasses on the Upper Texas coast. The Service along with other Federal, State and local partners work cooperatively to restore seagrass meadows utilizing a combination of hand planting and specially designed boats which rapidly inject nutrients, plant growth hormones, and springs of seagrass in the bottom substrate.

Biotic and abiotic threats due to point and non-point sources of pollution, decreasing water clarity, excessive nutrient runoff, sedimentation, sea level rise, and prop scarring have negatively affected these diverse communities coast wide. Conservation and protection of seagrass meadows is recommended for this valuable natural resources.

Oyster Reefs

Eastern oyster reefs are present throughout the Texas coast although at a substantially reduced amount than historically. Most oyster reefs are subtidal or intertidal, and can be found near passes and cuts, and along the edges of wetlands. Oyster reefs may be formed wherever there is a hard substrate and adequate currents to bring nutrients and for future recruits to set. Currents carry nutrients to the oysters and take away sediment and waste filtered by oyster.

Oyster reefs provide ecologically important functions including maintaining or improving water quality and providing productive habitats. Oysters can filter water 1,500 times the volume of their body per hour which, in turn, influences water clarity and phytoplankton abundance. Due to their lack of mobility and their tendency to bioaccumulate pollutants, oysters are an important indicator species for determining contamination in the bay.

Many organisms, including mollusks, polychaetes, barnacles, crabs, gastropods, amphipods, and isopods, can be found living on the oyster reef, forming a very dense community. Oyster reefs are dependent upon food resources from the open bay and wetlands. Many organisms feed on oysters including fish, such as black drum, crabs (*Callinectes spp*.), and gastropods such as the oyster drill (*Thais haemastoma*). When oyster reefs are exposed during low tides, shore birds use these intertidal reef areas as resting places.

Oysters support a valuable commercial fishery in Texas, with 22,760 acres of public reef and 2,321 acres of private reef available for harvesting. Texas A&M reports that Texas provides nearly 15% of the nation's total oyster harvest resulting in a $50 million impact on the State's economy (USFWS, 2017). Approximately 90% of the public reefs utilized by commercial and recreational fishermen are found in Galveston, Matagorda and San Antonio Bays with Galveston Bay landings usually the highest. Galveston Bay's oyster reefs were hit particularly hard during Hurricane Ike in 2008 and Hurricane Harvey in 2018, leaving many of the reefs buried in layers of sediment and debris that ultimately smothered live oysters. The Hurricane Ike event destroyed almost 60% of the oyster reef habitat in Galveston Bay and 80% of the Easy Bay population. The oyster population was slow to recover from the devastation of Hurricane Ike. Extreme conditions of drought, algae, red tide, and extreme influxes of freshwater beginning in 2010 led Galveston County to declare a disaster declaration for the oyster industry affected by commercial losses.

Reef restoration work in Texas goes back to the 1940s, but the first large scale cultch planting took place in East Galveston Bay in September 2008. This type of reef restoration has been used for years along the Gulf and mid-Atlantic coasts. Since Hurricane Ike, TPWD and several project partners across the state have invested $20 million to restore more than 1,700 acres of oyster habitat (TPWD 2019).

Despite ongoing restoration actions, the creation of larger artificially constructed reef pads is necessary to continue oyster reef growth in all of the Texas bay systems. Potential restoration areas being considered include areas in the bay systems where there is a lack of hard substrate and where historically oyster reef was present, but has been severely degraded or lost due to degraded water quality and quantity, increased shoaling and sedimentation rates, oil and chemical spills, storms, disease, overharvesting, and destructive fish practices. Implementation of oyster restoration ER measures would increase the long-term availability of oyster reef in each of the applicable action areas.

Water and Sediment Quality

Water and sediment quality along the Texas coast are measured by various agencies and organizations. Water quality criteria, desired uses, and nutrient and chlorophyll *a* screening criteria are determined by Texas Commission of Environmental Quality (TCEQ) through evaluation of water and sediment samples collected by this state agency. On the upper coast there are many areas of the bay that do not meet current water and sediment criteria due to storm water runoff or discharges of commercial, industrial, municipal, and agricultural uses surrounding Galveston Bay and its companion bays and tributaries and (TCEQ 2020). Along the middle to upper coast in the Matagorda/Lavaca Bay complex, some areas have elevated bacteria and oxygen levels below criteria (TCEQ 2020). In the middle coast, San Antonio Bay to the Aransas Bay complex, has occasional bacteria above suitable levels for oyster-harvest waters, depressed oxygen levels, elevated chlorophyll *a*, nitrates, ammonia, and total phosphorous (TCEQ 2020). Along the lower coast, the Arroyo Colorado has more water quality issues than other estuarine waters in this region, including elevated bacteria, nitrates, and chlorophyll *a* contributing to low oxygen levels (TCEQ 2020). The Laguna Madre occasionally has had low oxygen and chlorophyll a above screening criteria. The Baffin Bay complex has had high levels of chlorophyll *a*, and the Brownsville Ship Channel occasionally has low oxygen levels and elevated bacteria (TCEQ 2020).

Gulf and coast wide, the EPA (2012) conducted an intensive biological, chemical, and physical sampling across the Gulf coast from 2003 to 2006 and found there were no discernable Gulf trends in any of the parameters over the period of analysis. All waters off the Texas coast from the Sabine River in the north to the Rio Grande in the south have fish consumption advisories for various offshore species (TDSHS 2013).

Economy of the Study Area

The Texas coast is an integrated network of built infrastructure and natural environments that should be considered in partnership to understand and achieve coastal resiliency. The state's natural coastal environments contribute resources and invaluable ecosystem services – such as cultural and recreational benefits, seafood, flood prevention, and habitat productivity – that bolster business development, improve quality of life, and attract people to Texas. The built environments along the coast provide the support services, transportation and infrastructure systems that allow communities, businesses and families to grow and flourish up and down the coast.

The Texas coast contributes to the regional and the national economies through many avenues ranging from energy and agricultural industries, the port system and military transportation, to commercial fisheries, tourism, and recreation. Approximately 40% of the Nation's petrochemical industry, 25% of national petroleum-refining capacity, eight deep-draft ports, and 750 miles of shallow-draft channels (including 400 miles of the GIWW) are present in the study area. Texas ports generate over $82.8 billion in economic value to the region, with more than 500 million tons of cargo passing through Texas ports annually, including machinery, grain, seafood, oil, cars, retail merchandise, and military freight. Texas ports are also home to four of the eight largest refineries in the country and provide 25% of national refinery capacity and most of the National Petroleum Reserve. The GIWW plays a key role in all of the economic sectors. It is the third busiest inland waterway, with the Texas portion handling over 63% of its traffic and passing over $25 billion in cargo annually.

A concentration of this critical network of infrastructure and industries within the State's coastal region evolved over time because of the area's important and abundant natural resources. For example, the large, natural harbor on the lee side of Galveston Island is sheltered from the strong coastal wind. This created opportunities for commerce and industry to invest and grow in the region. The location of the port was the reason that development grew on and around the barrier islands in the upper coast. As the transportation network surrounding the port expanded, agricultural, manufacturing, and petrochemical investments followed. Continued funding for roadways, railways, and water access shows the commitment of federal, state and local government in providing support to industries who rely upon the infrastructure that not only serves the Houston and Galveston area, but also the State and the Nation.

Federal investment in harbor access up and down the Texas coast, and expenditures in port capacity have been consistent over time. Recent industry investments in refinery capacity draw residents and support services to reside and work in the coastal region. Population centers in and around the barrier islands and coastal area are essential to support the region's industry. The same physical conditions that make the area vulnerable to coastal storms provide the setting for continued growth of industry and residential areas for the where employees live.

The region is growing, and jobs are being created because the country needs what flows from Texas's coast including tourism, recreational fishing, commercial fishing, and the State's ports, intracoastal waterways, and energy production. The 18 coastal counties make up less than 6% of the State's land area but contain 24% of the State's population. The population living within the coastal counties is expected to increase from 6.1 million in 2010 to 7.0 million in 2020, and to over 9.0 million by 2050.

FISH AND WILDLIFE RESOURCE CONCERNS AND PLANNING OBJECTIVES

Fish and wildlife resource concerns in the study area include ecosystem-wide hydrologic alterations associated with construction of major navigation channels, insufficient sediment supply, sea level rise, shoreline retreat, erosion, the continued loss or transition of coastal wetlands due to salt water intrusion or conversion to urban or agricultural uses, loss of oyster reefs, loss of seagrass habitat, and loss of beach and dune habitat. These natural and anthropogenic changes to the Texas coast may lead to significant declines in coastal fish and shellfish production, which in turn can limit carrying capacity for wading and migratory bird usage, decrease available nesting, and forage habitats for migratory waterfowl and trust resources (threatened and endangered species, and critical habitats), decrease recreational opportunities, and affect local economic growth.

Additionally, the Service is concerned with water-quality degradation from industrial discharges, and agricultural and urban run-off into Galveston Bay. Galveston Bay and the Houston Ship Channel (HSC) is a major industrial and commercial shipping area. The United States Environmental Protection Agency (EPA) conducted a study and reported elevated levels of persistent legacy contaminants (e.g., dioxins and their congers) in the sediments of the upper HSC (EPA 1986). Based on the results of this study, the Department of State Health Services (DSHS) began testing fish and shellfish tissues in the upper HSC. Their findings of elevated levels of dioxin in fish and shellfish tissues resulted in a seafood consumption advisory issued for the HSC and upper Galveston Bay in 1990 (DSHS, 1990; 2008). This seafood consumption advisory remains in effect based on recent fish and crab tissue testing in 2018 and 2019 (DSHS 2019). The Texas Commission on Environmental Quality (TCEQ) also placed the upper HSC Segments 1005 and 1006 on the Texas 303(d) list of impaired waterbodies for elevated levels of dioxin in fish and crab tissues (TCEQ, 2020). Recent testing of the sediments deposited from Hurricane Harvey scouring and runoff in the upper HSC also shows increased levels of dioxins (Due et al., 2019).

The distribution of dioxins in suspended sediments, dissolved phase, and bottom sediments of the upper HSC have been correlated with maintenance dredging activities (Suarez et al., 2006; Yeager et al., 2006). These environmental studies suggest dredging activities allow dioxins to remain resuspended in the water column and more available for bioaccumulation in fish and shellfish tissues. Persistent dioxins in fish and shellfish tissues are bioaccumulated through aquatic food webs to fish-eating birds and other wildlife (Crocker and Young 1990; Frank et al. 2001).

In addition to the historic and persistent contaminant levels in Galveston Bay, the Service is concerned that fire-fighting foam and industrial chemicals from the Intercontinental Terminal Company Second 80’s Fire were released into upper HSC area in 2018 and subsequently distributed into the Galveston Bay ecosystem (ITRC, 2018a). Chemicals present in the fire-fighting foam included fluorinated alkanes (polyfluoroalkyl and perfluroalkyl substances, commonly referred to as PFASs) that are toxic to aquatic organisms, highly persistent in the environment, highly mobile, and able to bind to sediments (ITRC, 2018b). Recent environmental studies show PFASs and their degradation products in the water column and sediments are bioaccumulated and biomagnified along all trophic levels in the food chain (Holzer et al., 2011; Ahrens and Bundschuh, 2014; Fair et al., 2019).

Another Service concern is the current status of available oyster habitat within Galveston Bay. Oysters, the primary filter feeders in an estuary such as Galveston Bay, provide a significant ecosystem service by removing nutrients that cause eutrophication and degraded water quality. However, oysters consume algae that have filtered or absorbed contaminants or toxins directly from the water column, which are then stored and accumulated in their tissues. As oysters bioaccumulate these toxins, they become harmful once ingested by other aquatic organisms (e.g., crabs, finfish, etc.), colonial waterbirds, humans and other consumers. Despite these potentially lethal aspects of an oyster, the Service recognizes the many essential aquatic ecosystem services oysters provide as a food source for aquatic organism and birds, in addition to reducing shoreline erosion, buffering storm waves, and contributing to the Texas economy as a commercial fishery. Although Galveston Bay oysters are resilient survivors under harsh circumstances, they are also sensitive to changes in salinity (flooding events that may lower salinity or prolonged drought conditions that may raise salinity), contamination by toxic chemical spills, and the redistribution of sediments by large storm events. While pulses of fresh or saline conditions may only temporarily affect oysters since they can remain closed for 10 to 30 days without feeding, inundation of flood or storm waters with excess sediments can have long term detrimental effects to oyster populations. Recent examples of severe ecosystem fluctuations occurred during excessive sediment deposition over 60% of the oyster reefs in East Bay during Hurricane Ike in 2008 (Rohrer, et al., 2010). Unfortunately, several years of drought conditions followed Hurricane Ike, which disrupted freshwater inflows that were essential in maintaining optimum salinity conditions and much needed nutrients to the oysters populations already impacted by less substrate being available for recruitment. These drought years were followed by three consecutive years of major flood events (2015-2017). The most extreme rainfall event occurred when Hurricane Harvey (2017) dropped more than 60 inches of rain on the Houston area flooding Galveston Bay with fresh water, which lowered salinities to lethal levels killing almost 80% of the oyster populations in Galveston Bay (Knapp, 2017). These natural disasters, in addition to water quality degradation have resulted in a downward trend for oyster populations in Galveston Bay.

Given the magnitude of the natural and anthropogenic changes that have occurred in Galveston Bay and the uncertainties regarding the Galveston Bay Storm Surge Barrier System measures, the Service has concerns that the predicted reduction in tidal exchange, reduced circulation, increased nutrient levels, and increased bay water retention times may accelerate the current downward trend in upper coast ecosystem health. These proposed storm risk reduction measures may increase eutrophication and contaminant levels within Galveston Bay and its tributaries, which will indirectly impact trust resources such as colonial waterbirds that forage on the fish and shellfish directly impacted by lower dissolved oxygen levels or contaminants. Reduced tidal exchanges may also cause longer retention of freshwater inflows from floods, or Gulf waters from higher tides due to relative sea level rise. Longer retention of nutrient loaded waters may also promote toxic algal blooms (e.g., *Karenia brevis*) (Brand and Compton 2007), as well as promote the production of other pathogens which affect fish, shellfish, colonial waterbirds that forage on fish and shellfish, and the federally listed West Indian manatee (*Trichechus manatus*), which is susceptible to toxic algae blooms. Reduced tidal exchange and increased bay retention times may also lead to extended impacts from oil or chemical spills on colonial waterbirds, West Indian manatee, and other marine mammals, and sea turtles. The Service recommends the Corps consider a shift in paradigms that transitions from "predict then act" to more "scientifically informed decision-making" in order to reverse these downward trends with less environmentally damaging alternatives than currently proposed for the Galveston Bay Storm Barrier System which includes hard structural changes to Bolivar Roads, Dickinson Bayou, Clear Lake and Galveston Island. The Service plans to remain involved in the Corps planning process, and will continue to provide guidance and coordination to minimize impacts to fish and wildlife resources.

EVALUATION METHODOLOGY

Several potential impacts were identified early in the study process that would require modeling to determine environmental impacts or benefits. All of the models address habitat quality and availability in some manner. A Habitat Evaluation Procedure (HEP) model was used to assess habitat quality of potentially impacted habitats under the existing condition, in the future without project (FWOP), and in the future with a project (FWP). The HEP model was run for all ER measures to determine the benefits of doing the action, for all CSRM features where habitat was adversely modified or lost through construction and/or long-term operation of the structures, and at mitigation sites to determine the potential lift that could be gained by completing the mitigation action.

Concerns over potential constrictions in the flow of water between the Gulf and Galveston Bay from closure structure across the Houston Ship Channel (HSC) were assessed using a 3D Adaptive Hydraulic (AdH) model that could simulate potential changes in tidal exchange, tidal amplitude, salinity, velocities and sediment transport. Additionally, there was concern that the structure could affect movement of organisms into and out of Galveston Bay, so a “Particle Tracking Model” (PTM) was developed to simulate how organisms would move with a structure in place. Both of these models were only applied to Galveston Bay and the Gulf areas near Galveston Bay.

In 2016, the Corps requested the Engineer Research and Development Center, Coastal and Hydraulics Laboratory (ERDC-CHL) to perform hydrodynamic and salinity transport modeling of proposed storm surge protection measures. The modeling results were necessary to provide data for hydrodynamic and salinity analysis as well as ecological models to determine impacts on aquatic habitat. The details of this analysis are provided in the EIS, with additional documentation in McAlpin et al. (2019) and Lackey and McAlpin (2020).

Habitat Impact Modeling

An Interagency Team made up of state and federal natural resource agencies selected Habitat Evaluation Procedure (HEP) models to be used for this study. The team reviewed all Corps-certified species’ models based on the range of each modeled species, existing and future cover types, and specific habitat requirements described by the models and selected from the certified lists. For cover types where no certified model would work, species model development was considered.

Initially nine species models were identified as potentially applicable to identifying impacts and benefits. However, following further refinement during interagency workshops held in 2016 and 2017, the interagency team narrowed the selection to five certified Habitat Suitability Indices (HSI) models which represent those species that were presumed to be the most responsive to the proposed CSRM and ER actions due to the sensitivity of the variables and the life history requisites. It was also agreed that one additional HSI model needed to be developed in order to address changes to beach and dune complexes because existing certified models did not meet the need. The final list of HSI models includes brown shrimp, American alligator, spotted sea trout, brown pelican, American oyster, and Kemp's ridley sea turtle. Each of the HEP models used are approved for regional or nationwide use in accordance with documented geographic range, best practices and its designed limitations, except for the Kemp's ridley sea turtle model which is going through certification for one-time use. The Corps' National Ecosystem Restoration Planning Center of Expertise (ECO-PCX) for certifying models and the resource agencies supported use of these models.

The following reasons support the final selection of each HSI model.

- **Brown Shrimp Model** (Turner and Brody, 1983) – Brown shrimp was selected to capture benefits to estuarine wetlands. The HSI model variables were determined to be sensitive and responsive to wetland habitat restoration, and the model assumptions are consistent with Corps policy for habitat restoration.

- **American Alligator** (Newsom et al., 1987) – American alligator was selected to capture impacts to non-tidal palustrine wetland for analysis of the CSRM measures only. American alligator was removed from the ER model evaluation because the model application is limited to land tracts larger than 12 acres that are not isolated. All land tracts identified by the land cover datasets for the ER measures were less than 1 acre and were isolated. By consensus of the interagency team, the palustrine and estuarine wetland cover types were merged with the estuarine cover type.

- **Spotted Seatrout** (Kostecki, 1984) – Spotted seatrout was selected to capture benefits to SAV. The HSI model variables were determined to be sensitive and responsive to SAV habitat restoration, and the model assumptions are consistent with Corps policy for habitat restoration.

- **Brown Pelican** (Hingtgen et al., 1985) – Brown pelican was selected to capture benefits to bird rookery islands. The HSI model variables were determined to be sensitive and responsive to island habitat restoration, and the model assumptions are consistent with Corps policy for habitat restoration.

- **American Oyster** (Swannack et al., 2014) – The American oyster model is designed as a spatially explicit, grid-based model that calculates habitat suitability for restoration of oysters.

- **Kemp's Ridley Sea Turtle** (USACE, 2021) – The Kemp's ridley sea turtle model was developed by the interagency team to address beach and dune complexes since other certified models were not responsive to the anticipated changes. The model is going review through the Corps certification process for one-time use.

The NOAA C-CAP 2010 and wetland mitigation land cover datasets were used to evaluate and identify cover for each existing FWOP and FWP conditions for areas within the project footprint and areas indirectly affected beyond the footprint. These land cover datasets were determined to be the most applicable because they provide future conditions that incorporate migration of plant communities due to RSLR and allow for consistency and repeatability of the model evolutions. The Corps computed future rates of RSLR from years 2017 to 2085 for each of the four regions.

Each HEP model was associated with a cover type to evaluate the project-related benefits of ecosystem restoration on ecosystem resources within the project footprints. Table 2**Error! Reference source not found.** describes which habitat or cover type and the ER or CSRM measures that applied to each HSI model.

Table 2. Models Used to Conduct FWOP and FWP Analyses

Model	**Cover Type**	**Measure Location Where Model Applied**
Brown Shrimp *Farfantepenaeus aztecus*	Estuarine Wetland	G-28, B-12, M-8, CA-5, CA-6, Bolivar Roads Gates, Galveston Ring Barrier
Spotted Seatrout *Cynoscion nebulosus*	Submerged Aquatic Vegetation (SAV)	Bolivar Roads Gates, Galveston Ring Barrier, Dickinson Surge Gate, Clear Lake Surge Gate
Brown Pelican *Pelecanus occidentalis*	Bird Rookery Islands	CA-5, SP-1, W-3
American Oyster *Crassostrea virginica*	Oyster Reefs	G-28, M-8, SP-1, W-3
Kemp's ridley sea turtle *Lepidochelys kempii*	Beach/Dune	G-28, B-12, M-8, CA-5, SP-1, W-3, Bolivar Roads Gates

Following the completion of modeling for the ER and CSRM measures, the net average annual habitat unit (AAHU) outputs were combined per ER or CSRM alternative and were used to determine the ecosystem restoration (net increase in AAHUs) or mitigation requirements (net loss in AAHUs) based on projected changes in habitat.

Detailed methodologies regarding cover types, cover type mapping, assumptions made for the applications of the HSI models, and detailed results and spreadsheets are presented described in the Ecological Modeling Appendix of the EIS (Appendix I).

Impact Assessment to Open Bay Bottom Habitat

The same concept as described above was used to assess quality of and impacts to open bay bottom habitat, which primarily will be impacted by constructing and operating the Galveston Bay Storm Surge Barrier System. However, some additional assumptions and steps were required because of the difficulty in quantifying and mitigating for subtidal bay bottom areas that are part of a large and dynamic system for which no community-based models are available and species-specific models would only target specific habitats, not the whole system. Seasonal shifts in fauna and siltation also complicate selecting a species-specific model.

The interagency team considered developing a model that would be better suited to quantifying open bay bottom impacts. However, concerns arose over how to mitigate for open bay bottom. In general, the quality of open bay bottom is consistent where present, so there are no locations where actions could be taken to create lift in the quality of the habitat. To mitigate for the loss, additional bay bottom would have to be created through removal of other habitat types, such as oyster reefs, sea grass meadows, or estuarine wetlands, each of which are substantially more productive and a relatively scarce and significant habitat that would result in a net-loss that would require additional mitigation. Terrestrial habitat could also be converted to open bay bottom. However, this poses its own challenges for comparison of FWOP and FWP conditions.

The interagency team worked through these challenges and identified a strategy to quantify the impacts and calculate commensurate mitigation. The team decided to use a meta-analysis developed by the National Marine Fisheries Service (NMFS) that they use to determine compensation for interim losses related to oil spills and other environmental impacts. A meta-analysis is a statistical technique that combines the results of several studies and pools them to estimate the ratio of average productivity between pairs of estuarine habitats across all three trophic levels (Peterson et al. 2007). The ratio of average productivity across all three trophic levels between subtidal flat (open bay bottom) and oyster reef was estimated to be 8.9 to 1 (Peterson et al., 2007), meaning that 8.9 habitat units (HUs) for open bay bottom would be equivalent to one HU of oyster reef.

The team decided to assign a surrogate HSI score of 1.0 (optimal habitat) for open bay bottom, since available models did not accurately reflect existing conditions in Galveston Bay. The team also assumed that any location which was permanently converted to non-subtidal habitat (e.g. permanent structures and gate islands), was assumed to be a complete and permanent loss (i.e. HSI score of 0.0 or habitat not present). After the area of permanent loss was identified at each location, the HUs were calculated by multiplying the acreage by 1.0. This resulted in the total HUs/AAHUs under the existing and FWOP condition and the loss expected under the FWP condition. The FWOP and FWP values were then multiplied by 8.9 HUs (ratio of open bay bottom HUs equivalent to oyster reef HUs) in order to determine the net loss of AAHUs of equivalent oyster reef that would be required as mitigation for loss of open bay bottom habitat.

Hydrodynamic Modeling

The 3D Adaptive Hydraulics (AdH) model was developed and validated by ERDC-CHL for simulation of hydrodynamics, salinity, and sediment transport specifically for the Study. The AdH model was developed such that the natural driving forces of the system are included – winds, tides, salinity, freshwater inflows, friction effects, and sediment behavior. The model is compared to field data collected during the simulation period to ensure an accurate representation of nature and validated using data from 2010 and 2011 with 2005 used as the model calibration period. The model was validated to available field data for all parameters and then utilized to test project alternatives for present and future conditions.

For the purposes of this study, the 3D shallow water module of AdH was applied for all simulations in this study. This code solves for depth and velocity throughout the model domain. Detailed descriptions of the hydrodynamic modeling can be found in McAlpin et al. (2019).

The model domain extends over 3,200 square miles from the Gulf of Mexico to Houston, Texas, and includes the offshore areas from San Luis Pass on the west to Rollover Pass on the east. The 3D mesh in the model domain contains over 900,000 elements and nearly 200,000 nodes. Resolution is finest in the Houston Ship Channel to accurately capture the salinity wedge that moves along the bottom of the water column in this deep channel. Finer resolution is also seen in areas where geometric features need to be defined accurately, such as in the break in the north jetty. However, the model does not extend past San Luis Pass offshore, in the pass, or into West Bay.

Establishing Water Surface Elevations in the AdH Model

Tidal water surface elevations and salinity were applied at the ocean boundary. Winds were included throughout the model domain. Freshwater inflow was applied for the Trinity River and the San Jacinto River, as well as at Oyster, Double, Cedar, Buffalo, Dickinson and Chocolate bayous and Clear Creek inflow locations to account for ungauged flows in the area. Inflow discharge for the nine locations were computed through a hydrology model maintained by the Texas Water Development Board (TWDB) (Schoenbaechler and Guthrie 2012).

In addition to freshwater inflows, a tidal boundary was applied at the ocean boundary of the mesh. The tidal water surface elevation was based on harmonics for the area and measured data from National Oceanic and Atmospheric Administration (NOAA) gages at Freeport (8772447) and Sabine Pass (8770822), Texas. The harmonic constituents and the non-predicted, or subtidal, signal (the difference between the predicted value based on tidal constituents and the observed value, which includes winds and other factors) for each station was used to generate a tidal forcing or water surface elevation at each node along the tidal boundary for the simulation time period. The values for each node were determined by performing a linear interpolation of the gage amplitude and phase for each tidal constituent as well as for the non-predicted signal. The tide was then reconstituted at each location along the boundary using these interpolated parameters. The variation along the tidal boundary was typically less than 0.1 m.

Initially, the water surface elevation was set to the average along the tidal boundary and is a flat surface throughout the model domain. A one-year spin-up period was executed, and the variable water surface from the end of that simulation was used as the initial condition for the analysis period model simulation.

Establishing Salinity in the AdH Model

Salinity was also applied at the model's Gulf of Mexico tidal boundary. A Texas Automated Buoy System (TABS) salinity gage (GERG_B) is maintained by the Texas General Land Office and the Geochemical and Environmental Research Group (GERG) at Texas A&M University. The monthly average data set from the GERG_B data was used as the Gulf of Mexico salinity boundary condition. This data set was used for all calibration/validation years.

To accurately reproduce salinity values in Trinity Bay, it was determined that rainfall and precipitation should be included in the model. These data were also obtained from the TWDB, and the data are based on wind and temperature computations validated to several measurement locations using the Texas Rainfall Runoff Model. The combination of precipitation (rainfall only in south Texas) and evaporation is applied equally over the model domain.

Initially, the salinity was set to an average time period throughout the model domain. A 1-year spin-up period was executed for each simulation year (typically using input data for the prior calendar year), and the salinity field from the end of that simulation was used as the initial conditions for the complete model simulation.

Establishing Wind Conditions in the AdH Model

The wind conditions applied to the model were obtained from the Wave Information Studies (WIS) computed wind field for points that lie in the vicinity of the model domain (Hubertz 1992). There are 26 WIS sites for this model. The WIS model was validated against measurement sites where applicable, and these wind data allow for variable wind conditions across the domain. The wind data were supplied to the AdH model as time series of x- and y-velocities. These wind components were then converted to a shear stress dependent on conditions set for each material — deeper water uses a Wu formulation (Wu 1969, 1982) and shallow regions use a Teeter formulation (Teeter 2002).

Establishing Sediment Model Boundary of the AdH Model

The sediment model is fully coupled with the hydrodynamic model when simulating AdH with SEDLIB. The boundary conditions for the sediment model include grain characteristics, bed definitions, and sediment loads. This model includes five fine sediment classes (sizes defined by the American Geophysical Union [AGU]), which encompasses the majority of the sediment present in the domain. Sand is dominant at the entrance at Bolivar Roads, but it primarily remains in that area and therefore is not included in these simulations. Sediment-specific parameters were utilized for suspended and newly deposited grains.

Since the data available to define the sediment bed throughout the full model domain are limited mostly to the HSC and are many years old, the hydrodynamics of the system are used to sort the bed prior to validation and alternative simulations. This step is performed by setting the top-most defined bed layer to equal fractions for all of the grains (0.2 for all five grains). This layer is also defined as 0.2 meters thick – selected because erosion beyond this value during the course of the simulation year is likely prevented due to bed armoring or non-erodible material; it is known that the bay system is not eroding at a significant rate (Nichols 1989). Three additional bed layers are defined to track deposition events and help define bed features that may change the erosion/deposition potential. The cohesive bed properties that help determine erosion potential of a bed layer are defined with bulk density of 1,400 kilograms per cubic meter, critical shear stress for erosion of 1.0 Pascal, erosion rate constant of 0.000062, and erosion rate exponent of 1.0.

As the model runs and the bed begins to sort and change, the bed properties vary from these initially defined parameters. An initial one-year simulation was performed with no bed displacement allowed so that the bed can sort based on the erosion and deposition tendencies in each area. The results of this spin-up simulation were then used as the initial conditions for the analysis model run with the bed allowed to change due to computed erosion and deposition.

Flocculation properties were not included in the AdH code but should be considered when defining the sediment grain properties. No bedload is included in the present 3D Shallow Water AdH code, and cohesive bed consolidation was not included in this model due to the short simulation time of 1 year for each analysis model run.

Sediment loads were applied to the two major rivers in the area: the Trinity River and the San Jacinto River. These sediment loads were determined from a rating curve correlating discharge with concentration generated using data from the U.S. Geological Survey (USGS) as documented in Tate et al. (2008).

Particle Tracking Model

With input from the resource agencies, the Corps modified an existing Particle Tracking Model (PTM) to show indirect impacts, and the extent of those impacts, from constructing the storm surge barrier system at Bolivar Roads Pass on the larval stages of the marine life that travel in and out of Galveston Bay. The PTM simulates the transport of particles, or local marine larval species, using environmental inputs such as circulation, salinity, currents, and water surface elevation from the 3D Adaptive Hydraulics (AdH) model and local marine species' transportation characteristics (e.g. bottom dwellers, top dwellers etc.). The particle movements represent a multitude of aquatic species including shrimp, blue crabs, and commercially and recreationally important finfish (e.g. spotted sea trout and flounder).

PTM is a Lagrangian particle tracker designed to allow the user to simulate particle transport processes. PTM has been developed for applications to coastal projects which focus on a wide range of particle types: water, sediment, and biological particles. The model contains algorithms that appropriately represent transport, settling, deposition, mixing, and resuspension processes in nearshore wave/current conditions.

PTM uses hydrodynamics developed through other models and input directly to PTM as forcing functions. In this work, as has been described in detail in the previous section, AdH hydrodynamic output was used as the model input for PTM. A five-week period was extracted from the year-long AdH simulation during the months of February and March. The need to select a five to six-week period was discussed with state and federal resource agencies (Agency Meeting, 24 June 2019). The five-week period during the months of February and March was chosen to capture a time when several commercially important species that exhibit various larval behaviors migrate into the Galveston Bay system.

Characteristic Larvae Transport Behaviors

PTM models assume larval marine species particles are neutrally buoyant (passive particles) with added characteristic transport behaviors. Neutrally buoyant particles move based solely on the flow field. The particle velocity is interpolated from the hydrodynamic velocity at the surrounding nodes in the computational grid. The particle X is then transported over a set distance and the new location of the particle X is determined based on the previous location and an added distance dependent on the interpolated velocity and the time step to reach that distance. The characteristic behaviors are added either to a component of the velocity vector (V) or added as a restriction to the location of the particle X.

Six larval marine species characteristic transport behaviors were modeled for this study based on a variety of marine species native to the area and derived from the field data used in the Keith Lake Fish Pass Larval Transport study (Hartman et al. 1987) which included:

1. Tidal Lateral (particles move to center of channel during incoming tide)
2. Diel Vertical (particles move up during day)
3. Tidal Vertical (particles move up during incoming tide)
4. Bottom movers (particles remain 1 meter from bottom)
5. Surface movers (particles remain 1 meter from top)
6. Passive (neutrally buoyant particles)

In each behavior that requires the particle to move at a specific swimming speed towards an area, the velocity that particles move in these simulations was 0.01 cm/s based on interagency team consultation.

Initial Particle Release

During simulation runs, particles were initially released at a location upstream on the gulf-side of the planned gate structure (**Error! Reference source not found.**). Approximately 7,400 particles were released over the five-week simulation period. Fifty percent of the particles were released uniformly across the channel in the section shown in red. Twenty-five percent of the particles were released on either side of the channel in the white and yellow sections respectively. The particles were initiated in the upper one meter of the water column.

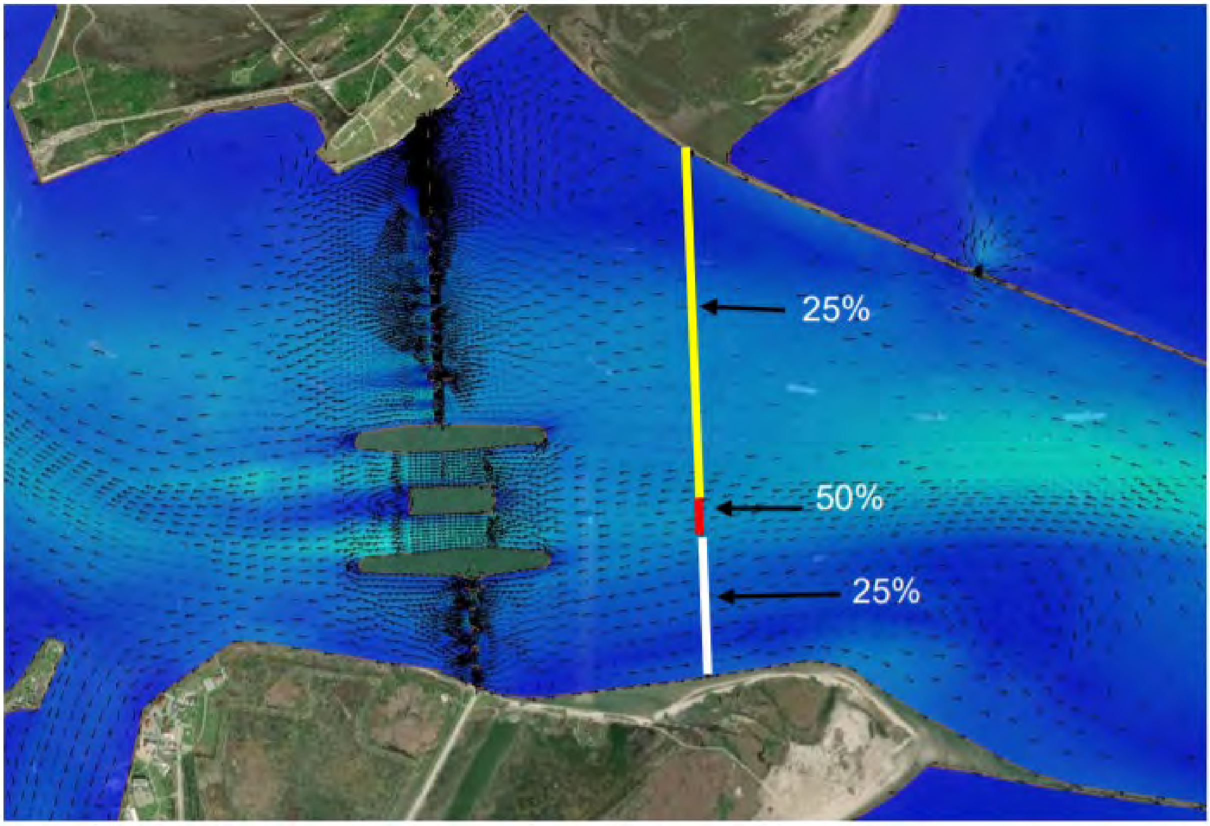

Figure 3. Initial Release Location and Percentage of Total Particles

Recruitment of Larvae

Larval recruitment is defined as the date/time at which particles reach one of four designated recruitment areas that were defined by the interagency group. During transport, once particles reach a recruitment area, the particle identification, recruitment location, and date/time of recruitment are denoted by the PTM model. This information is later post-processed to determine statistics and time series of recruitment.

The recruitment areas were chosen to represent larval recruitment to three sections of Galveston Bay known to contain important nursery habitats for marine species. Those sections of Galveston Bay are East Bay, West Bay, and Trinity Bay (**Error! Reference source not found.**). A fourth recruitment area was added to ensure that particles that were created in the channel and were pushed offshore would not be counted if they entered East Bay through Rollover Pass which is now closed. These recruitment areas were agreed upon and refined in an interagency meeting held on June 24, 2019.

Figure 4. Recruitment Areas Defined by the Interagency Team

Model Assumptions and Limitations

Larval transport utilizing PTM has been previously performed and published (Tate et al., 2010) for transport of larval fish into Lake Pontchartrain. The six behaviors used in this model simulation are consistent with the previous work. It is important to note that this method for understanding larval fish transport is simplistic in the fact that it focuses on modeling "characteristic" transport. That is, the particle transport method included in this work does not suggest that it contains all the intricate behaviors of a live biological larvae. However, the focus is on simple characteristic behaviors, defined by experts, which potentially dominate transport of larvae. In addition it should be noted that the behavior for specific species may change based on the lifecycles of individual species. Therefore, in this work the focus is applied to the impact of the behavior on transport of particles that have characteristic behaviors. Extrapolation of the impact of the structures to the population of a specific species is not within the scope of work of this project. Additional information on this modeling can be found in Appendix D, Annex 6 of the Feasibility Report or in Lackey and McAlpin (2020).

FISH AND WILDLIFE RESOURCES WITHOUT THE PROJECT

The Service extensively described the Study's natural resources, available habitats, and recommendations for protection of those very resources and habitats along the Texas Coast in the 2017 Coastal Texas Planning Aid Letter (PAL) (EIS, Appendix A). Habitat values, fish, and wildlife resources described in the 2017 PAL has been updated in this report where necessary. The Service received no comments on the 2017 PAL provided to NMFS and TPWD.

Existing Conditions

The following sections describe the existing conditions of fish and wildlife resources and their habitats as of the writing of this report.

Threatened and Endangered Species

The Endangered Species Act (ESA), as amended, establishes a national policy designed to protect and conserve threatened and endangered species and the ecosystems upon which they depend (16 USC 1531–1543). The ESA is administered by the Department of the Interior, through the Service, and by the National Oceanic and Atmospheric Administration, through the NMFS. Section 7 of the ESA specifies that any agency that proposes a Federal action that could jeopardize the "continued existence of any endangered species or threatened species or result in the destruction or adverse modification of habitat of such species" (16 USC 1536 Section 7(a)(2)) must participate in the interagency cooperation and consultation process. According to Section 7(a)(2) of the Act and the implementing regulations, it is the responsibility of each federal agency to ensure that any action they authorize, fund, or carry out is not likely to jeopardize the continued existence of any federally listed species. Based upon an inventory of listed species and other current information, the federal action agency determines if any endangered or threatened species may be affected by the proposed action. The Service's Consultation Handbook (http://endangered.fws.gov/consultations/s7hndbk/s7hndbk.htm) is available online for further information on definitions and process.

The following Federally-listed threatened (T) and endangered (E) species and/or their designated critical habitat (CH) may potentially occur within the study area: piping plover (*Charadrius melodus*) (T) and its designated critical habitat, rufa red knot (*Calidris canutus rufa*) (T), whooping crane (*Grus americana*) (E), eastern black rail (*Laterallus jamaicensis jamaicensis*) (T), Northern Aplomado Falcon (*Falcon Falco femoralis septentrionalis*) (E), West Indian manatee (T), loggerhead sea turtle (*Caretta caretta*) (T), Kemp's ridley sea turtle (*Lepidochelys kempii*) (E), green sea turtle (*Chelonia mydas*) (T), leatherback sea turtle (*Dermochelys coriacea*) (E), and hawksbill sea turtle (*Eretmochelys imbricate*) (E). The Service has coordinated with the Corps regarding the final determination of the Biological Assessment (BA) for the six ER measures that will be included in Appendix B of the DEIS, in accordance with requirements outlined under ESA Section 7. The Service recommends the Corps coordinate with the Service on Section 7 consultations for all beach and dune restoration measures and the Galveston Bay Barrier System measures in in the Tier Two Assessment of the RP.

For the purposes of a conservation strategy, the Service's Southwest Region has defined "at-risk species" as those that are; proposed for listing as threatened or endangered under the Act; a candidate for listing, or; it has been petitioned by a third party for listing. The Service's goal is to work with resource agencies, private and public entities on proactive conservation approaches to conserve these species thereby precluding the need to federally list as many at-risk species as possible.

The Service recommends the Corps conduct a review for threatened and endangered species two years prior to construction of the ER measures. In order to obtain information regarding fish and wildlife resources concerning a specific project or project area, we recommend the Corps first utilize the Service developed Information, Planning, and Conservation (IPaC) System. The IPaC system is designed for easy public access to information about the natural resources for which the Service has trust or regulatory responsibility such as threatened and endangered species, migratory birds, National Refuge lands, and the National Wetland Index. One of the primary goals of the IPaC system is to provide this information in a manner that assists project proponents in planning their activities within the context of natural resource conservation. The IPaC system can assist users with the various regulatory consultation, permitting, and approval processes administered by the Service, helping achieve more effective and efficient results for both the project proponents and natural resources. The IPaC system can be found at https://ecos.fws.gov/ipac/.

Piping Plover

Listed as a threatened species under the Act in 1985 (50 FR 50726), the piping plover is a small stocky shorebird approximately 7 inches in length with a wingspan of about 15 inches (Palmer 1967, USFWS 2009). Plumage and descriptive characteristics include a pale back, nape, and crown, white under parts, a stubby bill, and orange legs and during the breeding season, the legs and bill are bright orange, the bill has a black tip, and a single black breast band and forehead bar are present. In winter, its legs become pale orange, its bill turns black, and the darker bands and bars are lost (Wilcox 1959, USFWS 2009). The historic range of the piping plover has traditionally been divided into breeding and wintering ranges. The breeding range encompasses the northern Great Plains and Prairies, the Great Lakes, and the North Atlantic ecoregions of the United States and Canada while the wintering range extends along coastal areas of the U.S. from North Carolina to Texas and portions of Mexico and the Caribbean (USFWS 2009). The species current range remains similar to its historic range except that piping plovers have been extirpated from several Great Lakes breeding areas (USFWS 2003). On the lower Texas coast, piping plovers from the prairie regions of Canada and the U.S. concentrate heavily in the winter in southern Texas and into Mexico" (Gratto-Trevor et al. 2012).

On their migration and wintering range, piping plovers forage and roost among a mosaic of beach and bay habitats and move locally (within a home range) among these habitats in response to a variety of factors including tidal stage, weather conditions, human disturbance, and prey abundance (Drake et al. 2001, Cohen et al. 2008, Noel and Chandler 2008). Foraging habitats include bayside flats and islands, the intertidal zone of ocean beaches, wrack micro habitats, washover passes (channel cuts created by storm driven water), and shorelines of ephemeral ponds, lagoons, and estuarine wetlands. Important components of the beach/dune ecosystem include surf-cast algae for feeding of prey; sparsely vegetated backbeach (beach area above mean high tide seaward of the dune line, or in cases where no dune exists, seaward of a delineating feature such as a vegetation line, structure, or road) for roosting and refuge during storms; and spits (a small point of land, especially sand running into water), salterns (bare sand flats in the center of mangrove ecosystems that are found above mean high water and are only irregularly flushed with sea water), and washover areas for feeding and roosting (USFWS 2003).

Roosting habitats include back-beach areas, dunes, wrack microhabitats, inlets, and river mouths as roosting habitats (Arvin 2009, USFWS 2009). Nesting sites include sandy beaches, especially where scattered tufts of grass are present; sandbars; causeways; bare areas on dredge-created and natural alluvial islands in rivers; gravel pits along rivers; silty flats; and salt-encrusted bare areas of sand, gravel, or pebbly mud on interior alkali lakes and ponds (Haig and Elliot-Smith 2004).

Approximately 35 percent of the known global population of piping plovers winters along the Texas Gulf Coast, where they spend 60 to 70 percent of the year (Haig & Elliott-Smith, 2004). Piping plovers are a common migrant and rare to uncommon winter resident on the upper Texas coast most likely due to habitat conditions (Lockwood, 2004). Plovers on Texas wintering grounds suggest that they show stringent site fidelity (+/- 400 feet in lateral distance), returning to the same stretch of beach year after year (USACE 2009). On the lower Texas coast, piping plovers are known to use areas about 3,000 acres in size, moving two miles or more between foraging sites as tidal movements shift the availability of productive tidal flats.

Piping plovers begin arriving on their wintering ground in late July, although most wintering birds arrive at the Texas coast in August and September. They begin leaving the wintering grounds in late February and by mid-May, almost all wintering birds have left the Texas coastal area for their nesting grounds. Because these birds may cross over from the Gulf or Atlantic coasts, birds on Texas wintering grounds may be from any of the three breeding areas. (USFWS 2008)

Major threats to wintering piping plover identified at the time of listing included destruction or modification of beach and littoral habitat and human disturbance. Human-caused disturbance factors that may affect the survival of piping plover or utilization of wintering habitat include recreational activities, inlet and shoreline stabilization projects, dredging of inlets that can affect spit formation, beach maintenance and renourishment, and pollution. In some areas, natural erosion of barrier islands may also result in habitat loss. The construction of houses and commercial buildings on and adjacent to barrier beaches results in increased human disturbance and habitat loss.

Critical Habitat for Piping Plover

Critical Habitat for wintering piping plover was designated on July 10, 2001 (66 FR 36038) and originally included 142 conservation units encompassing approximately 1,793 miles of mapped shoreline and 165,211 acres along the coasts of North Carolina, South Carolina, Georgia, Florida, Alabama, Mississippi, Louisiana, and Texas. There are 37 CH units (approximately 62,454 acres, 797 miles) designated in Texas. These areas were believed to contain the essential physical and biological elements for the conservation of wintering piping plovers, and their physical features necessary for maintaining the natural processes that provide appropriate foraging, roosting, and sheltering habitat components.

The primary constituent elements (PCEs) for piping plover wintering habitat essential for the conservation of the species include the following essential physical and biological elements of the habitat:

1) Intertidal sand beaches including sand flats or mudflats between annual low tide and annual high tide with no or very sparse emergent vegetation for feeding.
2) Unvegetated or sparsely vegetated sand, mud, or algal flats above annual high tide for roosting. Such sites may have debris or detritus and micro-topographic relief offering refuge from high winds and cold weather.
3) Surf-case algae for feeding.
4) Sparsely vegetated back beach which is the beach area above mean high tide seaward of the dune line, or in cases where no dunes exist, seaward of a delineating feature such as a vegetation line, structure, or road. Back beach is used by plovers for roosting and refuge during storms.
5) Spits, especially sand, running into water for foraging and roosting.
6) Unvegetated washover areas with little or no topographic relief for feeding and roosting. Washover areas are formed and maintained by the action of hurricanes, storm surges, or the extreme wave actions.
7) Natural conditions of sparse vegetation and little or no topographic relief mimicked in artificial habitat types (e.g. dredge spoil sites)

The units designated as CH are those areas that have consistent use by piping plovers and that best meet the biological needs of the species. The amount of wintering habitat included in the designation appears sufficient to support future recovered populations, and the existence of this habitat is essential to the conservation of the species.

<u>Rufa Red Knot</u>

Service, listed the rufa red knot as a threatened species under the Act throughout its entire range under the ESA in January 12, 2015 (79 FR 73705-73748). The rufa red knot (red knot) is a medium-size shorebird about 9 to 11 inches in length. The red knot is a specialized molluscivore, eating hard-shelled mollusks, sometimes supplemented with easily accessed and/or shallow-buried softer invertebrate prey, such as shrimp- and crab-like organisms, marine worms, and horseshoe crab (*Limulus polyphemus*) eggs (Piersma and van Gils 2011). Mollusk prey are swallowed whole and crushed in the gizzard (Piersma and van Gils 2011). Foraging activity is largely dictated by tidal conditions, as the red knot rarely wades more than 0.8 to 1.2 inches and cannot effectively dig deeper than 0.8 to 1.2 inches. It has been reported that Coquina clams (*Donax variabilis*) serve as a frequent and often important food resource for red knots along Gulf beaches.

The rufa red knot generally flies more than 9,300 miles from south to north every spring and fall without stopping, making this species one of the longest-distance migrants in the animal kingdom (Morrison et al. 2004, USFWS 2019a). Breeding takes place in the Canadian Arctic with arrival beginning in late May or early June varying with snowmelt conditions. Most adult and juvenile red knots leave the breeding grounds in late July however some remain as late as mid-August. Red knots occupy all wintering areas of Texas as early as September and as late as May in Texas with the majority migrating to the Laguna Madre or barrier islands along the Texas Coast. In addition, these birds are found in coastal bays, estuaries, and inlets returning to the same wintering ground yearly. Declines in the red knot population occurred in the 2000s primarily from reduced food availability from increased harvest of horseshoe crabs in Delaware Bay (the main stop over point for red knots).

While red knot numbers declined in the 2000s, their numbers have remained at low levels relative to earlier decades and warranted federal protection. In the final listing rule, the Service determined that the rufa red knot's primary threats under the ESA are due to: loss of breeding and nonbreeding habitat (including adverse effects from sea level rise, coastal engineering, coastal development, and arctic ecosystem change); likely effects related to disruption of natural predator cycles on the breeding grounds; reduced prey availability throughout the nonbreeding range; and increasing frequency and severity of asynchronies (mismatches) in the timing of the birds' annual migratory cycle relative to favorable food and weather conditions. These primary threats driving the red knot's status as a threatened species under the ESA are classified as High Severity (USFWS 2019a). In the final listing the Service also evaluated secondary factors that are likely to cause additive mortality. Although individually these secondary factors are not expected to have direct effects on this species, cumulatively these factors are expected to exacerbate the effects of primary threats and further reduce the subspecies resiliency. These secondary factors were identified as hunting in nonbreeding areas; predation in nonbreeding areas; harmful algal blooms; human disturbance; oil spills; and wind energy development, especially near the coasts. These secondary threats are classified as Moderate Severity and the potential for adverse effects from human disturbances and construction in the study area may occur.

No CH has been designated for red knot as of this evaluation period.

Whooping Crane

The whooping crane was federally listed as endangered on March 11, 1967 (32 FR 4001). Whooping cranes from the wild flock from the Aransas-Wood Buffalo National Park have expanded their spatial distribution up the coast and outside of the Aransas NWR on the mid-coast. Individuals and families with tracking identification have been sighted in the Powderhorn Ranch WMA directly adjacent to the north unit of the Aransas NWR on Powderhorn Lake, and at the Mad Island WMA.

The whooping crane, with less than 600 birds in the wild, winters along the wetlands of the central Texas coast and feeds on aquatic invertebrates such as insects, blue crabs, small vertebrate fish, amphibians, birds, mammals, and plants commonly found in freshwater to brackish wetlands regimes and coastal prairies. Cranes occasionally fly to upland sites when attracted by freshwater or foods such as acorns, snails, crayfish and insects, and then return to these wetlands to roost at night. Rice fields or uplands are particularly attractive to the cranes when partially flooded by rainfall, burned to reduce plant cover or when food is less available in the salt flats and wetlands.

A portion of the original wild flock (defined as self-sustaining Aransas-Wood Buffalo National Park (wild population) winters at the Aransas NWR October through April each year and then migrates north to breed at Wood Buffalo National Park in Canada. Birds from a non-essential experimental population of 59 whooping cranes from Louisiana also occasionally use the upper Texas coastal wetland habitat and the Anahuac NWR.

Across the Texas coast, the primary threat to whooping cranes remains habitat loss from conversion of wetland habitat to agricultural fields. Other threats include: human disturbances, uncontrolled hunting, specimen and egg collection, collisions with power lines, fences, and other structures, loss and degradation of migration stopover habitat, diseases, lead poisoning, loss of genetic diversity. As well, adequate food supplies are also critical to whooping crane recovery efforts. Lack of freshwater inflows can create saline conditions not favorable for key forage species and can threaten whooping crane overwinter and migration success. Biological factors such as delayed sexual maturity and small clutch size prevent rapid population recover. Drought during breeding seasons presents serious hazards to this species. Exposure to disease is a special problem when large numbers of birds are concentrated in limited areas during drought conditions or fragmented habitats where foraging is limited (Lewis, 1995, Campbell, 2003, USFWS, 2007).

Migration flights to and from the breeding grounds are not direct or non-stop; and stop overs are required for rest and refueling. Healthy wetlands (of all types) on the wintering grounds and along the migratory route continue to play an integral part in the whooping crane's survival and should be preserved. All wetland areas along the coast have the potential to support foraging or resting birds; however, those closest to Aransas NWR on the mid-coast and along the upper Texas coast are most likely to receive use by whooping cranes.

Critical Habitat for Whooping Crane

CH for the whooping crane was designated in 1978 (43 FR 20938), originally in nine areas in seven states, but has since been revised to only include five areas in four states in the US, including one in Texas at Aransas NWR.

The Service considers five requirements for survival and recovery of the species when designating CH. These requirements generally include space for individual and population growth, nutritional and physiological requirements, shelter, sites for reproduction, and habitats protected from disturbance or representative of the species' geographic distribution. Whooping cranes are territorial; pairs require hundreds of acres of undisturbed wetland habitat and unmated birds require undefended territory in Aransas NWR (USFWS, 1978).

All of the designated CH areas provide for the nutritional and physiological needs of the cranes (USFWS, 1978). This includes the tidal flats and wetlands of Aransas NWR which provides crustaceans (blue crabs) and mollusks (clams), essential components of the whooping cranes on their wintering grounds. Each of the designated CH areas provide areas essential to rearing young (USFWS, 1978).

Eastern Black Rail

The eastern black rail was listed as threatened on October 8, 2020 with a Section 4(d) Rule (FR 63764). No CH has been designated for the species. The Section 4(d) Rule allows the Service to establish prohibitions or exceptions to prohibitions for threatened species while providing for the conservation of a threatened species by allowing flexibility under ESA.

The eastern black rail is the most secretive of the secretive wetland birds and one of the least understood species in North America. This sparrow-sized bird with slate gray plumage and red eyes lives in remote wetlands of the Midwest and in salt and freshwater wetlands along the coasts of the Atlantic and Pacific oceans and the Gulf of Mexico. Because this bird is primarily nocturnal, it, prefers to walk hidden in tall grasses instead of fly and rarely makes a call. Based on these cryptic secretive attributes there is very little is known about its behavior and habitat needs.

The subspecies is known to require dense vegetation that allows movement underneath the canopy, and plant structure is considered more important than plant species composition in predicting habitat suitability (Watts 2016). Eastern black rails also require adjacent higher elevation areas (i.e., the wetland-upland transition zone) with dense cover to survive high water events due to the propensity of juvenile and adult eastern black rails to walk and run rather than fly; and the chicks' inability to fly. (USFWS 2019a)

The primary threats to eastern black rail are: (1) habitat fragmentation and conversion, resulting in the loss of wetland habitats across the range; (2) sea level rise and tidal flooding; (3) land management practices (*i.e.,* incompatible fire management practices, grazing, and haying/mowing/other mechanical treatment activities); and (4) stochastic events (*e.g.,* extreme flooding, hurricanes). Human disturbance, such as birders using excessive playback calls of eastern black rail vocalizations, is also a concern for this species. Additional stressors to the species include construction activities, oil and chemical spills, environmental contaminants; disease (specifically West Nile virus); and predation and altered food webs resulting from invasive species (fire ants, feral pigs, nutria, mongoose, and exotic reptiles) introductions.

Texas is an eastern black rail crossroad making it difficult to differentiate breeders from winter residents from migrants. Eastern black rail in Texas use densely vegetated tidal wetlands along the barrier islands and the mainland fringe, but are also found within drier palustrine emergent coastal prairies adjacent to GIWW.

The upper Texas coast (Jefferson, Chambers, Galveston, Harris, and Brazoria counties) has a long history of eastern black rail records that are concentrated within NWRs and WMAs. Much of this activity along the upper Texas coast has been concentrated on the Bolivar Peninsula or in Anahuac, Brazoria, and San Bernard National Wildlife Refuges. In the central Texas coast (Matagorda, Calhoun, Aransas, San Patricio, Nueces, and Kleberg counties) region, properties with significant eastern black rail histories include Matagorda Island WMA Mad Island WMA, Aransas NWR, Powderhorn Ranch, and the Magnolia Beach Wetlands where birds have been detected during breeding bird surveys for many years. The south Texas coast (Kenedy and Cameron counties) has had a few reports of eastern black rails in the Laguna Atascosa NWR on South Padre Island, and they have also been detected around South Padre Island Nature and Birding Center in Cameron County, and on the Kenedy Ranch in Kenedy County (Watts 2016).

Northern Aplomado Falcon

The Service listed the Northern Aplomado falcon (*Falco femoralis septentrionalis*) as an endangered species on February 25, 1986 (51 FR 6686). The Northern Aplomado falcon is one of three subspecies of the Aplomado falcon (*Falco femoralis*) (USFWS, 1990). The weak differentiation between the subspecies is based upon size and coloration (Keddy-Hector, 2000). Adults are characterized by rufous (rust) underparts, a gray back, a long and banded tail, and a distinctive black and white facial pattern. Aplomado falcons are smaller than peregrine falcons and larger than kestrels. The average clutch size is 3 eggs per nest.

Historically, the species' range extended from Trans-Pecos Texas, southern New Mexico and southeastern Arizona, to Chiapas and the northern Yucatan along the Gulf of Mexico and along the Pacific slope of Central America north of Nicaragua. By mid-century, the falcon was absent from most of its range in the US with very few sightings reported. Since their listing, there have been reintroduction efforts in west Texas, at the King Ranch in Kleberg County, Matagorda Island and Laguna Atascosa NWR. There are established nesting populations in Brownsville and on Matagorda Island in Texas. Matagorda Island was not historically associated with falcons and the population was established to improve survival success since the island was devoid of great-horned owls. (USFWS 2014)

In the U.S., this species is found along yucca-covered sand ridges in coastal prairies, riparian woodlands in open grasslands, and in desert grasslands with scattered mesquite and yucca from sea level to about 4,500 feet. Nest platforms of sticks or twigs are often placed in mesquite or tall yuccas, 10-14 feet above ground. These falcons have successfully nested on larger expanses of seasonally inundated salty prairie, vegetated with gulf cordgrass, marshhay cordgrass, gulf dune paspalum, gulf bluestem, sea ox-eye daisy, and glasswart. Woody vegetation on these salty prairies is sparse, except where honey mesquite (*Prosopis glandulosa*) and huisache (*Acacia farnesiana*) occur more frequently at slightly higher elevations, with occasional small hills (lomas) unless controlled by periodic fire. The data collected by radio-tagged fledglings in south Texas suggest that most pairs use the vicinity of previous season's nesting platform as a hunting, roosting, and display area throughout the year.

West Indian Manatee

The Service listed the West Indian manatee as endangered on March 11, 1967 (32 FR 4001) and it later received protection under ESA in 1973. On May 5, 2017, the species was reclassified from endangered to threatened because the endangered designation no longer reflected the status of the species at the time of reclassification (82 FR 16668). CH for the Florida manatee subspecies (*Trichechus manatus latirostris*) was designated in 1976 (41 FR 41914), but is outside the study area.

Manatees are large, elongated marine mammals with paired flippers and a large, spoon-shaped tail. They can reach lengths of over 14 feet and weights of over 3,000 pounds. Manatees are herbivores that feed opportunistically on a wide variety of submerged, floating, and emergent vegetation.

Manatees live in diversity of habitats that includes marine, brackish, and freshwater systems in coastal and riverine areas throughout their range. Their preferred habitats are near submerged aquatic vegetation like seagrass and eelgrass, which are found in Christmas and West Bays on upper coast, in Aransas Bay on the mid coast, and Laguna Madre on the lower coast. They feed along edges of these submerged aquatic beds with access to deep water channels, where they can escape when threatened. Manatees often use secluded canals, creeks, embayments, and lagoons, near the mouths of coastal rivers and sloughs for feeding, resting, cavorting, mating, and calving (Marine Mammal Commission 1986).

West Indian manatees occurring west of Florida and to the north of Mexico are generally considered to be strays originating from populations in either Florida or Mexico (Domning, 1986). Traveling manatees use warm-water refuges along their migratory routes during the early spring and late fall (Fertl et al., 2005). The West Indian manatee has been observed to migrate through Galveston Bay and its associated coastal waters, boat basins, and power plant effluent waters. Infrequently reported because of their secretive nature, manatees journey along the upper Texas coastal areas while the average water temperature is warm. Based on data maintained by the Texas Marine Mammal Stranding Network, over 80% of reported manatee sightings (1999-2017) in Texas have occurred from the months of June through November with the majority occurring in October and November. Most sightings are single individuals; however, rare sightings of calf/cow pairs have occurred between June and December. Reported manatee occurrences in Texas appear to be increasing as populations from Mexico and Florida make their way along coastal shorelines including canals and coastal wetlands of Galveston Bay. Cold weather and outbreaks of red tide may adversely affect these animals. However, human activity is the primary cause for their decline in numbers due to collisions with boats and barges, entrapment in flood control structures, poaching, habitat loss, and pollution (USFWS 2019a).

Although this species historically inhabited the Laguna Madre, the Gulf and tidally influenced rivers, they have been observed either as individuals or in pairs in the study area in the Laguna Madre, Port Mansfield Pass, Aransas Pass, Christmas Bay, Salt Lake, and Galveston Bay (Schmidly, 2004; Rice 2012; Würsig, 2017; and Dawson, 2019). Despite the few manatee sightings off the coast of Galveston Island in the Gulf of Mexico, as recently as July 30, 2019 a single manatee was confirmed on the north side of the Texas City Dike and remained in the area for about 12 hours. Intermittent sightings of manatees on the upper coast have occurring as far back as 1995 when a manatee traveled up Buffalo Bayou a tributary to Galveston Bay and stayed below the outfall of a municipal wastewater treatment plant during the winter months until it was recovered and returned to warmer waters. Although, the Galveston Bay and upper coast in general does not have an abundance of its preferred habitat and food sources, Christmas and West Bay have abundant seagrass beds that could sustain this passive marine mammal. When the sightings have occurred, Galveston Bay and its tributaries have had a higher incidence of water hyacinths being moved down the Houston Ship Channel from rain and upstream flooding, which may be the reason these individuals were attracted to these areas. None of the individuals observed stayed in the area for any substantial length of time, and are not expected to regularly frequent the upper coast bays or its tributaries.

Sea Turtles

The Service and NMFS share joint jurisdiction over five species of sea turtles found in U.S. waters and nesting on U.S. beaches including the loggerhead, leatherback, hawksbill, green and Kemp's ridley sea turtles. NMFS retains jurisdiction when sea turtles are in a marine environment and the Service has jurisdiction when sea turtles emerge to nest on beaches along the Texas coast. Texas sea turtle nesting season occurs from March 15 to October 1, with the loggerhead, green, and Kemp's ridley sea turtles documented to nest along the Texas coastal beaches. Kemp's ridley sea turtles nest bi-annually with most nesting occurring along the Tamaulipan coast of Mexico.

Loggerhead Sea Turtle

The loggerhead sea turtle was listed as threatened throughout its range on July 28, 1978 (43 FR 32808). Although the loggerhead is the most abundant sea turtle species in U.S. coastal waters (NMFS 2006), the decline of the species, like that of most sea turtles is the result of overexploitation by man, inadvertent mortality associated with fishing and trawling activities, and natural predation. The most significant threats to its population are coastal development, commercial fisheries and pollution (NMFS 2006). The loggerhead sea turtle is a medium to large turtle. Adults are reddish-brown in color and generally 31 to 45 inches in shell length with the record set at more than 48 inches. Loggerheads weigh between 170 and 350 pounds with records set at greater than 500 pounds. Loggerhead turtles are essentially carnivores, feeding primarily on sea urchins, sponges, squid, basket stars, crabs, horseshoe crabs, shrimp, and a variety of mollusks. Adults are primarily bottom feeders, although they will also eat jellyfish and mangrove leaves obtained while swimming and resting near the sea surface. Croaker have been found in stomachs of stranded individuals which indicate they are feeding on the by-catch of shrimp trawling (Landry, 1986). Young feed on prey concentrated at the surface, such as gastropods, fragments of crustaceans, and sargassum. The loggerhead is the most abundant turtle in Texas marine waters, preferring shallow inner continental shelf waters, and occurring only very infrequently in the bays. Nesting within or near the other action areas has rarely been recorded. Between 2015 and 2020, nesting occurred in four of the six years with between 2 and 5 nests recorded each year at Padre Island National Seashore. During that same period, no nesting was documented in the same two years as at Padre Island National Seashore and in nesting years only 1 nest was found except for in 2018 when two nests were recorded at South Padre Island. (Turtle Island Restoration 2020). However, there is potential for this species to occur in any of action areas especially along the lower Texas coast.

Green Sea Turtle

The green sea turtle was listed on July 28, 1978, as threatened except for in Florida and the Pacific Coast of Mexico (including the Gulf of California) where it was listed as endangered (43

FR 32808). In 1998, NMFS designated CH to include the coastal waters around Culebra Island, Puerto Rico (63 FR 46693). On May 6, 2016, NMFS and USFWS revised the listing to identify 11 green sea turtle distinct population segments (DPS) worldwide. The proposed DPS would list the North Atlantic DPS as threatened. The green sea turtle is the most common sea turtle in Texas. However, the principal cause of the historical, worldwide decline of the green turtle is long-term harvest of eggs and adults on nesting beaches and juveniles and adults on feeding grounds. These harvests continue in some areas of the world and compromise efforts to recover the species. Other threats include incidental capture in fishing gear, primarily gillnets, but also in trawls, traps and pots, longlines, and dredges, as well as nesting habitat loss and disturbance from recreational use of beaches, development, erosion, and vegetation changes. Green turtles are also threatened, in some areas of the world especially in Hawaii and Florida, by a disease known as fibropapillomatosis, or "tumor" infections. These infections have been observed in green sea turtles visiting or nesting on the Texas coast. Green sea turtles are the largest of all the hard-shelled sea turtles, but have a comparatively small head. Adult turtles are unique among sea turtles in that they are herbivorous, and feed primarily on seagrasses and algae found in the inshore bays and passes found on the lower coast. Juveniles consume some invertebrates including seagrasses, macroalgae and other marine plants, mollusks, sponges, crustaceans, and jellyfish (Mortimer 1982). The Gulf of Mexico, Laguna Madre and Port Mansfield Channel waterways are an important foraging areas for juvenile green sea turtles. Recent records show increasing numbers of nesting green sea turtles, with 211 nests reported between 1987 and 2019; and 36 nests along the mid to lower coast reported in 2020 (Shaver et al., 2020). The majority of the 2020 green sea turtle nests were recorded at Padre Island National Seashore (28) and South Padre Island (7) (Turtle Island Restoration 2020).

Kemp's Ridley Sea Turtle

Kemp's ridley sea turtle was listed as endangered throughout its range on December 2, 1970 (35 FR 18320). Populations of the species have declined since 1947, when an estimated 42,000 females nested in one day (Hildebrand 1963), to a total nesting population of approximately 1,000 in the mid-1980s. The decline of the species was primarily due to human activities including collection of eggs, fishing for juveniles and adults, killing adults for meat and other products, and direct take for indigenous use. Threats affecting Kemp's ridley are often specific to life stages and the habitats where they occur. On the shoreline (nesting beach) threats to the species include: illegal harvest; beach cleaning; human presence during recreation or construction; recreational beach use; beach vehicular driving; construction activities such as beach nourishment, shoreline stabilization, and development; energy exploration, development and removal; ecosystem alterations such as beach erosion, vegetation composition changes, and invasive species; pollution from oil spills, exposure to toxins and chemicals from illegal dumping and garbage, and light; predation; and disease (NMFS et al., 2011). In open water, sea turtles caught in commercial and recreational fisheries are often injured or killed. Of all commercial and recreational fisheries in the US, shrimp trawling has had the greatest effect on the status of these sea turtle populations, followed by dredges, longlines, nets, and traps/pots. Entanglement in fishing gear can lead to abrasions, restrictions, tissue necrosis, and drowning. Kemp's ridley sea turtles are also susceptible to illegal harvest and boat strikes while in the water (NMFS et al., 2011). The Kemp's ridley sea turtle is the smallest of the sea turtles, with adults reaching about 2 feet in length and weighing up to 100 pounds. The species has a triangular-shaped head and a slightly hooked beak with large crushing surfaces. This specie's diet consists mainly of swimming blue crabs, but may also include fish, jellyfish, sea stars, snails, bivalves, shrimp, sea urchins, an array of mollusks, and occasional marine plants (NMFS et al. 2011). This species has nested sporadically in Texas over the last 50 years. However, the number of Kemp's ridley sea turtle nesting have increased recently, with a record setting 352 nests along the Texas coast (Shaver et al., 2017a). The majority of Kemp's ridley nests recorded in Texas were at the Padre Island National Seashore (Shaver 2017a).

Leatherback sea turtles

The leatherback sea turtle was listed as endangered throughout its range on June 2, 1970 (35 FR 8495), with CH designated at Sandy Point, St. Croix in the US Virgin Islands on March 23, 1979 (44 FR 17710). NMFS established a leatherback conservation zone extending from Cape Canaveral to the Virginia-North Carolina border and includes all inshore and offshore waters. Leatherback sea turtles face threats on both nesting beaches and in the marine environment. The greatest causes of decline and the continuing primary threats to leatherbacks worldwide are long-term harvest and incidental capture in fishing gear. Harvest of eggs and adults occurs on nesting beaches while juveniles and adults are harvested on feeding grounds. Incidental capture primarily occurs in gillnets, but also in trawls, traps and pots, longlines, and dredges. Additionally, leatherbacks are threatened by the existence of marine debris such as plastic bags and balloons, which they often consume after mistaking them for their preferred prey, jellyfish. Leatherback sea turtles are named for their appearance, because they do not have same type of shells as other sea turtles do. Instead, their backs are covered by a slate black to bluish-black leathery skin with irregular white or pink patches. They are the largest turtles in the world, reaching over 6 feet in length and weigh 650-1,200 pounds (NPS 2013). Despite their large size, the diet of leatherbacks consists largely of jellyfish and sea squirts. They also consume sea urchins, squid crustaceans, fish, blue-green algae, and floating seaweed (NFWL 1980). The leatherback, rarely nest in the southeastern U.S., but offshore waters are important feeding, resting, and migratory corridors for these species. No nests of this species have been recorded in Texas for at least 70 years (NPS 2006). One was recorded from the late 1920s and one from the mid-1930s, were both from Padre Island National Seashore (Hildebrand 1982, Hildebrand 1986).

Hawksbill Sea Turtle

The hawksbill sea turtle was federally listed as endangered on June 2, 1970 (35 FR 8495) with CH designated in Puerto Rico on May 24, 1978 (43 FR 22224). In 1998, NMFS designated additional CH near Isla Mona and Isla Monito, Puerto Rico, seaward to 3.9 miles (63 FR 46693—46701). The greatest threat to this species is harvest to supply the market for tortoiseshell and stuffed turtle curios (Meylan and Donnelly 1999). Hawksbill shell (bekko) commands high prices. Japanese imports of raw bekko between 1970 and 1989 represented the loss of more than 670,000 turtles. The hawksbill is also used to manufacture leather oil, oil, perfume, and cosmetics (NMFS 2006). Other threats include destruction of breeding locations by beach development, incidental take in lobster and Caribbean reef fish fisheries, pollution by petroleum products (especially oil tanker discharges), entanglement in persistent marine debris (Meylan 1992), and predation on eggs and hatchlings. The hawksbill sea turtle is a small to medium-sized marine turtle with an elongated oval shell with overlapping scutes on the carapace, a relatively small head with a distinctive hawk-like beak, and flippers with two claws. An adult may reach up to 3 feet in length and weigh up to 300 pounds, although adults more commonly average about 2.5 feet in length and typically weigh around 176 pounds. While the species is omnivorous, it prefers invertebrates, especially encrusting organisms, such as sponges, tunicates, bryozoans, mollusks, corals, barnacles, and sea urchins. Pelagic species consumed jellyfish and fish, and plant material such as algae, sea grasses, and mangroves, have been reported as food items for this turtle (Mortimer 1982). The young are reported to be somewhat more herbivorous than adults (Ernst and Barbour 1972). Stranding data from 2004 through 2007 show that 59 hawksbill were found along Texas waters or shorelines. Of the hawksbill strandings reported during that period, 17 were from the mouth of the Rio Grande to the vicinity of Yarborough Pass near Baffin Bay and includes the action areas of South Padre Island. Further up coast, hawksbill sea turtles become rarer with none being recorded from the upper coast region. No hawksbills have been killed or captured during relocation trawls or dredging operations since record-keeping began in 1995 at any of the dredging locations (USACE 2019). However, the hawksbill sea turtle has a higher likelihood of occurrence within the Port Mansfield Channel and South Padre Island beach nourishment areas than any of the other action areas. Despite the lack of observed occurrence in many of the action areas, this species could occur in any of the action areas.

Migratory Birds

The Service is the principal federal agency with the oversight for all species (16 U.S.C. 703-712) protected under the Migratory Bird Treaty Act of 1918 (MBTA) (50 CFR 10.13). The Migratory Bird Species list published by the Service was last published on April 16, 2020 and includes 1,093 avian species protected under the MBTA (85 FR 21282). The Act makes it illegal for anyone to take, possess, import, export, transport, sell, purchase, barter, or offer for sale, purchase, or barter, any migratory bird, or the parts, nest, or eggs of such a bird except under the terms of a valid permit issued pursuant to Federal regulations. While the purpose of the FWCAR is to identify key focal habitats within the study area and determine methods to minimize adverse effects to trust resources if alternatives are presented, we recommend the Corps evaluate each ER and CSRM measures for negative effects to resident and migratory bird species, specifically those that are listed on the BCC and the North American Bird Conservation Initiative. We recommend the use of the Service's Nationwide Standard Conservation Measures as guidance to reducing adverse effects to birds and their habitats.

The Gulf Coast of Texas lies within the Central Flyway, a critically important conservation area that sustains the millions of migratory birds that seasonally move along the Texas coast. Tens of millions of individuals of at least 300 species of migratory birds funnel through the Texas coast. They rest, and replenish fat reserves throughout coastal Texas as they move between temperate breeding areas in North America and wintering areas in Central and South America. Of these migratory species, many are also designated as conservation priorities due to declining, threatened, or otherwise vulnerable populations. These priorities are generated by federal and state natural resource agencies and international bird conservation initiatives such as Partners in Flight.

The Service's list of Birds of Conservation Concern (BCC) includes species of migratory birds of high conservation priority at national, regional, and eco-regional scales. Species identified on these lists are considered vulnerable and are among the highest bird conservation priorities for the Service and our partners. Many of these species are experiencing widespread declines and could potentially become candidates for federal listing under the ESA in the future. Therefore, it is particularly important to fully consider adverse effects to BCC species when assessing short-term and cumulative effects of projects that can reasonably be expected to influence habitats, behaviors, and demographics of these species.

The study area lies within BCR – 36 Tamaulipan Bushlands and BCR 37 – Gulf Coastal Prairie (U.S. portion only). The BCC list for this Bird Conservation Region includes 44 species (USFWS 2008). In addition to BCC lists maintained by the Service, TPWD maintains lists of state listed species (http://tpwd.texas.gov/huntwild/wild/wildlife_diversity/nongame/listed-species/birds.phtml) and rare species by county (http://tpwd.texas.gov/gis/rtest/). Many of the species identified in BCR 37 are found within the Texas Coastal Study footprint.

The study area contains many geographic features that concentrate migratory bird species. The Gulf, barrier islands, and peninsular land-masses all act as funnels or concentrating geologic features. Gauthreaux et al. (2006) identifies the Texas Chenier Plains located between Houston, Texas and Lake Charles, Louisiana as particularly important to Neotropical migrants, in part due to the geology of the continental shelf, and microhabitats related to the geomorphology of the Gulf of Mexico. Neotropical migrants, shorebirds, waterbirds, and waterfowl migrate through this funnel every spring. Several million of these birds, comprised of about 75 species, make trans-gulf migrations through the upper Gulf Coast of Texas (Krueper, pers. comm 2016, Shackelford et al. 2002). During favorable weather, migrants will continue their trans-gulf migration up to 75 miles inland as they seek large patches of wooded habitat (Gauthreaux 1971). In less favorable weather, more coastal sites such as High Island Bird Sanctuary, or other small patches of isolated woods closer to the coast are used heavily. Radar studies indicate high volume of migrants passing through during the spring, with estimates of 50,000 birds occurring in a single night (Gauthreaux 1971). Migrants are recorded nearly nightly during spring migration, (Gauthreaux 1971, Gauthreaux et al. 2006) and the upper Gulf Coast of Texas and southwestern Louisiana are targeted preferentially by Neotropical migrants (Gauthreaux et al. 2006). Migration altitude, bird density, and migration timing are highly dependent on local and regional weather conditions. During poor weather especially, migrant birds are prone to collisions due to lower flight heights, reduced visibility, or high wind conditions that may impact their flight (Anderson et al. 1999).

Coastal wetlands found within the study area are preserved and managed for migratory birds on many Texas NWRs and WMAs including the recent TPWD land acquisition of Powderhorn Ranch. These trust resources provide wintering habitat for hundreds of thousands of geese and ducks and provide critical landfall in the spring for Neotropical migratory birds. Coastal wetlands, prairie, and woodland habitats also provide important habitat for 37 of the 48 avian species listed by the Service as Species of Conservation Concern in the Gulf Prairies Bird Conservation Region (USFWS, 2005). Wetland-dependent avian species of conservation concern occurring in the study area include: yellow rails (*Coturnicops noveboracensis*), eastern black rails, American bittern (*Botaurus lentiginosus*), white ibis (*Eudocimus albus*), hudsonian godwit (*Limosa haemastica*), long-billed curlew (*Numenius americanus*), short-billed dowitcher (*Limnodromus griseus*), least tern (*Sterna antillarum*), seaside sparrow (*Ammodramus maritimus*), and sprague's pipit (*Anthus spragueii*). Agricultural practices, navigation, residential and industrial developments have contributed to the decline in the habitats that support these migratory bird species. The ER measures proposed by this study have the potential to restore these habitats crucial for sustaining these migratory bird populations.

Colonial Waterbirds

Colonial waterbirds are birds that gather in large groups called rookeries or colonies during the nesting season and they obtain all or most of their food from the water. Colonial nesting waterbirds and/or seabirds commonly inhabit the dredge spoil and natural islands, and where suitable habitat may be located on mainland. Islands typically provide a boundary to most predators. However, predators such as coyotes and raccoons are known to swim to these nearby islands. Islands located greater than a mile from any shoreline are more likely to have minimal predator interference and provide opportunities for greater fledging success.

The Texas Colonial Waterbird Society (TCWBS) recognizes over 500 active and historic colony and sub colony sites along the Texas coast, although additional colonies may be present within the study area that are not currently listed in the database. The database is updated annually by monitoring previously known colony sites. However new sites are added as new colonies are located. Since 1978, the TCWBS annually surveys 23 colonial waterbird species during the primary breeding and nesting season (February 1 to September 1) to identify population trends and make management recommendations to our partners along the coast. Recent trends (2000 through 2020) indicate a decline for many of the surveyed species which may be attributed to predator presence (including humans) and habitat erosion or conversion. Although several comprehensive coast-wide surveys have been recently conducted to determine the location of newly-established nesting colonies, the Service recommends that a qualified biologist inspect the proposed work site for the presence of undocumented nesting colonies prior to finalizing any construction plans for the proposed ER measures.

While many species of colonial waterbirds appear to have stable populations, they face many threats such as oil pollution associated with increased tanker traffic and spills, direct mortality from entanglement and drowning in commercial fishing gear, depletion of forage fish due to overexploitation by commercial fisheries, habitat limitations, and the presence of predators at nesting sites.

Comprehensive restoration of priority islands for breeding birds is needed as many islands are still overrun by invasive species. Some of these rookery islands or colonial bird nesting sites are no longer suitable due to: the presence of invasive predator species; overgrown vegetation; lack of open ground nesting habitat; erosion or subsidence; and no longer have appropriate elevations to support nesting birds, or the lack of available forage sites in close proximity to nesting habitat. The once endangered brown pelican (*Pelecanus occidentalis*), considered a major conservation success story, was delisted in 2009 in large part due to intensive rookery management and island creation at North and South Deer Islands, in West Bay and Evia Island in East Bay, in Texas. These islands were managed to promote optimal breeding and foraging habitats for brown pelicans and other colonial waterbirds.

The construction of bird islands using dredged material is well documented, but it was not until the 1970s that the importance of this dredged material to nesting waterbirds was realized (Golder et al. 2008). Dredge spoil islands created out of local sand and clays provide immediate nesting opportunities for bare ground nesters such as terns and skimmers. Successional vegetation including mangroves (*Baccharis halmifolia*) and other shrub spices provide suitable nesting habitat for three species of egrets, five species of herons, white ibis, and rosette spoonbills (*Platalea ajaja*). The ER measures proposed in this study and subsequent projects could positively contribute to the colonial waterbird populations across the Gulf of Mexico.

The North American Waterbird Conservation Plan (NAWCP) (Kushlan et al. 2002) classified colonial and semi- colonial breeding water bird species into one of several “at risk” categories, including “not currently at risk”, “low”, “moderate”, “high”, “highly imperiled”, and identified those species for which there is “insufficient information available to assess risk.” Wetland habitats found within the study area also provide important wintering, migration and/or nesting habitat for 14 colonial and semi-colonial water bird species deemed at moderate risk, and 6 species deemed at high risk. High risk species include: tri-colored heron (*Egretta tricolor*), little blue heron (*Egretta caerulea*), snowy egret (*Egretta thula*), least tern, wood stork (*Mycteria americana*), and gull-billed tern (*Gelochelidon nilotica*). The NAWCP identifies the major threat to colonial waterbirds is deterioration of habitat in the Southeast U.S.

Waterfowl

It has been estimated that the coastal wetlands of Texas and the nearby rice fields and coastal waters of the Gulf of Mexico provide winter homes for up to 45% of the ducks and 90% of the geese in the Central Flyway. Of these migratory species, many are designated as conservation priorities, by a number of organizations, due to declining, threatened, or otherwise vulnerable populations.

Additionally, wetland habitats within the Study area provide important wintering and migration habitat for many species of Central Flyway waterfowl, including several species of ducks whose continental populations are below the goals established by the North American Waterfowl Management Plan (NAWMP) (USFWS 2018). These species include northern pintail (*Anas acuta*) lesser scaup (*Aythya affinis*), and ring-necked duck (*Aythya collaris*).

The mottled duck (*Anus fulvigula*) is a year-round resident of the Gulf Coast, and conservation and management of this species is a major goal of the NAWMP Gulf Coast Joint Venture (GCJV) Chenier Plain Initiative Plan (Esslinger and Wilson, 2001). Meeting the waterfowl population objectives established by the GCJV Chenier Plain Initiative Plan requires restoration actions for coastal wetlands to increase their value to waterfowl (Esslinger and Wilson 2001). These actions include reducing wetland loss (conversion to open water) and restoring degraded wetlands. This medium sized dabbling and non-migratory duck, is the only duck species adapted to breed in the southern wet coastal prairies and wetlands of the Texas gulf coast. Although mottle ducks are not federally listed under ESA, it is a focal species for the Service and many others. Mottled ducks spend their entire life on the coastal prairie and adjacent wetlands relying on the availability of these habitats for its existence (Merendino et al. 2005). Once abundant along the Texas coast, the mottled duck is primarily found along preserved and development free areas with highest densities often observed in fresh and intermediate coastal wetlands of the Texas Chenier Plain Refuge Complex and moderate densities found in the coastal wetlands of the Texas Mid-Coast Refuge Complex. Most common habitats include fresh to brackish coastal wetlands, ponds, emergent freshwater wetlands, and flooded rice fields of the prairie. In south Texas, mottled ducks are frequently found in resacas of the Rio Grande Valley and freshwater ponds associated with coastal grasslands. Mottled duck populations have declined over the years due to the loss of suitable nesting and brood-rearing habitat (Krainyk & Ballard, 2015), which includes grasslands and palustrine and estuarine wetlands.

Although the amount of Gulf coastal prairie is small, it provides wintering habitat for large concentrations of waterfowl: 95% of gadwall, 90% of mottled duck, 80% of green-winged teal, 80% of redheads, 60% of lesser scaup, 25% of pintails, and mid-continent lesser snow and white-fronted geese populations (Ducks Unlimited). Additionally, coastal prairie provides migration habitat for most of the blue-winged teal that winter in Central and South America. With such large waterfowl populations migrating through or wintering in coastal Texas, federal and state partners have set aside land specifically aimed to conserve wetlands and coastal prairies for the benefit of waterfowl.

Existing Fishery Resources

The Study area's wetlands and associated shallow waters provide nursery and feeding habitat for recreationally and commercially important estuarine-dependent fishes and shellfishes (e.g., red drum, black drum, Atlantic croaker, spot, sand seatrout, spotted seatrout, southern flounder, Gulf menhaden, striped mullet, blue crab, white shrimp and brown shrimp). These fisheries are also important food sources for piscivorous migratory birds, threatened and endangered species, and other wildlife.

Essential Fish Habitat

The Magnuson Stevens Fishery Conservation and Management Act (MSFCMA) (PL 94-265), as amended, provides for the conservation and management of the Nation's fishery resources through the preparation and implementation of Fishery Management Plans (FMPs) (16 USC 1801 et seq.). The MSFCMA calls for NMFS to work with regional Fishery Management Councils to develop FMPs for each fishery under their jurisdiction. One of the required provisions of FMP specifies that Essential Fish Habitat (EFH) be identified and described for the fishery, adverse fishing impacts on EFH be minimized to the extent practicable, and other actions to conserve and enhance EFH be identified. When NMFS finds that a Federal or State action would adversely affect EFH, it is required to provide conservation recommendations.

Essential Fish Habitat is defined as "those waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity" (16 United States Code 1802(10)). EFH is found in the tidally influenced or estuarine emergent wetland communities and brackish or marine open-water communities within the proposed project areas. These communities play an important role in the cycling of nutrients and food energy through coastal ecosystems. Communities, such as wetlands, produce detritus that is transferred to food energy for higher trophic levels via zooplankton, bivalves, crustaceans, and small fish.

Estuaries along the Texas coast often contribute to the shellfish resources of the Gulf. Shellfish species range from those located only in brackish wetlands to those found mainly in saline wetlands and inshore coastal waters. Multiple species of penaeid shrimp are expected to occur in the vicinity of the proposed project areas; however, brown shrimp (*Farfantepenaeus aztecus*) and white shrimp (*Litopenaeus setiferus*) are the most numerous (Nelson et al., 1992). At least eight species of portunid (swimming) crabs are common residents of the coastal and estuarine waters of the northern Gulf. Brown shrimp, white shrimp, blue crabs (*Callinectes sapidus*), and Eastern oyster are the primary shellfish located throughout Texas that comprise a substantial fishery (Turner and Brody, 1983). Life histories of many Gulf fish can be characterized as estuarine-dependent. These species typically spawn in the Gulf, and their larvae are carried inshore by currents. Juvenile fish generally remain in these estuarine nurseries for about a year, taking advantage of the greater availability of food and protection that estuarine habitats afford. Upon reaching maturity, estuarine-dependent fishes migrate to sea to spawn (returning to the estuary on a seasonal basis) or migrate from the shallow estuaries to spend the rest of their lives in deeper offshore waters (Pattillo et al., 1997).

Detailed information on federally managed fisheries and their EFH is provided in the 2005 generic amendment of the Fishery Management Plans for the Gulf of Mexico, prepared by the Gulf of Mexico Fishery Management Council (GMFMC) and can be found at http://gulfcouncil.org/fishery-management/.

The Service recommends the Corps initiate consultation with NMFS Southeast Regional Office Habitat Conservation Division located in Galveston, Texas (409) 766-3699 to determine specific impacts to EFH as a result of the proposed Study.

<u>Finfish and Shellfish</u>

There are more than 600 species of Texas marine fishes occupying all habitats from the estuaries to the ocean depths of the abyssal zone 150 miles off the barrier islands (Anderson and Ditton 2004). The Study area includes multiple bays and bayous with estuarine emergent wetlands, which are important nursery habitat for recreational and commercially harvested marine and estuarine finfish and shellfish that are important to the local economy of Texas. Approximately 97% of all finfish and shellfish are dependent in some way on the coastal bays where fresh water inflows from streams and rivers combine with tidal waters of the Gulf of Mexico. Many economically important migratory finfish and shellfish species, such as striped mullet, Atlantic croaker, gulf menhaden, spotted seatrout, sand seatrout, southern flounder, black drum, blue crab, white and brown shrimp, migrate from the bays through the natural passes into Gulf waters to spawn. Their new recruits migrate back through natural passes to bay waters to utilize the estuarine wetlands within rivers and bayous for refugia and foraging from juvenile to adult life stages.

Economic Value of Fisheries

The following information is summarized from Bohannon et al. (2015). Commercial fishing supports many communities along the Gulf Coast, providing employment, income and revenue from sales. Between 1994 and 2012 over 959 million pounds of seafood products (excluding bait shrimp), with an ex-vessel value of over $2.7 billion, were reported harvested from Texas bays and the Gulf of Mexico offshore of Texas. Total landings and ex-vessel value have declined 32% and 34%, respectively during this 19-year period, from nearly 58 million pounds in 1994 to 39 million pounds in 2012.

During the five year period from 2008-2012, brown shrimp (*Farfantepenaeus aztecus*), pink shrimp (*F. duorarum*), and white shrimp (*Litopenaeus setiferus*), represented approximately 72% of the total coast-wide bay and Gulf landings by weight, and 79% of total ex-vessel value. During this same five year period, blue crab represented 7% of total landings and 2% of total ex-vessel value; eastern oyster represented 15% of total landings and over 17% of total ex-vessel value; and finfish represented 10% of the total landings and 8% of the total ex-vessel value.

A comparison of landings between major bay systems for the five year period 2008-2012 indicated that the majority of white shrimp landings came from the Galveston Bay system (76%). The majority of brown and pink shrimp landings were also landed from Galveston Bay (45%), with additional contributions from Matagorda Bay (29%) and San Antonio Bay (11%). Blue crab landings were predominantly from Galveston Bay (34%), Aransas Bay (18%), San Antonio Bay (17%) and Sabine Lake (16%). Most of the eastern oyster landings were from Galveston Bay (54%), with San Antonio Bay (24%) and Aransas Bay (14%) increasing their landings from previous years. The majority of finfish were landed in the upper Laguna Madre (55%), followed by Galveston Bay (15%) and lower Laguna Madre (14%). Black drum (*Pogonias cromis*) was the dominant fish in all bay landings during this five year period. Snapper were the dominant finfish landed in all Gulf grid zones during the five-year period 2008-2012.

Finfish species reported in 2012 total landings data primarily consisted of snapper (, black drum, grouper (Family Serranidae), tilefish (Family Malacanthidae), Atlantic croaker (*Micropogonias undulatus*), and flounder (Family Paralichthyidae). Total finfish landings and ex-vessel value in 2012 increased 1% and 22%, respectively, since 2011. Flounder landings and ex-vessel value declined 20% and 14%, respectively, between 2011 and 2012. Although 2012 black drum landings declined 9% from 2011, ex-vessel value increased 3% over the same time period.

Coastwide total shrimp landings and ex-vessel value declined by 9% and 13%, respectively, from 2011 landings. Coastwide blue crab landings and ex-vessel value declined by 1% and increased by 1%, respectively, between 2011 and 2012. Coastwide eastern oyster landings and ex-vessel value increased by 34% and 67%, respectively, during this same period.

Numerous factors, both natural and human-induced, have contributed to the notable decline in both landings and ex-vessel value (32% and 34%, respectively) between 1994 and 2012. Natural factors include both short-term events such as hurricanes (Allison in 2001, Claudette in 2003, Rita in 2005, Erin in 2007, Ike in 2008, Hermine in 2010, Harvey 2017), and longer events such as prolonged drought and associated reduced freshwater inflow in 2011. Hurricanes may force closures of fishing grounds for several months after the storms make landfall, as well as temporarily impact wholesale and retail seafood dealer infrastructure, both of which could influence fishery landings and value (NMFS 2007). Prolonged drought has been documented to negatively impact abundance, metabolic costs, and commercial fishery harvest of several of the more important commercial species in Texas (Longley 1994), including white shrimp, brown shrimp, eastern oyster, blue crab, and black drum.

Finfish are usually highly mobile, therefore any impacts to those species will be minimal and temporary. However, increases in suspended sediments and turbidity levels from dredging and disposal operations, could under certain conditions, result in adverse effects on marine animals and plants (seagrass) by reducing light penetration into the water column and by the actual physical disturbance. Elevated suspended solids in the water column may also impair respiration and foraging, or result in mortalities for shellfish (e.g., oysters, crabs, shrimp) and juvenile finfish (Wilbur & Clarke, 2001).

Future Conditions

Sea level rise, shoreline retreat and the loss or conversion of coastal wetlands remains the primary issues affecting the study area's fish and wildlife resources. Although these natural and anthropogenic factors can be attributed to changing climates and human disturbances, there are other physical factors to be considered. Given the coastal area's low elevation, flat terrain, and proximity to the Gulf, the people, economy, and unique environments along the Texas coast are at risk due to tidal surge flooding and tropical storm waves. In addition, continued loss of natural surrounding ecosystems will contribute to the region's loss of biodiversity. Land subsidence, combined with rising sea level, is expected to increase the potential for coastal flooding, shoreline erosion, saltwater intrusion, and loss of wetland and barrier island habitats in the future.

The terms "climate" and "climate change" are defined by the Intergovernmental Panel on Climate Change (IPCC). "Climate" refers to the mean and variability of different types of weather conditions over time, with 30 years being a typical period for such measurements, although shorter or longer periods also may be used (IPCC 2007). The term "climate change" thus refers to a change in the mean or variability of one or more measures of climate (e.g., temperature or precipitation) that persists for an extended period, typically decades or longer, whether the change is due to natural variability, human activity, or both (IPCC 2007). Various types of changes in climate can have direct or indirect effects on species. These effects may be positive, neutral, or negative and they may change over time, depending on the species and other relevant considerations, such as the effects of interactions of climate with other variables (e.g., habitat fragmentation) (IPCC 2007). Changes in temperature and/or precipitation patterns will influence the status of the coastal landscape. These changes may contribute to threats that have already been identified and discussed for listed species.

Effects of climate change on ecosystems are difficult to predict, due to both uncertainty in climate change scenarios (direction and magnitude of temperature and precipitation) and uncertainty in understanding how species will respond to those changes. Changes in extreme weather events, precipitation, temperature, and sea-level rise are expected to alter coastal habitats resulting in loss of habitats and their component wildlife species.

The repetition of tropical storm events, hurricanes, and human modification of hydrology and coastal features has increased ecosystem vulnerability throughout the Texas coast. Successive disturbance and salt stress from interference with freshwater flows has put in jeopardy the process by which wetlands accrete sediments and land accumulation occurs. Without a healthy plant community, sedimentary deposition decreases due to the loss of plants in the water column, biogenic accretion ceases due to the lack of plant detritus, and the substrate becomes exposed, leading to rapid erosion (Williams et al., 2009). At some point in time when wetlands are unable to accrete enough sediment to maintain target elevations for plant survival as sea level rises, there will not be an adequate density of wetlands along the coast to withstand impacts of storm surge, and delay post-storm recovery efforts. As these conditions are currently occurring within the context of climate change, there is also an increase in the intensity of tropical storms, rising average annual temperatures, and an increase in the rate of relative sea level change.

In the future, marine influences and other natural and human factors, such as subsidence, sea level change, navigation channels, oil and gas development, industry growth, and population increases would be expected to result in continued coastal habitat loss in the study area. The coastal vegetation resources would continue to decline through shoreline erosion, sloughing of the shoreline, and continued fragmentation and conversion of existing brackish and saline wetlands to shallow open water habitats.

RSLR is the most likely factor to result in significant changes to biological communities. Future RSLR threatens existing vegetated wetlands with submergence and conversion to open water. Increased saltwater intrusion and introduction of tidal energies to historically non-tidal or micro-tidal freshwater wetlands is expected to continue causing plant mortality, peat collapse and erosional loss of organic wetland soils, leading to habitat switching and conversion of vegetated wetlands to open water. It is likely that these impacts have been and will be the most severe in areas subject to saltwater intrusion from the navigation channels and seawater overwash and in areas with rapid subsidence.

Significant reductions of the brackish and saline wetlands in the future is anticipated because of the accelerated rate of land loss and the narrowing of zones based on differing salinity regimes. Land loss, saltwater intrusion, and marine influences, conditions that would exacerbate the loss of barrier beach system, would result in the narrowing of the broadly delineated zones of coastal habitat types that exist today. As these zones narrow into smaller bands of coastal habitat types, the acreage associated with each coastal habitat type, particularly brackish and saline wetlands, would also diminish.

The barrier beach system, which includes the beach and dune, would continue to erode under normal conditions and would likely be breached during significant storm events. The only location where this would not be as catastrophic is at locations where beach nourishment restoration efforts are already underway and renourishment is expected to continue into the future or where beach accretion is occurring. Without the protective buffer provided by the beach and dune systems, interior wetlands would be at an increased risk to severe damage from tropical storm events.

There are anticipated long-term impacts to wetlands along the coast due reductions in freshwater inflows as a result of an increasing demand for water as the population of Texas is expected to double during the life of the project. Lower freshwater inflows into wetlands and inland freshwater habitats, in addition to increased development from population growth is also anticipated to reduce the acreage of coastal wetland habitats.

In marine habitats, salinity changes from increased rainfall or tidal influences, increases in water temperatures, extreme weather events, and increased absorption of carbon dioxide is contributing to a reduction or redistribution of reef forming organisms. The reduction in oyster habitat has also resulted in a decrease in nursery habitat for recreationally and commercially important fish species, and a reduction in suitable habitat for rare or imperiled species. Without addition of cultch materials or management practices to protect the substrate vital to oyster recruitment, this negative trend is very likely to continue into the future.

Impacts to coastal habitats found in the study area and the associated wildlife and fisheries resources are expected to vary both temporally and spatially; but without robust measures to halt alteration of these habitats, these trends may be irreversible and severe, particularly for listed species, species of concern, and rare, unique, or imperiled communities. The added impacts of climate change on coastal habitats may greatly increase the threats to already vulnerable populations and species, resulting in reduced biodiversity (Ohlemuller et al. 2008). It is likely without significant changes in management of these valuable resources, that there will be an increase in species warranting conservation and protection, and even extirpation in the study area.

Approaches for managing climate change risk include: maintaining wetlands and urban green spaces; coastal afforestation; watershed and reservoir management; reduction of other stressors on ecosystems and of habitat fragmentation; maintenance of genetic diversity; manipulation of disturbance regimes; community-based natural resource management (IPCC, 2014).

DESCRIPTION OF RECOMMENDED PLAN AND EVALUATED ALTERNATIVES

The following is a summary of the plan formulation process that took place to arrive at the recommended plan (RP). A complete detailed description of the plan formulation process is available in Appendix A of the Feasibility Report.

Also because of the uncertainty and complexity of a number of the potential solutions to the problems, the Study employs a tiered NEPA compliance approach, in accordance with the Council on Environmental Quality's (CEQ's) Regulations for Implementing the Procedural Provisions of the National Environmental Policy Act (40 CFR 1500—1508, specifically 1502.20). Under this structure, rather than preparing a single definitive EIS as the basis for approving the entire project, the Corps will conduct two or more rounds – or "tiers" – of environmental review. For projects as large and complex as the Study, this approach has been found to better support disclosure of potential environmental impacts for the entire project at the initial phase. Subsequent NEPA documents are then able to present more thorough assessments of impacts and mitigation need as the proposed solutions are refined and more detailed information becomes available in future phases of the project. This tiered approach also provides for a timely response to issues that arise from specific, proposed actions and supports forward progress toward completion of the overall study.

A Tier One assessment analyzes the project on a broad scale, while taking into account the full range of potential effects to both the human and natural environments from potentially implementing proposed solutions. The purpose of the Tier One EIS is to present the information considered to selected a preferred alternative, describe the comprehensive list of measures, and identify data gaps and future plans to supplement the data needed to better understand the direct, indirect, and cumulative effects of the proposed solutions.

Once refinements and additional information is gathered, Corps will shift to a Tier Two assessment, which involves preparation of one or more additional NEPA documents (either an EIS or Environmental Assessment) that build off the original EIS to examine individual components of the Recommended Plan in greater detail. Whether an EIS or EA is developed will be dependent on the significance of impacts anticipated from the action. In either situation, Tier Two assessments will comply with CEQ Regulations, including providing for additional public review periods and resource agency coordination. The Tier Two document would disclose site specific impacts to the proposed solution and identify the avoidance, minimization, and compensatory mitigation efforts to lessen adverse effects.

The study authorization directed the study team to evaluate ER and CSRM solutions. These two purposes recognize that the study area is vulnerable to both storm risk and the gradual coastal processes that wear away natural coastal areas and habitats. To enhance the resiliency, redundancy, and robustness, measures were generally assembled to:

- **Form Multiple Lines of Defense:** This strategy recognizes the benefits natural landforms provide against coastal storms. By combining various lines of defense (e.g.

barrier islands, living shorelines, coastal wetlands, etc.), redundant levels of protection and restoration are provided for both humans and coastal ecosystems.

- **Be Comprehensive:** The CSRM alternatives were assembled within a systems approach to work in conjunction with other measures considered, connect to existing systems, and be adaptable over time.

Three phases occurred during the planning process:

- **Conceptual Plans:** Evaluates potential measures and assesses effectiveness of combined ER and CSRM measures to achieve study objectives.

- **Tentatively Selected Plan (TSP) Selection:** Quantifies and compares benefits and impacts to identify the TSP (National Economic Development [NED] and National Ecosystem Restoration plans [NER]), supporting publication of the 2018 Draft Report.

- **Integration and Refinement of the TSP:** Refines the benefits and impacts of the TSP, considers public, agency, and technical comments, in addition to refining technical information, and identifies the **Recommended Plan (RP)**.

Ecosystem Restoration Measures

For determining what ER measures were appropriate for the Texas coast to meet the objectives of the study, the Corps and interagency team assembled a wide variety of potential measures, drawn from the GLO's Coastal Resiliency Master Plan, past Corps studies, NEPA public scoping, and resource agency suggestions. Restoration of wetlands, oyster reef, bird island rookeries, beaches and dunes, and hydrology, as well as shoreline stabilization throughout various critical areas along the coast comprised the 67 ER measures that were initially considered, including 40 measures in Region 1, 15 measures in Region 2, eight measures in Region 3, and four measures in Region 4. During the conceptual phase of screening, the 67 restoration measures were evaluated and refined by an interagency team who screened them for performance, viability, and whether the measures would achieve the planning objectives. A total of eight ER measures in six different counties were retained (**Error! Reference source not found.Error! Reference source not found.**). The following describes the measures that were carried forward:

- **G-28: Bolivar Peninsula and West Bay Gulf Intracoastal Waterway (GIWW) Shoreline and Island Protection**
    - Shoreline protection and wetland restoration through the sediment nourishment of 664 acres of eroding and degrading wetlands and construction of 40.4 miles of breakwaters along unprotected segments of the GIWW on Bolivar Peninsula and along the north shore of West Bay,
    - Restoration of 326 acres (approximately 5 miles) of an island that protected the GIWW and mainland in West Bay, and

- Addition of oyster cultch to encourage creation of 18.0 acres (26,280 linear feet) oyster reef on the bayside of the restored island in West Bay.

- **B-2: Follet's Island Gulf Beach and Dune Restoration**
  - Restoration of 10.1 miles (1,113.8 acres) of beach and dune complex on Gulf shorelines of Follet's Island in Brazoria County.

- **B-12: West Bay and Brazoria GIWW Shoreline Protection**
  - Shoreline protection and wetland restoration through sediment nourishment of 551 acres of eroding and degrading wetlands and construction of about 40 miles breakwaters along unprotected segments of the GIWW that protects the shorelines, in Brazoria County,
  - Construction of about 3.2 miles of rock breakwaters along western shorelines of West Bay and Cow Trap Lake, and
  - Addition of oyster cultch to encourage creation of 3,708 linear feet of oyster reef along the eastern shorelines of Oyster Lake

- **M-8: East Matagorda Bay Shoreline Protection**
  - Shoreline protection and wetland restoration through the sediment nourishment 236.5 acres of eroding and degrading wetlands, and construction of 12.4 miles of breakwaters along unprotected segments of the GIWW in Matagorda County,
  - Restoration of 96 acres (3.5 miles) of island in East Matagorda Bay that protects shorelines directly in front of Big Boggy NWR, and
  - Addition of oyster cultch to encourage creation of 3.7 miles of oyster reef along the bayside shorelines of the restored island.

- **CA-5: Keller Bay Restoration**
  - Construction of 3.8 miles of rock breakwaters along the shorelines of Keller Bay in order to protect submerged aquatic vegetation (SAV), and
  - Construction of 2.3 miles of oyster reef along the western shorelines of Sand Point in Lavaca Bay by installation of reef balls in nearshore waters.

- **CA-6: Powderhorn Shoreline Protection and Wetland Restoration**
  - Shoreline protection and wetland restoration through the sediment nourishment of 529 acres of eroding and degrading wetlands and construction of 5.0 miles of breakwaters along shorelines fronting portions of Indianola, the Powderhorn Lake, and Texas TPWD's Powderhorn Ranch in West Matagorda Bay.

- **SP-1: Redfish Bay Protection and Enhancement**
    - Construction of 7.4 miles of rock breakwaters along the unprotected segments of the GIWW along the backside of Redfish Bay and on the bayside of the restored islands
    - Restoration of 391.4 acres of islands including Dagger, Ransom, and Stedman Islands in Redfish Bay, and
    - Addition of oyster cultch to encourage creation of 1.4 miles of oyster reef between the breakwaters and island complex to allow for additional protection of the Redfish Bay Complex and SAV.
- **W-3: Port Mansfield Channel, Island Rookery, and Hydrologic Restoration**
    - Restoration of the hydrologic connection between Laguna Madre and the Gulf of Mexico by dredging 6.9 miles of the Port Mansfield Channel, providing 112,864.1 acres of hydrologic restoration in the Lower Laguna Madre,
    - 9.5 miles of beach nourishment along the Gulf shoreline north of the Port Mansfield Channel using beach quality sand from the dredging of Port Mansfield Channel, and
    - Protection and restoration of existing Mansfield Island with construction of a 0.7 mile rock breakwater and placement of sediment from the Port Mansfield Channel to create 27.8 acres of island surface at an elevation of 7.5 feet (NAVD 88).

The eight ER measures retained in the RP were combined into alternatives based upon specific planning objectives and strategies. All eight measures were considered as Alternative 1, while subsets of these eight ER measures were combined into Alternatives 2 through 6, based upon specific planning objectives and strategies (Table 3 and

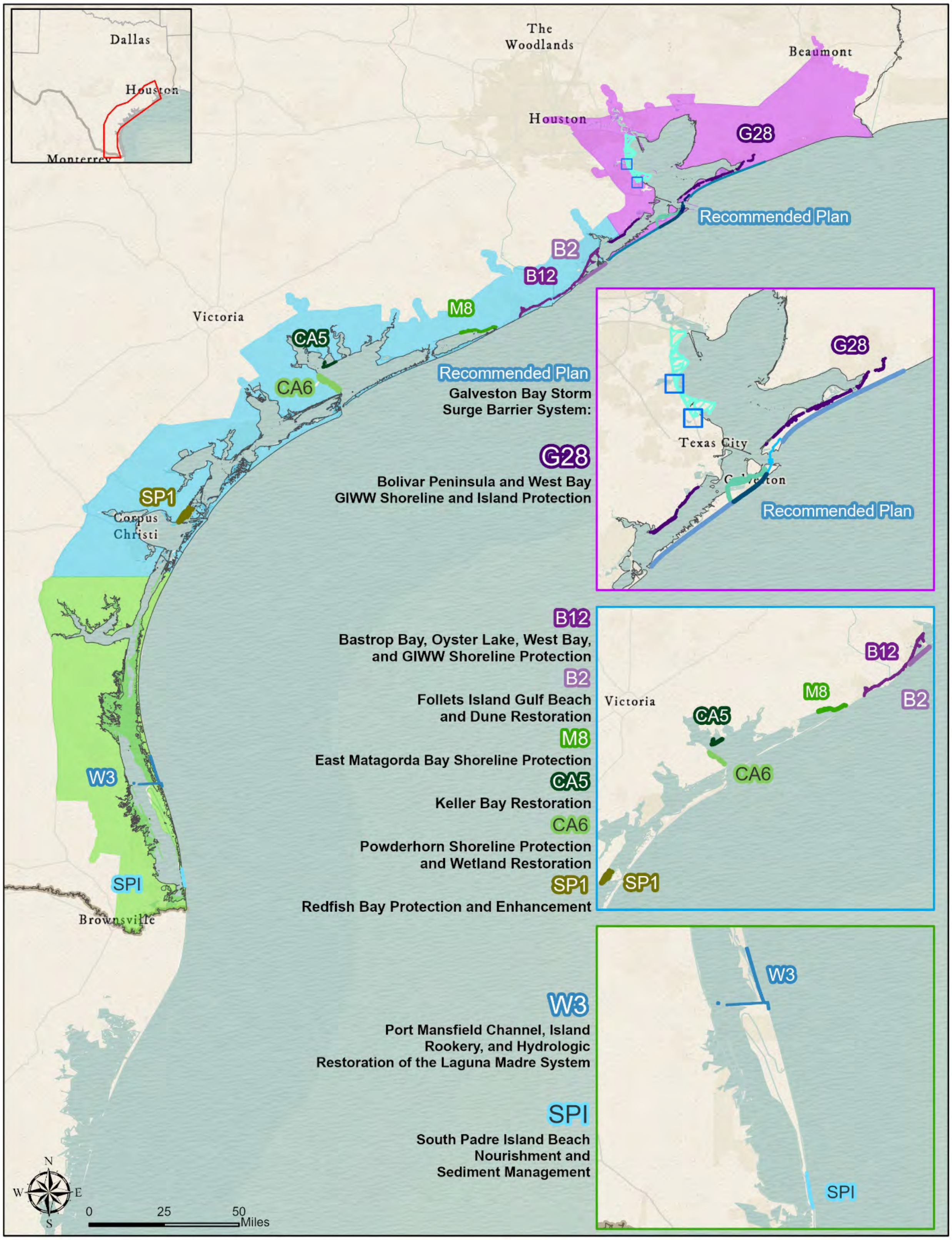

Figure 5. ER Measures Retained

Table 4).

Table 3. ER Measures in each Alternative

Alternative	G-28	B-2	B-12	M-8	CA-5	CA-6	SP-1	W-3
Alt 1	●	●	●	●	●	●	●	●
Alt 2		●	●			●		●
Alt 3	●	●						●
Alt 4	●		●	●	●	●	●	
Alt 5	●	●	●					
Alt 6	●	●	●		●			

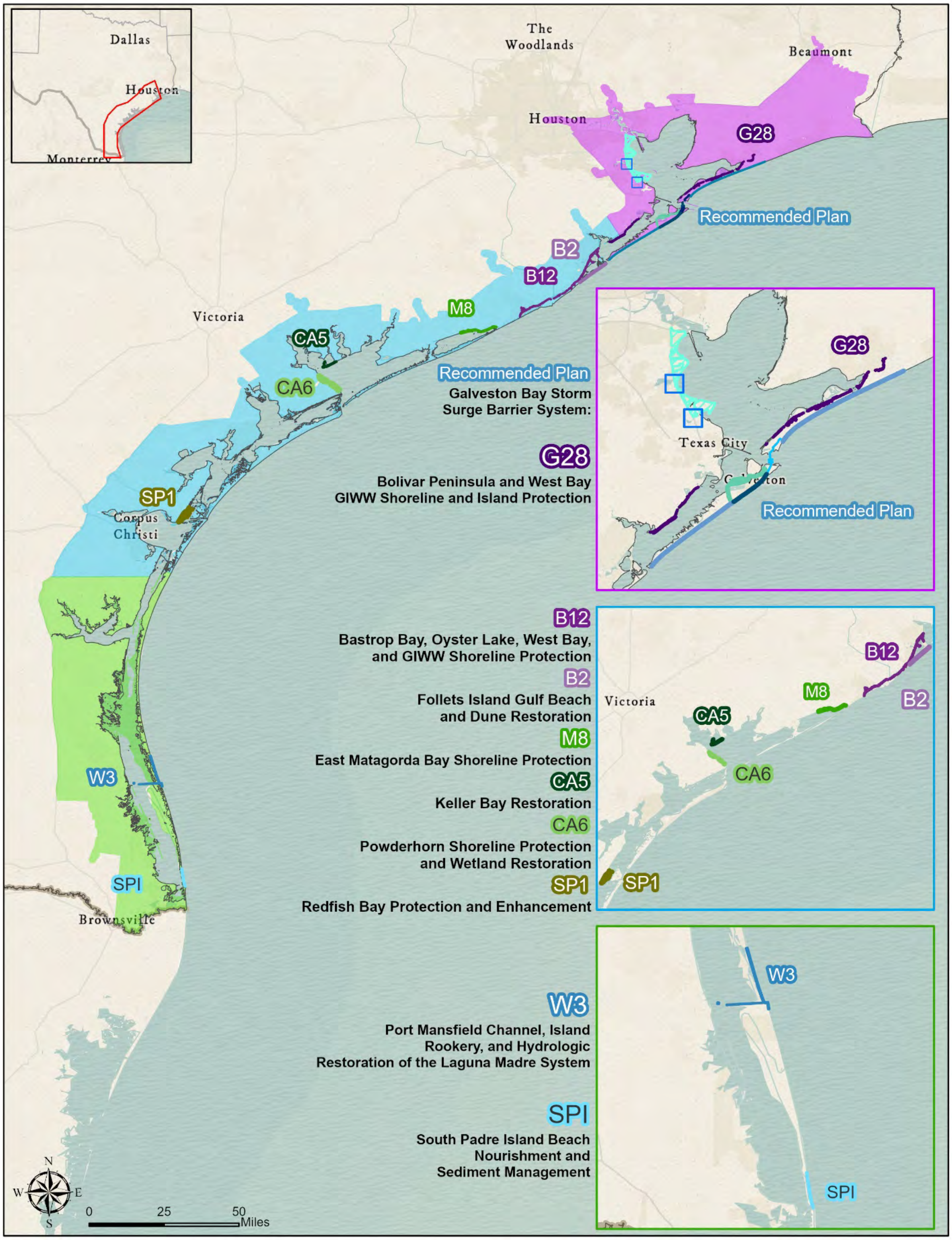

Figure 5. ER Measures Retained

Table 4. ER Alternative Strategies

Alternative/Scale	Strategy/Description
No-Action	No-Action
Alternative 1	Coastwide All-Inclusive Restoration Alternative
Alternative 2	Coastwide Restoration of Critical Geomorphic or Landscape Features
Alternative 3	Coastwide Barrier System Restoration
Alternative 4	Coastwide Bay System Restoration
Alternative 5	Coastwide ER Contributing to Infrastructure Risk Reduction
Alternative 6	Top Performers

The final screening iteration to identify the National Ecosystem Restoration (NER) plan requires estimation of the ecological lift, or benefits, between the future without- (FWOP) and future with-project (FWP) condition for each alternative in Average Annual Habitat Units (AAHUs). The modeling results as shown in Table 6 provides critical information needed to complete the cost effective analysis that helped identify the cost effective and incremental cost analysis (CE/ICA) and "Best Buy" plans from which a final recommended plan was selected. The net AAHUs of each measure is shown in the "Project Impacts" section of this report. Additional information on the modeling results can be found in Appendix I of the EIS. Additional information on the CE/ICA process can be found in Appendix E-3 of the Main Feasibility Report. Based on the outcome of this analysis Alternative 1 was identified as the NER plan and has been selected for inclusion in the recommended plan.

Table 5. Net AAHUs for Alternative Strategies

Alternative	FWOP AAHUs	FWP AAHUs	Net Change in AAHUs	Acres (FWP 2085)
Alt 1	77,887	99,787	21,920	55,353
Alt 2	46,223	55,452	9,230	46,828
Alt 3	35,292	53,254	17,962	45,359
Alt 4	62,922	76,872	13,970	11,138
Alt 5	50,738	62,565	11,827	5,469
Alt 6	51,639	63,484	11,845	6,089

<u>Detailed Description of Alternative 1 – Coastwide All Inclusive Restoration Alternative</u>

ER measures making up Alternative 1 have been developed to a feasibility level of design (i.e. estimates, design level that is not detailed enough for construction) based on currently available data and information developed during plan formulation. Although there is significant institutional knowledge regarding the construction of the restoration measures; there remains uncertainty about the site specific needs of each measure (e.g. exact sediment quantities, invasive species removal needs, extent of erosion control needs, construction staging area locations, pipeline pathways, timing and duration of construction, engineering challenges, etc.), which would need to be addressed during the PED.

Timing of initial construction of the ER measures is dependent on a number of factors including: timing of authorization, duration of PED phase, identification of a cost-share sponsor, and Federal- and non-federal funding cycles. As well, a number of measures depend on material dredged from existing channels during the normal operations and maintenance (O&M) cycle or as part of another project (e.g. dredged material from construction of the surge gates).

At this phase of the study potential pipeline routes and staging areas have not been identified. Identification of access routes, staging areas, pipeline routes, and placement of floatation docks would occur during PED. Each disturbance for access and staging would be placed outside of environmentally sensitive areas to the greatest extent practicable and utilize areas already disturbed when possible. As well, the disturbance would be limited to the smallest area necessary to safely operate during construction. All ground disturbance for access and staging areas would be temporary and fully restored to result in no permanent loss.

A Monitoring and Adaptive Management Plan (Appendix K of the EIS) has also been developed for the ER measures which provides a coherent process for making decisions in the face of uncertainty and increases the likelihood of achieving desired project outcomes based on the identified monitoring program. The Monitoring and Adaptive Management Plan addresses uncertainties associated with ecosystem function and how the ecosystem components of interest will respond to the restoration efforts in light of changing conditions (e.g. sea-level change is different than anticipated) or new information (e.g. surveys indicate the design needs modification in order to function properly).

The Service does not approve nor disapprove of the ER measures selected in this phase of the study. The Service previously provided general habitat descriptions and recommendations for the ecological restoration (ER) measures of the Study in a Planning Aid Letter (PAL) dated November 20, 2017 (Appendix A). The Service received no comments on the PAL from partnering agencies, NMFS or TPWD.

The following sections describe in more detail the eight ecosystem restoration measures of the RP. The designs described here would be applied to every restoration location where that measure is being employed unless specifically indicated that there are site specific features to be taken under consideration.(i.e. everywhere wetland restoration is being done would have the same wetland design but target elevations or amount or type of material utilized might differ).

Breakwaters

Protection of the shoreline along the GIWW would involve constructing 114 miles (601,920 linear feet) of breakwater structures at multiple locations along the GIWW that spans almost the entire waterway between upper coast (G-28) and mid coast (CA-6). These structures would be built in shallow water (<3 feet deep, -3 feet NAVD88) along unprotected portions of shoreline of the GIWW, at varying distances from the shoreline and where soils are conducive to supporting the weight of the stone without significant subsidence. The distance from the shoreline would be determined during PED, after site specific surveys have been completed, but sufficiently offset from the boundaries of the GIWW navigation channel to ensure continued safe navigation for commercial vessels.

The design would be a trapezoidal, step-down structure built of rock up to a height of +7.0 MSL, which will yield approximately 5.75 feet of rock exposed above the mean high high water level. Other approximate features of the design include a two 3-foot wide crests at +7 feet and +1 feet NAVD88, a 2H: 1V slope, and a base that is roughly 46 feet wide. The base of the structure would be on filter cloth ballasted to the water bottom to secure placement and prevent displacement of the outboard edges. The number of openings and width of each would be determined during PED and dependent on the location of major channel entrances or access points required for fishery access or circulation. It is anticipated that the breakwaters would need to be raised at least two times and throughout the 50-year period of analysis to keep up with relative sea level change and remain effective. For purposes of the study, supplemental materials would need to be added in year 15 and year 25, but timing could vary depending on observed local conditions and identified need to continue functioning as designed.

Rock materials would be purchased from a commercial quarry and transported to the site by barge, where it would then be placed in the waterway along the designed alignment by crane or hopper barge. Various support equipment would also be used, such as crew and work boats, trucks, trailers, and construction trailers to facilitate loading and unloading of personnel and equipment.

Breakwater constructed is currently proposed to occur at any time of year, without seasonal construction restrictions if best management practices are implemented and coordination with the Service on trust resource restrictions. The timing of construction is dependent on availability of funding.

Wetland Restoration

Wetland restoration measures involve placement of borrow material dredged from the GIWW during routine maintenance dredging or from the surge barrier gate disturbance area into wetland restoration locations. Sediments placed into these wetland creation sites would have similar properties to the existing native soils. Under the existing and projected future dredging cycles, there is enough quantities of suitable material available to meet all restoration needs without seeking other borrow sources (e.g. offshore, upland placement areas).

A total of 2,052 acres of estuarine wetlands would be restored in multiple locations throughout the study area including: along the GIWW adjacent to Anahuac NWR, and within the degraded wetlands on Bolivar Peninsula and in West Bay in Galveston County (G-28); along the GIWW adjacent to Brazoria NWR, Bastrop Lake, Oyster Lake, adjacent to San Bernard NWR, and Cow Trap and Cedar Lakes in Brazoria County (B-12); along the GIWW adjacent to Big Boggy NWR and East Matagorda Bay in Matagorda County (M-8); and along the shorelines of Powderhorn Lake near Indianola and Powderhorn Ranch WMA/State Park in Calhoun County (CA-6). Within each of the wetland restoration units, material dredged from the GIWW would be hydraulically pumped into open water areas with containment provided by breakwaters or earthern levees, or into degraded wetlands with open water spaces. Although final planning and design phases have not been started, the conceptual plan for wetland restoration assumes that 65% of each restoration unit will have a post-construction settlement target elevation of +1.2 feet mean sea level (MSL). As necessary, earthen containment dikes would be employed to achieve the desired initial construction elevation until settlement can occur. Earthen levees would be breached following construction to allow dewatering and final settlement to target wetland elevations.

Following wetland construction activities, non-native/undesirable species monitoring would be implemented. If non-native species are found, invasive species control measures would be taken to remove or prevent the expansion of these species within the restoration units.

Sediment transport equipment would include hydraulic dredges (e.g. hopper dredges or cutterhead suction dredge), pipelines (submerged, floating, and land) and booster pumps. Heavy machinery would be used to move sediment and facilitate construction. Heavy equipment could include bulldozers, front-end loaders, track-hoes, marsh buggy, track-hoes, and backhoes. Various support equipment would also be used, such as crew and work boats, trucks, trailers, construction trailers, all-terrain vehicles, and floating docks and temporary access channels to facilitate loading and unloading of personnel and equipment. Equipment will not be stored on existing wetlands during construction. All construction activities will be restricted to access by vessels.

Implementation of the wetland restoration measures is highly dependent on dredging cycles and the source of the dredged material. Currently, seasonal timing restrictions related to ESA compliance includes a seasonal dredging window for hopper dredge use between December 1 and March 31, unless work outside this window cannot be completed, in which NMFS would need to approve the deviation. This seasonal timing restriction would be applicable to wetland restoration sites that are dependent on material from the surge gate dredging actions where a hopper dredge may be used. Placement of material into wetland restoration sites would also be dependent on navigation channel maintenance dredging needs (GIWW, Houston Ship Channel, Brazos Island Harbor, etc.), which could occur any time of year due to the use of a cutterhead suction dredge, which has no seasonal restrictions.

Island Restoration

The general conceptual design for island restoration includes placing material dredged from nearby navigation channels to remnant island locations to raise the elevation of the island and prevent overwash of ground nesting birds. A total of 15.2 miles of bird rookery island restoration would be completed at four restoration sites. Island construction would use clean sediments consisting of clay, silts, and sands, which would be sculpted to prescribed slopes (5H:1V) and elevations (+7.5 to +9 feet NAVD88, post-settlement). The island would be sloped into the tidal zones at all edges to provide water access for juvenile colonial waterbirds and all for natural gradient of fringe wetland to upland vegetative communities. The island crest and bottom widths vary depending on the island site, shape and target acreage.

Fill material would be mixed with some in-situ water as it is placed, requiring a settlement period and the controlled discharge of decant water from within the restoration site. Breakwaters or temporary structures would be constructed where necessary to contain fill material in place. The height of any temporary structure and construction method required to contain the fill would be determined by the type of material used and its estimated water content. Where permanent structures are required to protect the island from waves and currents, breakwaters would be constructed 75 to 550 feet from the island shoreline in the same manner as described in section 0. The locations of temporary and permanent structures would ensure containment and settlement of the fill materials, using BMPs.

Once the fill has dewatered and sediments have settled, the temporary berms would be breached and portions of the island would be planted with species found at similar island sites to promote desired vegetation establishment; although the extent, specific species, and method of planting would be determined during PED. Monitoring for and removal of invasive or undesirable species would occur during the monitoring and adaptive management period.

Additionally, oyster reef restoration would be completed near all island sites in order to facilitate treatment of degraded water quality caused from the increase in bird defecation to the surrounding waters.

Construction may require temporary channels to access the restoration and borrow sites. The need for temporary channels would be determined during PED based on site specific conditions and the borrow location for each island. All temporary channels would be backfilled upon completion of construction work.

In general, construction would require the use of barges, small watercraft, large track hoe excavators, earth moving equipment, hydraulic dredges, and a dockside staging area. Equipment and materials for the construction activities would be transported via roads and marine waterways. Large equipment and materials moved by barges would use established interconnected waterways.

As with other dredged material placement measures, the timing of the action would be dependent on the dredging cycle of the source of material. Most of the action areas do not currently support nesting habitat, so no seasonal timing restrictions would be placed on construction. For the remnant islands, surveys would be completed prior to construction to confirm no nesting is occurring. If nesting is found, construction would need to avoid the nesting season, which is usually February 1 through August 15. However, some field activities that pose minimal disturbance to nesting birds may be acceptable during this time. Any such activities would be coordinated with state and federal resource agencies.

Beyond the adaptive management and monitoring period, no long-term maintenance of the islands are proposed as part of the recommended plan. Although at some point in the future, the islands could serve as a suitable site for disposal of dredge materials rather than placing materials in an upland or offshore disposal site.

Oyster Restoration

The goal of the oyster restoration measures is to increase the amount of hard substrate bottom in the restoration area to provide additional surface for oyster recruitment. Restoration would be achieved in one of two ways. Approximately 12.32 miles (65,050 linear feet) of oyster reef would be restored at five different sites. The first and most likely method involves placing cultch material, either loose or contained, directly on the soft bottom substrate of the restoration area. The cultch veneer would be clean crushed, limestone or concrete, or other suitable substrate deemed acceptable by TPWD. These materials have been successfully used in Galveston Bay reef restoration including those by Corps, the NFS, and TPWD. The cultch would most likely be barged in and then placed evenly over the restoration site submerged bottom. A 6-inch thick cultch layer has been assumed for all restoration sites but during PED the thickness would be modified based on local reef restoration target relief for the recruitment layer. The size of the substrate would vary depending on the material and site characteristics. Material that is approximately six to 10 inches in diameter and weighing approximately 25-75 pounds would be targeted to ensure suitable interstitial spaces for reef habitat and proper weight to withstand velocities and currents at the site.

For CA-5, oyster reef construction would involve placing a series of molded precast concrete structures that are designed to mimic the attributes of a natural three-dimensional oyster reef. The reef ball design is proposed and involves a hollow concrete mound with several holes that provide attachment points for oyster recruitment. The size of the reef balls would be determined during PED and would be specific to the restoration site conditions. A layer of hardened substrate, such as concrete rubble, may need to be placed on the bottom before the reef ball is placed. Supplementary shell and/or rock mats may be used if needed. The need for additional support would be determined during PED.

Oyster reefs would be constructed in the intertidal zone of the various bays. Considering post-construction settling of material, reef habitats would be built to an elevation that would avoid sedimentation of the reefs over time. If settlement occurs post-construction, additional material may be placed on the reefs in an adaptive management measure to ensure the height of the reef is approximately one foot above the existing bottom. Specific locations, size, and shape of reef may be revised after site-specific surveys are completed and based on resource agency recommendations for site selection criteria. The size and shape of the constructed reef is expected to range from small circular patches to elongated irregularly shaped reefs that extend for miles.

The GLO and TPWD would share responsibility for managing oyster restoration sites and each site would be retained in public ownership. Each oyster restoration site is within an area currently protected under state law from public or private commercial harvest and are not be eligible for private lease. The design of each restoration reef is expected to be self-sustaining, and larvae recruitment is expected to continue for the life of the project.

Oyster cultch and reef balls would be transported to each restoration site primarily by tugboat and barge, but large workboats may also be used. Cultch material would be washed overboard using high pressure water hoses or cannons, with the vessel moving continuously through the placement area to control the thickness and acreage of the placement. Larger materials, such as reef balls or blocks of alternative cultch material, may be placed on the restoration site using a crane/excavator or front-end loader from the barge. Each restoration site should be surveyed to determine elevation of reef height during construction to ensure navigational requirements of the waterway.

Oyster reef restoration would be completed at any time of the year and would not be dependent on the timing of other actions, except for funding. No long-term maintenance is included in the recommended plan.

Dune and Beach Restoration/Nourishment

The beach and dune restoration/nourishment measures would involve placing beach quality sand on the beach above the mean high water mark. Beach compatible fill is material that maintains the general character and functionality of the material occurring on the beach and in the adjacent dune and coastal system. Such material would be similar in color and grain size distribution (sand grain frequency, mean and median grain size, and sorting coefficient) to the material in historic beach sediment at the placement site.

Temporary training dikes would be constructed using existing beach sand parallel to the shore. The dikes would be used to contain the slurry discharge. A sand/water mixture would be pumped through a series of pipes laid parallel to the shoreline (no pipes placed directly on the beach) and sprayed onto the beach. Once the sand is pumped onto the beach, bulldozers would shape the fill in the design template from the backshore to the approximate mean sea-level (MSL) contour. Sand below the MSL would be shaped and redistributed to a natural profile by waves. As each section of beach is completed additional pipe would be added to the discharge line, pipe on the completed beach would be removed, and the active construction zone would move along the project area until all sections of beach have been nourished.

Although the plan drawings for beach and dune restoration includes sand fencing, the Service discourages use of sand fencing. The proposed plans also include planting native vegetation in strategic locations along the proposed dune following nourishment in accordance with a vegetation plan that would be developed with resource agency input during PED.

Nourishment would be accomplished by hydraulic dredge (cutterhead suction dredge), an off-shore platform with booster pumps, pipelines to the beach, and heavy equipment (bulldozers and loaders) shaping the fill on the beach.

W-3 Port Mansfield Beach and Dune Restoration
Discussions between Corps and Service, subsequent to the issuance of the DEIS, resulted in a decision to change the NEPA designation of W-3 in this tiered document from Actionable to Tier One measure. Consistent with the provisions stated in the EIS, the placement area associated with W-3 would only occur with "coordination of the designated land owner (National Park Service (NPS)) to allocate the area of disturbance." For this specific beach and dune restoration site, the material dredged from the Port Mansfield Channel to reopen the channel, would be beneficially used to nourish and restore 9.5 miles of Padre Island National Seashore from the Port Mansfield Channel and northward. This section of beach is currently severely sediment starved due to the presence of a jetty at the entrance of the Port Mansfield Channel. The proposed restoration efforts would aim to restore the beach profile similar to existing turtle nesting beaches in other parts of the Padre Island National Seashore.

The beach nourishment sections would consist of a berm starting at the toe of the dune at +5 feet NAVD88 and sloping seaward at 1V:275H for approximately 550 feet where it would then transition to a 50-foot wide swatch with a 1V:10H slope that transitions to existing grade. The berm width would vary according to fill density. In general, the active dry-sand beach would be situated between +5 feet and +0 NAVD88. During neap tides and low wave conditions, dry sand may be found at lower elevations.

A 150-foot wide, trapezoidal dune configuration with a crest elevation of +10 feet (NAVD88) and +5 feet (NAVD88) foundation elevation (toe of dune) would be constructed approximately 650 feet from the mean high high water (MHHW) elevation to the center line and parallel the current beach for 9.5 miles. The side slopes would be 1V:10H and the dune crest would be approximately 10 feet wide. The berm would be constructed from material dredged from the Port Mansfield channel.

The timing of the nourishment activities would occur outside the turtle nesting season (March 15 to October 1), to the greatest extent practicable. The specific timing would be dependent on the availability of funding and dredges to complete the Port Mansfield dredging, which would be completed simultaneously. Although the original plans indicated beach nourishment would occur any time of day or night, the Service recommends construction not be conducted during night. However, the Service recommends the Corps follow conservation measures further defined and included in the Biological Opinion developed for this Tier One measure.

South Padre Island Beach and Dune Improvement
Discussions between Corps and Service, subsequent to the issuance of the DEIS, resulted in a decision to change the NEPA designation of South Padre Island beach restoration project in this tiered document from Actionable to Tier One measure. For the South Padre Island beach and dune nourishment measure, the existing beach and dune profile maintained by past nourishment actions would be maintained for the life of the project. Existing beach access points, in the form

of breaks in the dune, would be plugged and sand walkovers would be installed to provide beach access. The proposed design would maintain a 120-foot wide berm with a crest height of +12.5 feet (NAVD 88) along 2.9 miles of developed shorefront (reaches 3 through 5). Material for nourishment would continue to come from the Brazos Island Harbor (BIH) navigation project during normal operation and maintenance cycles or from one of four offshore sand borrow sources located approximately 5 miles offshore.

Unlike in W-3, construction of an initial profile is unnecessary so the first nourishment action would occur in year 10. Thereafter, beach renourishment would be completed on roughly a 10-year cycle for the life of the project to maintain CSRM benefits, which would result in the same actions described here being completed 5 times throughout a 50 year period. However, the exact timing of nourishment would be dependent on site specific monitoring of erosion rates (i.e. erosion accelerates may need to complete the nourishment cycle sooner than 10 years, conversely if erosion rates slow down the nourishment cycle may be after 10 years). As well, the timing would need to be coordinated with the need for maintenance dredging of the BIH.

Nourishment of the South Padre Island beach and dune would occur between October 1 and March 15 to avoid turtle nesting season as well as the prime recreation season. Because this area is immediately adjacent to development, all construction activities would occur during daylight hours. However, the Service recommends the Corps follow conservation measures further defined and included in the Biological Opinion developed for this Tier One measure.

Hydrologic Connections Restored

The hydrologic connection measure involves opening Mansfield Pass in order to facilitate the exchange of water between the Gulf of Mexico and the Lower Laguna Madre. Opening Mansfield Pass requires excavation, or dredging, of deposited material within Port Mansfield Channel. Approximately 7 miles of the shallow-draft channel would be dredged from the Gulf of Mexico, through a jettied inlet and the pass to about the halfway mark to the mainland, although the actual length of the dredged area would be determined during PED to ensure that only sandy material is dredged. The authorized depth (-14 feet NAVD88) and width (125 feet) would be maintained and no widening or deepening is proposed, resulting in approximately 12 feet of sediment that needs to be removed from the channel. Shoaled material in the channel is primarily sandy and is not known to have any contaminants. Dredged material would be beneficially used for the island restoration and beach and dune restoration actions included with W-3.

Dredging would be completed by a hydraulic pipeline dredge, which creates a slurry combination of water and solids that is then pumped to the disposal site through floating and land based pipes. Other equipment needed to support the dredging operation include: tugboats, pipelines, booster pumps, and support watercraft.

The timing of the dredging would be dependent on funding and availability of equipment. No seasonal restrictions are proposed for the dredging; however, efforts would be taken to complete dredging and subsequent disposal between October 1 and March 15 to avoid the turtle nesting season, to the greatest extent practicable. Although the initial plan to conduct dredging activities

24 hours per day until all work is complete, the Service recommends the Corps follow conservation measures further defined and included in the Biological Opinion developed for this Tier One measure.

Monitoring and Adaptive Management Plan for ER Measures

As part of the monitoring and adaptive management process an adaptive management team (AMT) made up of Corps staff, the non-federal sponsor, interested resource agencies and other stakeholders will be officially established during the PED phase of the project. Pre-construction/baseline data, during construction, and post-construction monitoring will be utilized to determine the restoration of success. Monitoring will continue until the trajectory of ecological change and/or other measures of project success are determined as defined by project-specific objectives. Section 2039 of WRDA 2007 allows ecological success monitoring to be cost-shared for up to ten years post-construction. Once ecological success has been achieved no further monitoring would be performed. If ecological success cannot be determined within the ten-year post construction period of monitoring, any additional required monitoring would be the responsibility of the non-federal sponsor.

The Monitoring and Adaptive Management Plan is a fluid document that can be changed as the need arises, such as when new or modified monitoring techniques better meet the need or success criteria that was not accounted for but is later found to be prudent. With resource agency coordination, the Monitoring and Adaptive Management Plan would be revisited and confirmed or revised during PED. The monitoring results post-construction would be coordinated with the AMT at which time recommendations would be made that the project is on track to meet the success criteria or recommendations would be made to conductive adaptive management to get the project on a path toward success.

The following success criteria and monitoring have been tentatively developed for the feasibility phase:

- For the wetland restoration features, the three performance measures of success are reducing post-construction shoreline erosion rates compared to pre-construction by 50% by year 6, establish wetland elevation post-construction sufficient for healthy wetland survival and growth, and an average percent cover of 80% native wetland vegetation on restoration sites at year 5 compared to pre-construction conditions.
- For island restoration/creation features the three performance measures of success are reducing post-construction shoreline erosion rates compared to pre-construction conditions by 50% by year 6. Establishing island surface elevation that increases the sediment process of capture, settlement, dewatering of fill materials and the promotion of micro-topographical features, the resistance to erosion and accretion to keep pace with sea level rise, and elevate the growth of island vegetation annually be assessing plant species richness, diversity, health, abundance, distribution, and the presence of invasive or exotic species.
- Dune and beach restoration performance measures include the need to monitor beach and dune erosion and erosion rates annually using remote sensing to determine if beaches and

dunes maintain acceptable height, slope, elevation, and area as determined by the ranges of natural dunes in county management beach plans. Dune vegetation would be monitored annually beginning in year 1 and measure vegetation assessment parameters along transects for comparison with reference sites. In addition, field sampling of infaunal invertebrates would be completed quarterly at one-mile intervals on the shoreline to determine if the restored beaches and dunes maintain the same invertebrate communities as the reference sites.

- The performance measure for oyster reef restoration/creation is to determine oyster density, size class distribution, and recruitment semi-annually by performing random sampling with divers. The sites would be monitored following TPWD guidelines.
- For hydrological restoration the performance measure set forth in the monitoring plan is, one month after dredging, begin measuring salinity, water temperature, and tidal flow on a monthly basis at permanent sampling stations.

Coastal Storm Risk Management Measures

During the conceptual phase of scoping and evaluation process, the Corps reviewed a wide array of potential coast wide CSRM measures that consist of structural features including levees, floodwalls, surge barrier gates (both navigable and environmental flow control gates), and breakwaters. For CSRM, plan formulation was undertaken in a systems framework, to assemble and evaluate features using National Economic Development (NED) procedures into a comprehensive plan that reduces coastal storm risk damages and enhances resiliency in the region. Efforts focused on providing risk reduction within the lower and the upper Texas Coast, after assessing risk reduction needs across the entire coast.

Lower Texas Coast

On the lower Texas coast, South Padre Island (SPI) is considered vulnerable to coastal storms and is included as a hydrologically separate CSRM region. The region was included because of the City’s dense concentration of structures at risk from coastal storms. A history of beneficial use placements have occurred since 1988 to counter ongoing erosion and maintain sediment within the coastal zone along a heavily used stretch of coast. However, when timing and funding are limited, the structures and population remain at risk along the study area.

The initial planning evaluation focused only on beach and dune measures because revetments, seawalls, rock groins, or offshore breakwaters would have detrimental impacts to the longshore and cross-shore sediment transport processes. Nonstructural measures were initially considered but not carried forward since many nonstructural measures (flood proofing of structures, implementing flood warning systems, flood preparedness planning, establishment of land use regulations, development restrictions and elevated development) are already being implemented.

Analysis and refinements of beach nourishment alternatives confirmed that the NED scale alternative included 2.9 miles of beach nourishment to establish a 12.5foot (NAVD88) tall dune and 100-foot-wide berm between Reach 3 through 5. The economic analysis confirms that beach nourishment is cost effective when considering construction costs and benefits, and recreation benefits, but may not be feasible due to the real estate costs to acquire easements for privately owned portions of the dune and beach. The dune and beach nourishment planned for this site was previously discussed under ER measures due to the similar components of this CSRM measure to the W-3 ER measure.

Upper Texas Coast

On the upper Texas coast, the Galveston Bay region represents the most at risk area not being presently addressed by other programs, such as the Sabine Pass to Galveston Bay ER and CSRM project. In general, CSRM measures were formulated in systems along two alignments: one along the Gulf and one along the Bay. The outermost system (or Gulf Alignment) was formulated to reduce the penetration of Gulf surge across the barrier island and into the Bay. The alternative alignment (or Interior Alignment) reduces the penetration of storm surge from the Bay into the region's surrounding areas by placing the system around the Bay's landward perimeter. A total of five alternatives were developed.

Three of the conceptual strategies focused on a Gulfward Alignment to prevent storm surge entry into Galveston Bay and the surrounding communities. The three Gulfward Alignments all included a structure across the Bay to prevent storm surge pushing into the inland areas of the Bay, but propose different features connecting the barrier to high ground (**Error! Reference source not found.**). Each alternative included a ring barrier around the City of Galveston and Seawall elevation to address sea level change from the Gulf of Mexico and wind driven surge and flooding from the Bay. Two of the alternatives (A and B) added interior storm surge gates and pump stations to reduce flooding at Clear Lake and Dickinson Bay. Nonstructural measures along the bay rim, such as elevation or flood proofing, were also included.

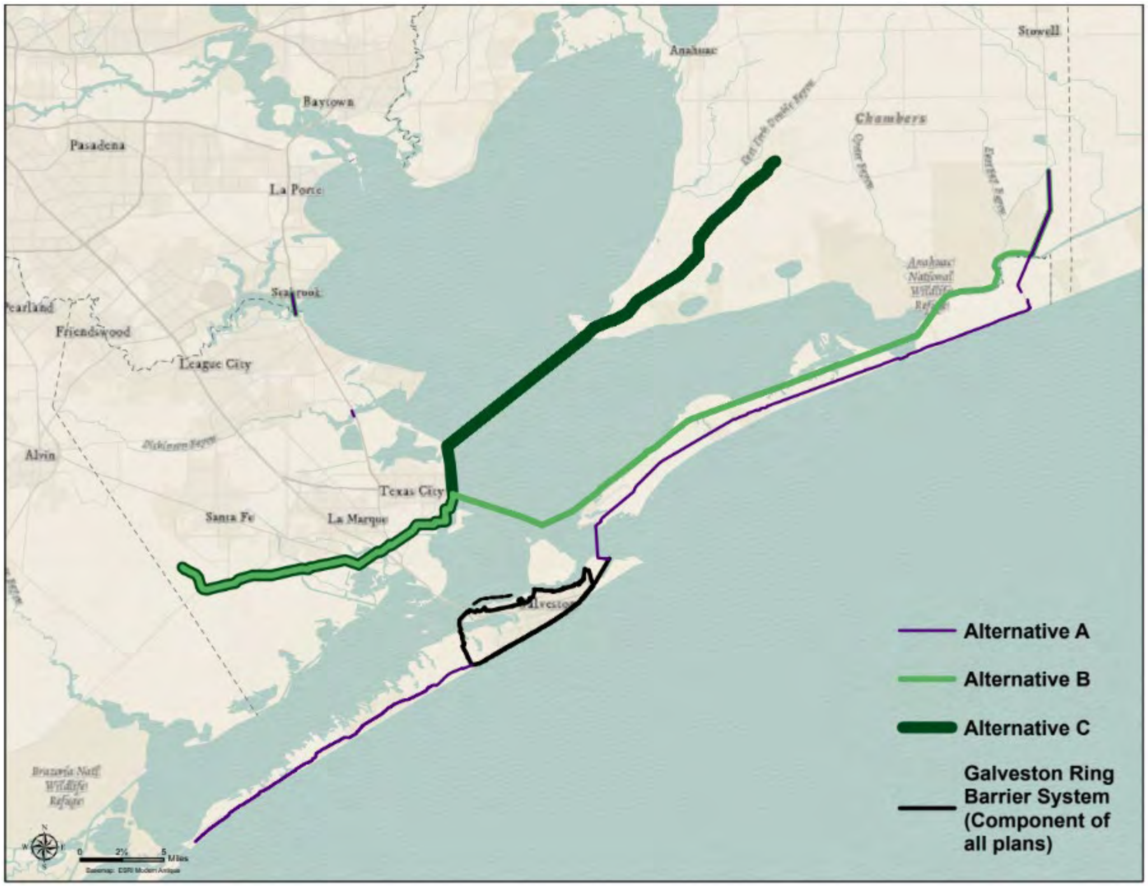

Figure 6. Gulf Alignments

The alternatives for Gulf Alignments are described further below and shown in **Error! Reference source not found.**:

- **Conceptual Alternative A – Coastal Barrier:** This alternative would prevent storm surge from entering Galveston Bay with a storm surge barrier across Bolivar Roads and tie-in features connected to the Galveston Seawall to the west and to a levee system to the east along Bolivar Peninsula.
    - **Navigation Concerns:** Deep-draft ships would have to transition through the surge-barrier gates, and anchorage areas would require relocation.
    - **Construction, Cost, and Maintenance Concerns**: The location in the center of the inlet would require environmental gates, or similar components, to maintain the natural water circulation into the Bay when the system is open. Initial modeling estimated that over 30 environmental gates would be needed to maintain existing circulation in the Bay. Initial construction and substantive operation, maintenance, repair, replacement, and rehabilitation (OMRR&R) costs would be associated with these gates.

- **Environmental Concerns**: Natural flow within the Bay would be impacted by constructing a barrier.

- **Conceptual Alternative B – Coastal Barrier:** This alternative places the storm surge barrier north of the GIWW and would tie into the existing Texas City Dike to the west and connect to some of the existing dredge disposal sites to avoid habitat along Bolivar Peninsula. The placement behind the GIWW would stop storm surge from the Gulf and reduce the barrier's exposure to high and intense surges compared to the location proposed in Alternative A.

  - **Navigation Concerns:** Shallow-draft tugs and barges and deep-draft ships would have to transition through the surge-barrier gates which raised concerns about navigation safety and efficiency

  - **Construction, Cost, and Maintenance Concerns**: The storm surge gate in Alternative B would connect to the Texas City Dike. The dike was built to protect the Texas City navigation channel from cross currents and excessive silting, not to withstand storm surge. The foundation of the existing dike would have to be improved to increase its existing height to function effectively against storm surge. Aside from cost, this action would have major impacts on the current recreational use on the dike during construction or would require permanent relocation of the fishing and recreational features.

  - **Environmental Concerns**: Natural flow within the Bay would be impacted by constructing a barrier.

- **Conceptual Alternative C – Mid Bay Barrier:** This alternative avoids some of the navigation impacts at Bolivar Roads by placing a surge barrier near the middle of Galveston Bay. The system would start on the east side of Galveston Bay near Smith Point, and continue across the bay, crossing the ship channel, and tie into the existing Texas City Levee System on the west side of the Bay.

  - **Navigation Concerns**: Navigation safety for recreational vessels was a concern when deep-draft ships, shallow-draft tugs and barges, and large recreational vessels would all be forced to use one opening in the storm surge gate.

  - **Construction, Cost, and Maintenance Concerns**: The location in the center of the bay would require environmental gates, or similar components, to maintain the natural water circulation in the Bay when the system is open. Modeling estimated that over 100 environmental gates would be needed to maintain existing circulation in the Bay. Initial construction and substantive OMRR&R costs would be associated with these gates.

  - **Environmental Concerns**: Natural flow within the Bay would be impacted by constructing a barrier. This alternative would have a large underwater footprint and is likely to have negative impacts on the historic "Redfish Oyster Reef" near the middle of Galveston Bay and the reefs along the Houston Ship Channel near the proposed surge barrier gates.

The alternatives proposed for an Interior Alignment were evaluated on the west side of Galveston Bay along State Highway 146, from Texas City to the Fred Hartman Bridge. These alternatives varied in the alignment of the levee, placing the barrier along the bay rim, or further inland along State Highway 146. These alignments avoided navigation impacts that a coastal barrier presented but provided limited risk reduction to portions of the Gulf shoreline. Both alternatives eventually tie into the existing Texas City Levee System and include improvements to that system. Additional improvements to that system further west into the communities of Hitchcock and Santa Fe would also be necessary. Each alternative also included a ring barrier around the City of Galveston and Seawall elevation to address sea level change from the Gulf of Mexico and wind driven surge and flooding from the Bay. In addition, surge gates and pump stations at Clear Lake and Dickinson Bay were also included for both alternatives, while Nonstructural measures along the Bay rim were proposed only for Alternative D1. The Interior Alignment alternatives are described further below and shown in **Error! Reference source not found.**7:

- **Conceptual Alternative D1 – Upper Bay (State Highway 146)/Nonstructural System:** The proposed a levee system on the west side of Galveston Bay along State Highway 146 from Texas City to the Fred Hartman Bridge. Communities between State Highway 146 and the Bay are left out of the system and would require nonstructural treatment.
    - **Environmental Concerns:** Placing the levee system path along SH 146 would reduce construction costs and environmental impacts by avoiding in-water construction, but could affect more wetland locations.
    - **Residual Risk:** The alignment would leave approximately 10,000 structures east of the levee outside of the area of risk reduction. This created a concern related to the overall project objective to reduce risk to critical infrastructure, such as medical centers, government facilities, universities, and schools, from coastal storm surge flooding. An evaluation of the future without project condition surges and economic damages determined that the area surrounding the system is one of the highest reaches for economic damages.
    - **Induced Risk:** Once a levee is constructed near SH 146, modeling showed that it would induce stages and damages in the area outside of the levee system. Economic modeling estimates that over $175 million in average annual equivalent damages would accrue to the area without addressing the induced damages.
- **Conceptual Alternative D2 – Upper Bay (State Highway 146)/Nonstructural System:** This alternative proposed the levee system along the Bay rim from Texas City to the Fred Hartman Bridge, which enclosed the 10,000 structures that were left out of the system in Alternative D1.

- **Environmental Concerns:** In-water construction has the potential to induce temporary and permanent adverse impacts through modification of flow and water quality; however, wetland impacts would be minimized.
- **Residual/Induced Risk:** None compared to Alternative D1.

Figure 7. Interior Alignments

The first assessment to be completed by the Study Team was to confirm the effectiveness of the five alternative risk reduction plans in the Galveston Bay region. Since the level of design of the alternatives was conceptual at this stage, the performance was measured by assessing high-level differences in performance, cost, and impacts.

As plans were developed, they were assumed to have similar levels of risk reduction as some of the existing risk reduction systems in the upper Texas coast. For example, plans which had a levee system tying into the Galveston Seawall were designed and evaluated based on similar heights of the existing seawall, an elevation of approximately 17 feet (NAVD88) tall. The same assumption was used for plans tying into the Texas City hurricane flood protection system. The Study Team made these simplifying assumptions to ensure that the analysis focused on an initial comparison of distinctly different plans rather than different scales of plans.

When compared to the future without project conditions, the Study Team identified strengths and weaknesses that allowed them to screen the alternatives based on relative risk reduction performance, construction and life cycle cost, and potential environmental and navigational impacts.

After comparing the relative performance of the CSRM alternatives and the potential cost or environmental impacts, Alternatives B, C and D1 were screened out because of impacts that were evident even with less detailed economic information, and Alternative A and D2 provided better performance in terms of risk reduction with fewer negative impacts. Alternative A and D2 were found to be the two most effective comprehensive alternatives to address coastal storm risk within the Galveston Bay system. The initial analysis demonstrated that these two alternative plans offered distinct approaches that achieved the study goals without creating unnecessary environmental and community impacts.

The second screening phase required more thorough refinement of the design and operation of the features within each alternative to conduct a meaningful comparison. The engineering performance was evaluated with more detailed models to simulate performance of the features when faced with representative storm conditions over the 50-year period of analysis. Updated engineering models produced more refined water surface elevations to generate a more detailed economic estimate of the benefits.

The comparison of Alternative A and Alternative D2 required standard national economic development (NED) benefit evaluation procedures for damage reduction be used to compare system-level alternatives and identify the TSP. The certified model applied to quantify NED benefits is HEC-FDA, a risk-based model that combines water surface elevation estimates for a representative storm suite and dollar damage assessments for resources within the study area. Additional NED benefits for recreation and extended Gross Domestic Product impacts were then estimated as part of the selection of the Recommended Plan.

When compared to Alternative D2, Alternative A has:

- **Higher net benefits –** Under all RSLR Scenarios and cost ranges.
- **Lower residual risk –** A lower residual risk in the event of extreme overtopping events because Alternative A is set farther away from the developed areas of the study area.
- **Greater flexibility and greater focus on critical infrastructure –** Alternative A provide greater benefits by protecting more areas across the region than Alternative D2. The alignment of structures encloses critical infrastructure within the risk reduction system and enhances resiliency in the region. Also, by establishing the first line of defense on an outermost alignment, greater adaptive options are possible to manage risk over time.

Table 6 provides a comparison of Alternative A and Alternative D2.

Table 6. Comparison of Alternative A and Alternative D2 (FY17 Price Level, 2.75% Discount Rate)

Criteria	Alternative A	Alternative D2
Comparison of Design Details	Complex design only focused on large navigation structure	Complex design due to multiple tie-ins
Construction Schedule and Benefit Assumptions	Lower acquisition risk	Higher acquisition risk
Environmental Impacts	High indirect environmental risk (Galveston Bay)	Localized direct and indirect risk (smaller waterbodies)
Potential Induced Flooding	Localized manageable risk	Localized to levee tie-in points
Navigation Impacts	Potential impacts to deep-draft operation but reduces risk to navigation infrastructure from storm surges	Potential impacts to both deep-draft and shallow-draft operations and navigation infrastructure still at risk from impacts from storm surges
Critical Infrastructure	Highway and navigation infrastructure included in system	Critical highway and navigation infrastructure left out of the system
RSLR Scenario	Limited cost for adaptation (Galveston Bay storage)	Substantial cost for adaptation (floodwall modification)
Project Cost	$14.2 - $19.9 billion	$18.2 - $23.8 billion
Net Benefits ($millions) and Benefit-Cost Ratios	Range: High RSLC and Low Cost – Low RSLC and High Cost (Without GDP Impacts) $571 – ($294) and 1.8–0.6 (With GDP Impacts) $1,192 – $14 and 2.7–1.0	Range: High RSLC and Low Cost – Low RSLC and High Cost (Without GDP Impacts) $255 – ($544) and 1.3–0.5 (With GDP Impacts) $923 – ($237) and 2.0–0.8
Residual Risk	Galveston Bay's storage capacity mitigates risk	Risk from exceedance surge events and rainfall events

After evaluation of performance and impacts of the two alternatives, Alternative A was selected as a component of the TSP in the October 2018 Draft Integrated Feasibility Report and EIS. During the public review period, the public and agency provided feedback on the analysis and designs completed. Based on public and resource agency comments, and supported by continued engineering design and optimization efforts, multiple changes to the TSP were considered and evaluated to enhance the performance of the CSRM measures and to further minimize environmental and social impacts. This is the third phase of the plan formulation process, building on the conceptual and TSP phases, and integrating comments and refining alternatives to generate the Recommended Plan. The following provides a brief overview of revisions to Alternative A:

- **Levee along West Galveston Bay and Bolivar Levee:** Public comment indicated that the roadway access issues were unfavorable, the real estate impacts were disruptive, and the views would be unacceptably changed. Many expressed dissatisfaction that the impacts would be borne by the residents and businesses on Galveston Island and Bolivar Peninsula, without reducing their storm surge risk. Many commenters also expressed that they are aware of the risks of development on a barrier island or peninsula and favored the risk of storm damage over the levee. In response, the Study Team found that the levee was not implementable and it was removed from the recommendation.

- **Beach and Dune Restoration (G-5)**: The beach and dune restoration feature proposed along the Gulf on West Galveston and Bolivar Peninsula was justified for inclusion within the ER purpose. It restored the coastal habitat that had lost sediment to years of coastal forces on the Gulf side and hardened features, yards, structures and roadways. Once the levee was found to be unacceptable, the beach and dune restoration was refined to include higher dunes and wider beaches to increase the risk reduction it provides. The beach feature does not provide a comparable scale of risk reduction as the levee, but is placed Gulfward of all structures, creates fewer community impacts, and benefits from the natural resiliency of sand systems. The larger beach feature also sustains the barrier features and supports the function of the Bolivar Roads Gate System.

- **Bolivar Roads Gate System**: The Bolivar Roads Gate System was refined to reduce the constriction of the flow in the channel. The refinement was undertaken in response to potential environmental impacts that were identified during the screening process. Operators of storm surge structures offered technical recommendations for design refinements to maintain function while reducing environmental impacts. Other refinement includes the replacement of a single larger gate with two smaller gates.

- **Galveston Ring Barrier System**: The Galveston Ring Barrier System was realigned to include additional areas and to avoid other impacts. Residents of Lindale Park opposed the partial enclosure of the neighborhood within the barrier, and the alignment that overlaid existing homes. Other alignment changes were made to reduce waterfront business and infrastructure impacts, and to reduce environmental impacts from crossing wetlands. Other comments opposed the disruption of traffic and access, the potential to exacerbate drainage problems, and the potential environmental impacts.

- **Galveston Seawall Improvements**: The Seawall height increase was proposed as a future adaptation to address sea level change. Following publication of the initial draft report, the height increase was proposed for the north side of Seawall Boulevard to avoid view impacts and to avoid impacting the existing Seawall stability.

The collective system of CSRM measures in Alternative A has been termed the Galveston Bay Storm Surge Barrier System. CSRM measures in the revised Alternative A (Galveston Bay Storm Surge Barrier System) include both structural and non-structural components (**Error! Reference source not found.** and 9**Error! Reference source not found.**) including:

- The Bolivar Roads Gate System, across the entrance to the Houston Ship Channel, between Bolivar Peninsula and Galveston Island (**Error! Reference source not found.Error! Reference source not found.**);
- 43 miles of beach and dune improvements on Bolivar Peninsula and West Galveston Island that work with the Bolivar Roads Gate System to form a continuous line of defense against Gulf of Mexico surge, preventing or reducing storm surge volumes that would enter the Bay system (**Error! Reference source not found.Error! Reference source not found.**);
- Improvements to the existing 10-mile Seawall on Galveston Island to complete the continuous line of defense against Gulf surge (**Error! Reference source not found.Error! Reference source not found.**);
- An 18-mile Galveston Ring Barrier System (GRBS) that impedes Bay waters from flooding neighborhoods, businesses, and critical health facilities within the City of Galveston (Figure 8);
- Two surge gates on the west perimeter of Galveston Bay (at Clear Lake and Dickinson Bay) that reduce surge volumes that push into residential and industrial areas that line Galveston Bay (Figure 8); and
- Complementary non-structural measures, such as raising homes or flood proofing structures, to further reduce Bay-surge risks along the western perimeter of Galveston Bay (Figure 8).

Figure 8. Galveston Bay Storm Surge System

Figure 9. Gulf Lines of Defense of the Galveston Bay Storm Surge System

The Gulf Bay Storm Surge System measures are further described in detail in the following sections.

Bolivar Roads Gate System

The Bolivar Roads Gate System is made up of a series of gate structures (**Error! Reference source not found.**) that would remain open until a storm surge event is eminent, at which time they would be closed to prevent storm surge from entering Galveston Bay.

The gate structure starts on Bolivar Peninsula at the end of Biscayne Beach Road with 3.03 miles of earthen levee and proceeds northwesterly to State Highway 87, where the levee turns south westerly to near the intersection of Keystone and 23rd Streets. The levee will consist of a 1V:3H slope on the protected side and a 1V:6H slope on the unprotected side. The unprotected side of the levee will be armored with stone protection and the reminder of the levee will be turfed. A Typical section of levee can be found in Appendix D, Annex 12 of the Feasibility Report.

The barrier continues southwest with a combi-wall for 5,000 feet reaching the start of the gate system across the Galveston Entrance Channel. The structure continues south with a series of gates. The 2.08- mile gate system crossing Galveston Harbor Entrance Channel consists of 16 shallow water environmental gates at elevation -5.0 feet MLLW; 5 vertical lift gate at elevation -20.0 feet MLLW; 3 vertical lift gates at elevation -40.0 feet MLLW; 125’ sector gate at sill elevation of -40.0 feet MLLW for recreational traffic; 2 vertical lift gates at a sill elevation of -40.0 feet MLLW; and 2-650’ floating sector gates at a sill elevation of -60.0 feet MLLW. The sill elevation across the ship channel will allow for any future deepening of the Galveston Harbor Entrance Channel, which is currently maintained at a depth of -48 feet MLLW. The sector gates across the ship channel are anchored and housed in man-made “islands” on either side of the Entrance Channel. The channel crossing continues with a 125’ sector gate at a sill elevation of -40.0’ for recreational traffic, 2 vertical lift gates at a sill elevation of -40.0, and 3 vertical lift gates at a sill elevation of -20.0. The gate system than ties into the end of the existing seawall at the San Jacinto Placement Area on Galveston Island. The top elevation for the crossing is 21.5 feet NAVD 88.

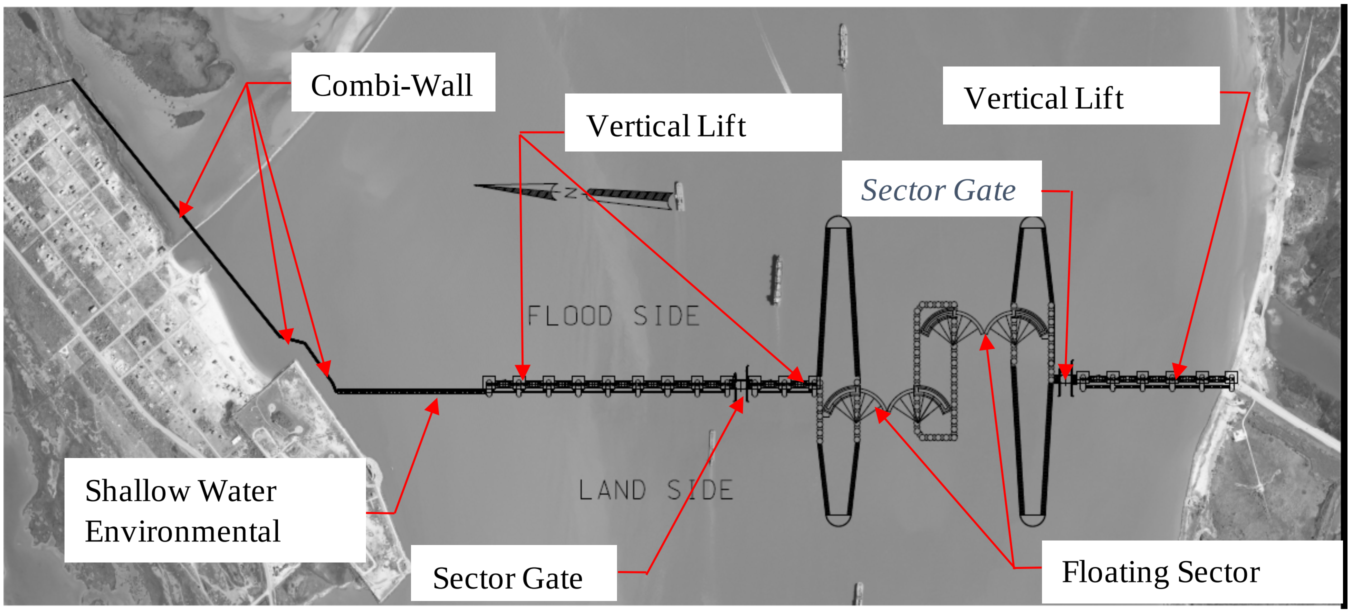

Figure 10. Bolivar Roads Gate

Combi-Wall

The proposed "combi-wall" is a continuous concrete barrier that does not allow tidal circulation (**Error! Reference source not found.**). There are no moving parts or gates for this feature that would require deployment in advance of impending tropical event.

To construct a traditional inverted T-type flood wall within the Galveston Bay would require a cofferdam in order to construct the flood wall in the dry. A cofferdam would add both cost and additional temporary impacts to the Galveston Bay bottom. The proposed combi-wall can be constructed in the wet with all the construction equipment located on a temporary platform, thus eliminating some of the bay bottom impacts and in more streamlined construction sequence. The proposed "combi-wall" system consists of vertically driven 66 in diameter hollow concrete spun cast piles with 18 in closure piles closing driven to complete the closure of the system. The lateral resistance for this system comes from a 36-in Ø steel batter piles with a concrete deck sections that ties the system together with a small parapet wall. The concrete deck sections will serve as an access roadway for the entire length of the combi-wall. A blanket of scour will be placed on both the flood and land side of this structure to prevent erosion.

It is assumed the combi-wall will be constructed from a temporary work platform in order to minimize the impacts of dredging a floatation channel for access on the marine habitat in this area. A similar type floodwall was constructed as part of the New Orleans Hurricane Storm Damage Risk Management System, Lake Borne Barrier. The Lake Borne Barrier has performed as designed during several tropical events without any issues.

Figure 11. Conceptual Drawing of the Combi-Wall

Vertical Lift Gates

The Vertical Lift Gates (VLGs) are proposed for the intermediate and deeper parts of the Bolivar Roads crossing. The VLGs are specifically designed to provide a large opening to allow for free passage of the tides for both sides of the gate. The VLGs will be stored in the up at normal/open position. The gates will remain in the up position until they are needed to be deployed for a tropical event (Figure). These gates have a low clearance between the bottom of the gates in the stored position and the normal water surface elevation in Galveston. Therefore, the VLGs are not intended for any type of navigation.

There are VLGs on both the Bolivar Island and the Galveston Island side of the barrier. There are eight (8) VLGs with a sill elevation of EL. -20.0 and seven (7) VLGs with a sill elevation of elevation -40.0 MLLW. The feasibility level design assumed the gate will transfer all the lateral load to the piers which is founded on a large matt foundation supported on 24-in Ø pipe piles. There is a concrete sill set at the gate invert that spans between the tower foundations and is founded on a large matt foundation supported on 24-in Ø pipe piles. A blanket of scour will be placed on both the Flood and Land side of this structure to prevent erosion.

The vertical lift gates will have an access bridge on the land side of the structure to allow maintenance crews access to maintain the gates and operate equipment. The access bridge is assumed to span the entire gate opening by using large precast pre-stressed concrete highway girders with a concrete deck serving as the roadway on top.

The vertical lift gates are suspended between the structure's towers on either side of the opening. The lift gates and the towers of the barrier have a unique shape: the gates are elliptical, and the towers are oval. The vertical lift gates are driven by hydraulic cylinders with a long piston which are hinged to the side towers. The VLG's for the Bolivar Road crossing have a clear opening of 300 ft.

The VLGs are assumed to be constructed using conventional cast in place construction methods. A temporary retaining structure consisting of cellular cofferdams that are dewatered to facilitate the construction of the structure. The dredging of a floatation channel is required for marine access to the VLG with a sill elevation of -20.0. However, the VLGs with a sill elevation of -40.0 MLLW do not require the dredging of a floatation because the location of these structures already have adequate draft for the marine equipment required for construction. It was assumed these structures will be constructed using equipment set on a floating plant.

The VLGs assumed for this study are modeled after the Hartel Canal storm surge barrier located in Spijkenisse, Netherlands. The Hartel Canal floodgate has been in operation and has been reliable since construction completion 1996. In the event the closing operating system fails, these gates have a local, automatic closure system, battery controlled, using gravity to close the gate. Like the Hartel Gates, it is assumed any minor maintenance will be performed while the gates are in place. If there are substantial repairs, the gate or the gate machinery will be removed from the site and brought to a dry dock where the required maintenance can be performed.

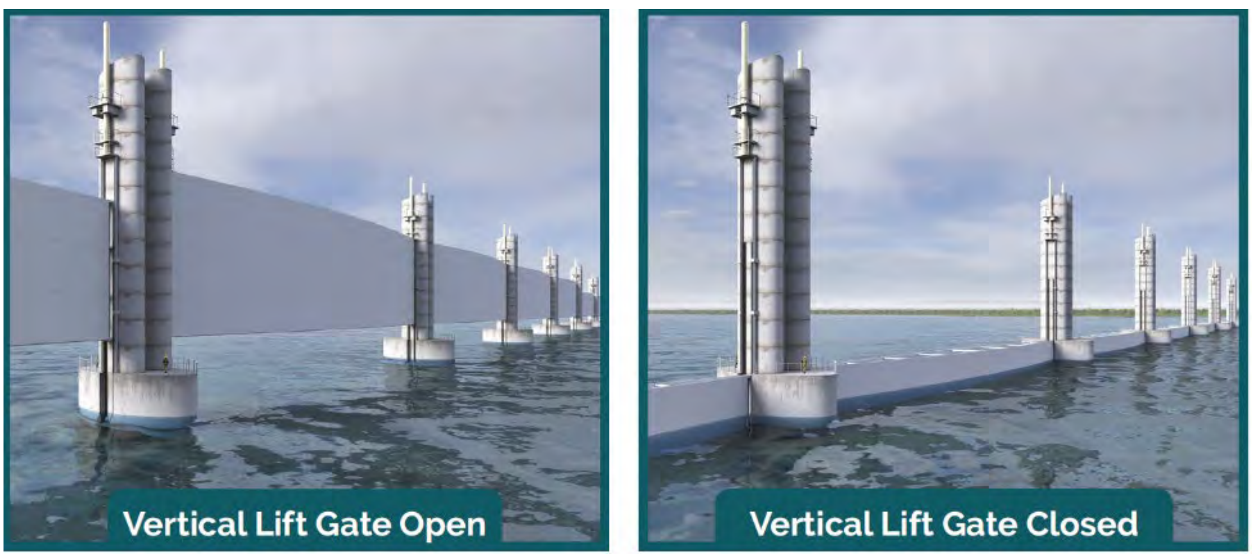

Figure 12. Conceptual Drawing of Vertical Lift Gates

Navigational Gates
The Houston Ship Channel (HSC) is the most active deep draft channel in the nation and is one of the hearts of the countries Entergy production. Galveston Bay sees both recreational and commercial vessels, for this reason, the Bolivar Road crossing must have navigation gates designed for both commercial and recreational vessels. Figure shows a rendering of the navigation gate complex. The navigation gates are intended to remain open year-round to maintain continuous navigation and existing flow characteristics. The gates are intended to remain open year-round to maintain continuous navigation and natural flow characteristics. The gates will be closed in the event of a tropical system threatening the coast.

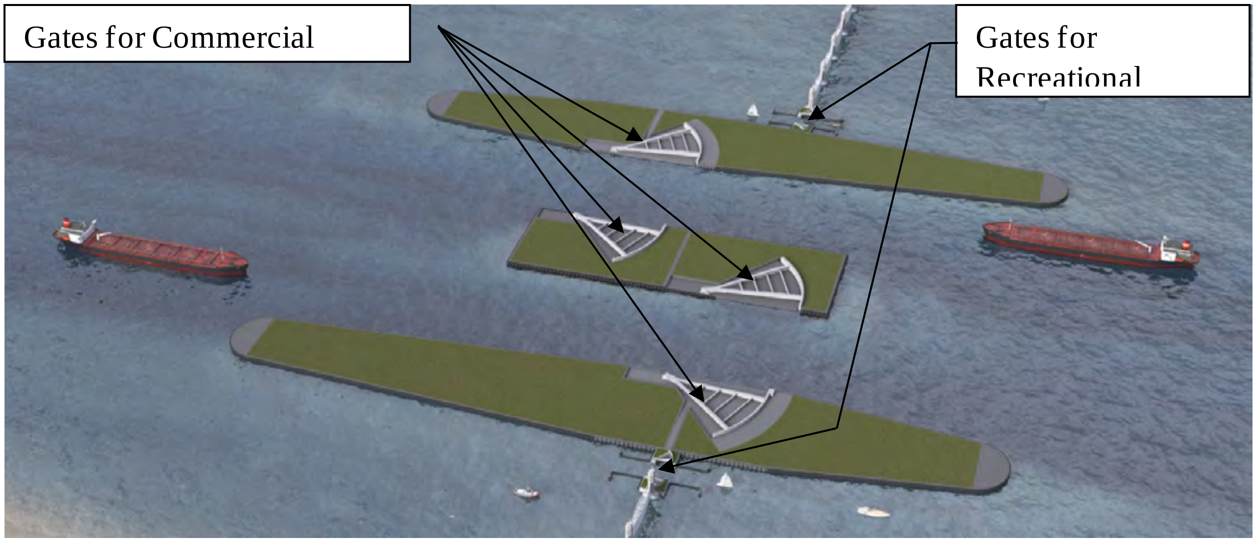

Figure 13. Conceptual Drawing of Navigational Gates

Recreational Sector Gate

There is one 125' opening sector gate complex on either side of the Houston Ship Gate Complex for recreational vessel passage. This will prevent recreational vessels from having to cross the Houston Ship Channel to travel from the Galveston Bay side of the system to the Gulf of Mexico side. While the gates are open, the steel fabricated gates would be stored in the structure gate bays to protect them from vessel impact. Timber guide walls are also part of the complex. These sector gates are assumed to have a clear opening of 125' opening with sill elevation of El. -40.0 MLLW. The feasibility level design assumed a large matt foundation supported on 24" Ø pipe piles. A blanket of scour will be placed on both the Flood and Land side of this structure to prevent erosion.

The sector gate is assumed to be constructed using conventional cast in place construction methods. A temporary retaining structure consisting of cellular cofferdams that are dewatered to facilitate the construction of the structure. This sector gate does not require the dredging of a floatation because the location of these structures already have adequate draft for the marine equipment required for construction.

The sector gate structures will have maintenance dewatering bulkheads that allow for the gate complex to be dewatered and the required maintenance can be done in the dry. Adjacent to the sector gate complexes. The gates will be designed to allow vehicles to use the gates as access from one side of the gate bay to the other side. The sector gate assumed for this study is modeled after the Harvey Canal Sector Gate constructed within in the New Orleans area, which has been in service for over 10 years and has shown to be reliable.

Houston Ship Channel Sector Gate

A horizontally rotating floating sector gate was deemed most suitable for HSC. A complex of two (2) gates and associated artificial islands to store the gates is proposed for this crossing. The decision to use 2 smaller gates in lieu of one large gate was for redundancy in navigation and assist in the maintenance cycles. In the unlikely event, one of the gates will not open after a storm or there is maintenance that requires the gate to be closed, navigation can continue through the other gate. The gate openings are assumed to be 650 feet wide each with a sill elevation of El. -60.0. The feasibility level design assumed the gate will transfer all the lateral load to the hinge which is connected to a large matt foundation supported large diameter steel pipe piles. A blanket of scour will be placed on both the Flood and Land side of this structure and around the islands to prevent erosion.

The gates will be stored in a dry dock within the manmade islands. The gates will be stored within the dry dock and only be deployed for a tropical event or for any required maintenance. With the floating sector gates in dry dock, this will help inhibiting corrosion and debris accumulation and facilitates routine maintenance. When it is time to employ the gate, the dry dock will be flooded allowing the gate to float into place and then water will be pumped in the sections of the gate allowing it to sink in place. Once the event has pasted, the gate sections will be pumped out and the gate will be floated back to the dry dock. With the gates stored within the dry dock area will help minimize the probability of vessel impacts while the gates are in the stored position.

The islands will be constructed with the perimeter of the island consisting of large cellular cofferdams backfilled with select fill material. The perimeter of the island will be constructed first followed by demucking the bay bottom and finally backfilling with dredged material to the final design grade. This sector gate does not require the dredging of a floatation because the location of these structures already have adequate draft for the marine equipment required for construction.

At no time will navigation be blocked during the construction of these gates. A temporary bypass channel will be dredged to allow for continued navigation. Prior to any island construction, navigation will be shifted to the bypass channel. Upon completion of one of the gate-and-island complexes, traffic will be diverted to the newly constructed channel and gate opening. At which time, the second gate and the other island will be constructed. The selected gate was modeled after the gate constructed in St. Petersburg Russia and the Maeslant Barrier in the Netherlands. The Corps determined it was important to model these gates after similar existing gates to ensure the reliability of the gates to open and close when necessary.

Channel Widening
Construction of the crossing across the Galveston Harbor Entrance Channel will be widened to accommodate the inbound channel and sector gate. The construction of the inbound channel will occur prior to the construction of the sector gate across the existing Entrance Channel in order to minimize impacts to existing channel traffic. The widening of the channel will be north of the existing channel toe, through existing anchorage areas and will be maintained at 800-foot toe to toe wide and depth of –48 MLLW, which is consistent with the existing channel authorized depths.

Due to the extension of the existing Galveston Entrance Channel toe to the east to accommodate an inbound lane through the sector gate existing aids to navigation will need to be relocated and additional aids provided due to extension. New aids will be required for the recreational sector gate structures that comprise the crossing. Existing and/or new aids to navigation aids would be can or conical type. Further coordination with the Coast Guard will be conducted during the detailed design phase.

The gate crossing the Galveston Entrance Channel will impact existing anchorages A, B and C. The PDT coordinated with industry to address the impacts and present proposed anchorage areas to mitigate the impacts to the existing anchorage areas. Because of the amount of dredging required and the need to relocate a 24" pipeline, the local sponsor and the District carried forward a New Anchorage Area A which is an expansion of the existing area and Anchorage Area D (Figure). The new anchorage area would cover an area of about 2.4 square miles.

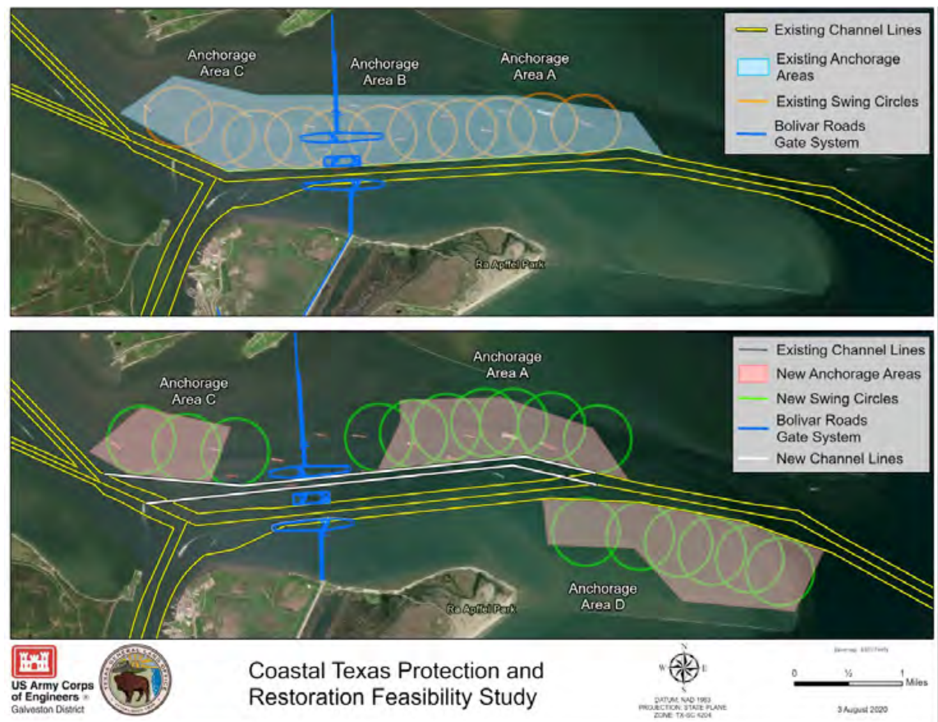

Figure 14. Existing and Proposed Study Anchorage Areas

Galveston Island Control/Visitor Center

The Bolivar Roads Gate System would also include a central control center on the Galveston side of the barrier. The Control Center will be located on the protected side of the barrier near the northeast corner of the San Jacinto Placement Area. The 5,000 square foot building would be on Government owned lands and would be accessible via the construction of a 0.32-mile all-weather concrete road from the existing USMC Reserve Center access road to the building location. The road would be aligned outside the San Jacinto Placement Area perimeter levee and have a width of 30 feet and a crown elevation of at least 21.5 feet. The Control Center would be at elevation +21.5 feet NAVD88 and would be equipped with backup systems to allow for continued operation during power lost.

The Control Center would also function as a Visitor Center. The Galveston Island Control Center site would also include a 2,500-square foot Maintenance Shop for the repair/rehab of gate fixtures, storage of maintenance equipment, spare parts, fuel, and lubricants. Additionally, to assure redundancy in the operation of the gates a 3,500-square foot auxiliary control center would be located on Bolivar on the protected side of the levee near the intersection of 23rd and State Highway 87. The Bolivar Auxiliary Control Center would be at the same elevation as the Main Operation Center.

Bolivar Peninsula and West Galveston Beach and Dune System

The Bolivar Peninsula and West Galveston Beach and Dune System would be constructed in a very similar manner to the beach nourishment actions being conducted for Ecosystem Restoration measures (previously described in Dune and Beach Restoration/Nourishment Section).

The Bolivar Peninsula beach and dune system starts approximately 2.0 miles east of State Highway 87 and continues southwest for 25.1 miles to the end of Biscayne Beach Road where the system will tie-into an earthen levee system adjacent to Fort Travis. The dune field will have a seaward elevation of +12.0 feet and a landward elevation of +14.0 feet NAVD88.

The West Galveston beach and dune system would start at the end of the existing Galveston seawall and continue westerly for 18.4 miles ending at San Luis Pass. The dune field system will have a seaward dune elevation of +12.0 feet and a landward dune elevation of +14.0 feet NAVD 88. Both beach and dune systems are further detailed in the Annex 12 and 13 Mapbook of Attachment A. Refer to Plate 1 (Annex 12) for a Typical Beach and Dune Section.

Beach and dune material sourcing and re-nourishment is discussed in Chapter 5.0 of the EIS. The design guidance for the beach and dune vegetation, sand fencing, walkovers and access is based on the, Dune Protection and Improvement Manual for the Texas Gulf Coast (GLO, n.d).

The dune would be planted with common grass species found on reference dunes including: bitter panicum (*Panicum amarum*), sea oats (*Uniola paniculata*), and marshhay cordgrass (*Spartina patens*). Dune plants would either be obtained from commercial sources or transplanted from natural stands along the cost. Plant species that are not available commercially would be obtained from natural stands, which would increase the survivability of the species. If suitable stands cannot be found on state-owned property, harvesting from neighboring private property could be accomplished with agreement from the property owner. The optimum time for transplanting and establishing vegetation on Bolivar and West Galveston is during the months of February, March, or April. It was assumed that 1,000 plants would stabilize a 50x100-foot strip within a year and include watering, mulch, fertilization, and replanting due to lost.

Standard slatted wood sand fencing would be installed at appropriate locations to allow for the sustainability of the dune system. A height of four feet, measured from the ground surface after installation, has been incorporated into the design, except for where sand conditions are poor for dune building, a height of two feet would be utilized. The fencing would be supported with treated pine posts at 10-foot intervals. Minimum practical length for posts is 6.5 feet; a length of 7 to 8 feet is optimum. Wooden posts be no larger than three inches in diameter. The fencing would be secured to each post with four ties of galvanized wire that is not smaller than 12 gauge.

The fencing material would be weaved between posts so that every other post has fencing on the seaward side. Sand fencing would be placed in non-continuous, diagonal segments—at least 35 degrees to the shoreline—so as not to adversely affect nesting sea turtles. A typical sand fencing installation detail is shown in Figure .

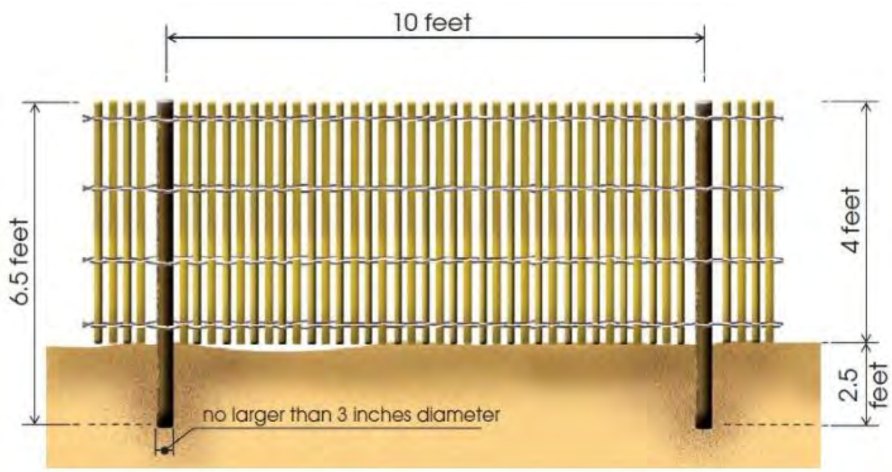

Figure 15. Typical Sand Fencing Installation Detail

Beach Access

The dune walkovers would be constructed of treated lumber and galvanized hardware. Typical structural design for the walkovers are shown in Figure 16. These designs have been successfully constructed for accessible dune walkovers. Pedestrian traffic volume will be investigated during PED to determine an appropriate walkover width for the location. During PED the PDT will work with local, state, and federal ADA/ABA boards to provide dune walkovers designs that improve accessibility for the handicapped. The structure height would be at least one to one and a half times its width (3' minimum) to allow sunlight to reach vegetation underneath the structure. The maximum slope for ADA is 1V:12H in inches and for every 30 inches in drop vertically, a level platform is required before proceeding at the maximum slope.

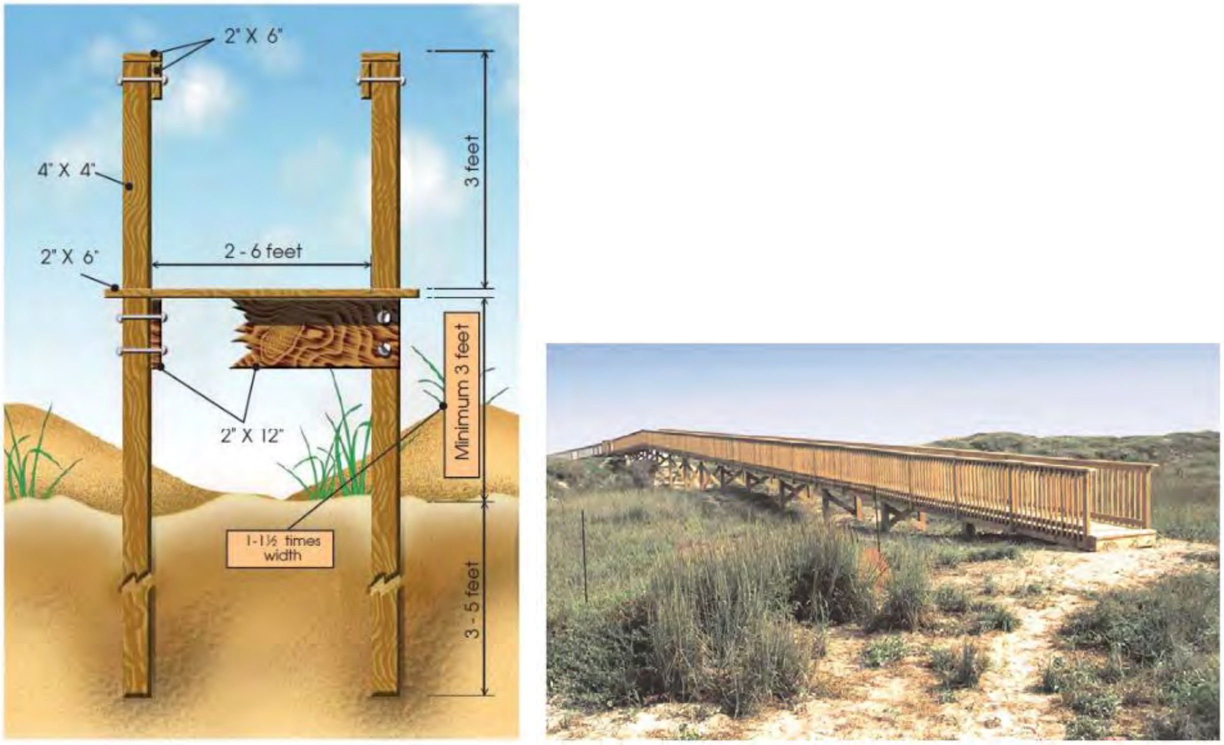

Figure 16. Typical Walkover Section and Ramp

Proposed vehicle access ramp locations are shown on the mapbooks for both Bolivar and West Galveston (Annex 11 and 13). The ramps would be oriented at an angle to the prevailing wind direction to reduce water and wind from being channeled along the ramp eroding the dunes at the side of the road cuts. The access ramp would slope to the elevation of the landward dune and would than slope down to a break in the seaward dune. This approach would minimize the ramp length needed to cross the two-dune system. Ramps would be 12-foot in width with a minimum ramp slope of 6% slope, constructed of sand fill, 8" of gravel base material stabilized with the utilization of a geogrid. The ramp concept is shown on Plate 3 (Annex 12). User surveys will be conducted during the design phase to identify heavy traffic use areas to properly locate access ramps.

Borrow Source

Construction of the Bolivar Peninsula and West Galveston Bay Beach and Dune System would require approximately 39.33 MCY. The potential source of beach-quality sand is located 25 to 32 miles (40 to 50 km) offshore in water depths of about 15 to 56 feet (4.5 to 17 m) in the Sabine and Heald Banks. These sand-rich shoals are reworked nearshore and shallow marine sediments and are generally considered beach compatible sediments. Despite the large total volume available (approximately 1.8 BCY) in the banks, there will be avoidance areas that need to be considered (e.g., offshore platforms, pipelines, etc.). Three will also need to be additional geotechnical and geophysical investigations during PED to better constrain locations with the most ideal sediment sources. During future refinements and investigations for this feature, other potential sources would be evaluated to include shoreface sediment, dredging associated with the

Houston Ship Channel deepening and widening project, measures complementary to navigation projects, and other paleo-channel deposits.

The method of dredging and placement will have to be determined during future phases of development. Based on previous studies, extraction of sand from Sabine and Heald Banks would require a dredge that is mobile and able to withstand moderate wave-energy conditions. Because the distance from the banks to the placement sites are all greater than 12.5 miles (20 km) away, it is very likely a hydraulic sidecast dredge or mechanical bucket dredge and a system of tugs and scows that would move sand between the banks and the placement site.

<u>Galveston Island Ring Barrier System</u>

The Galveston Ring Barrier System (GRBS) is a system of floodwalls, Navigation Sector gates, Shallow Water Environmental gates and roadway closure gates, roller and swing gates pump stations, and a levee that provides flood risk management to approximately 15 square miles of the City of Galveston. The proposed GRBS incorporates the existing Seawall and proceeds counterclockwise from the west end of the Sewall north in the proximity of 103rd street to Offatts Bayou, crosses the Teichman Point area and ties into I-45, continues east along the Harborside area to the 47st street area, then continues north to the Galveston Ship Channel, then continues east through the Port of Galveston to UTMB, turns northward to the Ferry and then back south to the seawall. See Figure 17 below for a map of the GRBS. Details of plans and cross sections are available in Annex 19 of EIS.

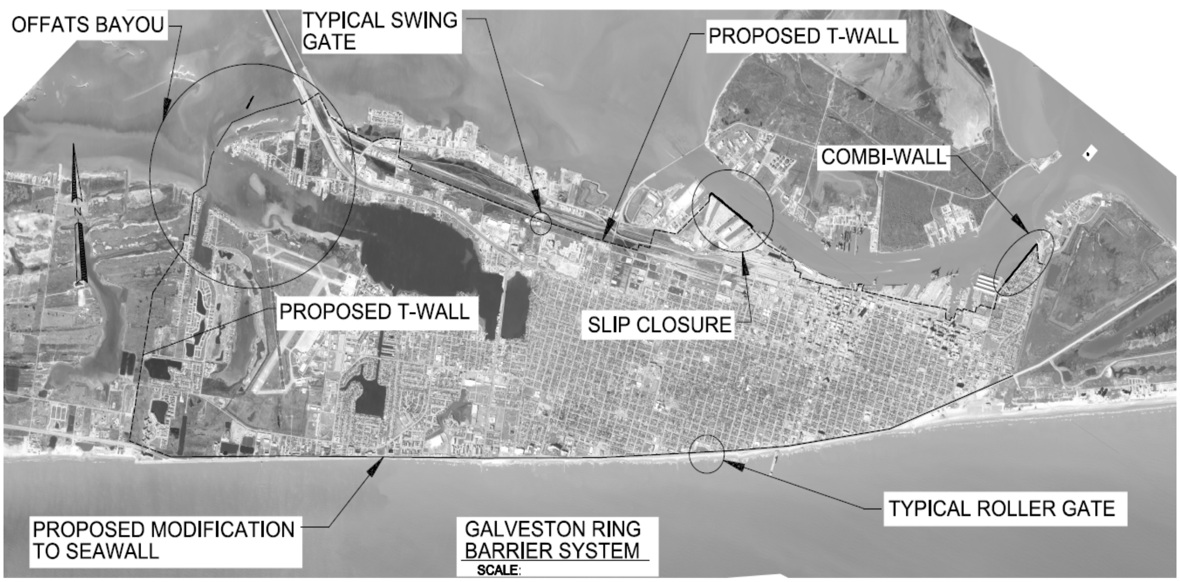

Figure 17. Galveston Ring Barrier System

Flood Wall

Galveston Island has significant stretches that don't have the real estate to construct levees or are subject to barge or boat impacts. For those reasons, an inverted "T-wall" was deemed the most appropriate type of floodwall for the GRBS system. The assumption of a T-wall, allows flexibility in wall height, inverted "T-wall's do not have any height limitations.

Only one design section for Galveston Island was used to develop quantities and one load case (water to the top of the floodwall) was analyzed (Figure 18). A top of floodwall elevation of elevation +14.0 feet NAVD 88 was assumed with an associated top of base slab elevation of elevation +0.0 NAVD 88. The slab was assumed to be 3 foot thick. The quantities assume a continuous line of steel sheet pile seepage cut-off wall driven under all of the T-walls. The wall is assumed to be founded on 18” Ø pipe piles.

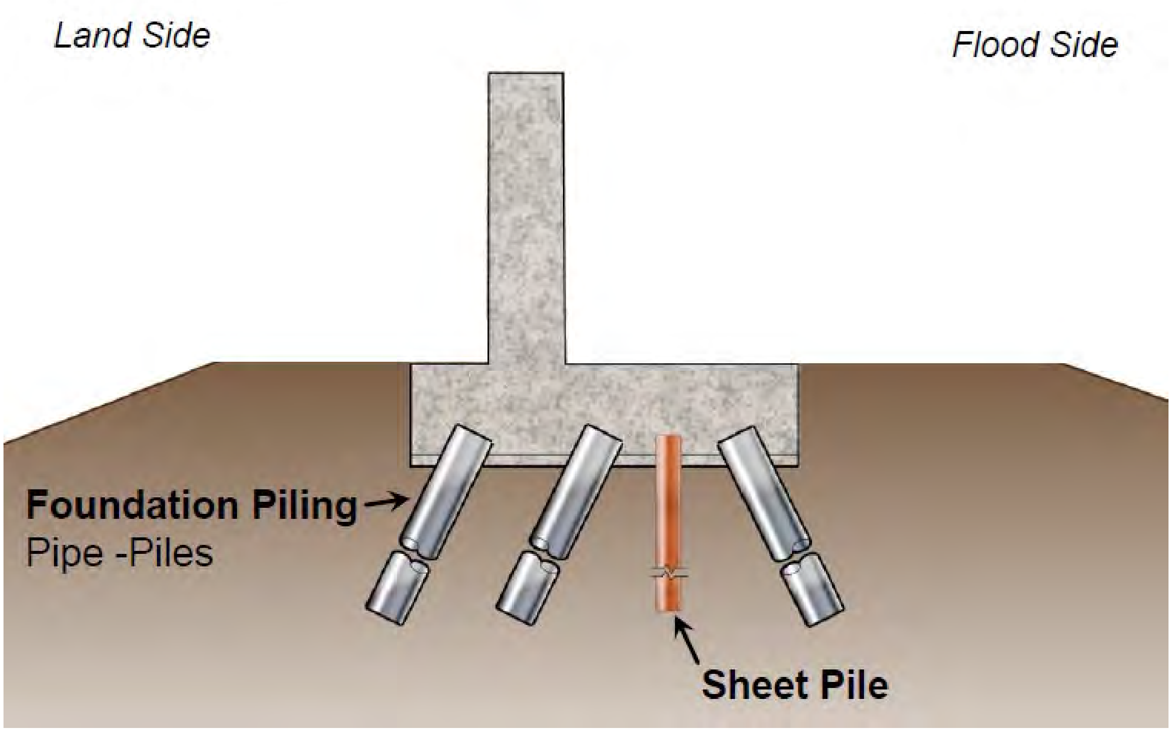

Figure 18. Typical Flood Wall Cross-Section

Offatts Bayou Crossing

The closure of Offatts Bayou starts at the edge of the Galveston Bay Foundation (GBF) property and continues north then northeast offshore of the Teichman Point neighborhood then ending at the Offatts Bayou pump station adjacent to the Galveston Causeway (Figure 19). This project feature is a combination floodwall system (Combi-wall) that consists of vertical piling, batter piling and a concrete cap system. This feature also includes a section of shallow water environmental gates/water circulation gates and two navigation sector gates. All of the Offatts Bayou structures will have a top of structure at +14.0 feet NAVD88.

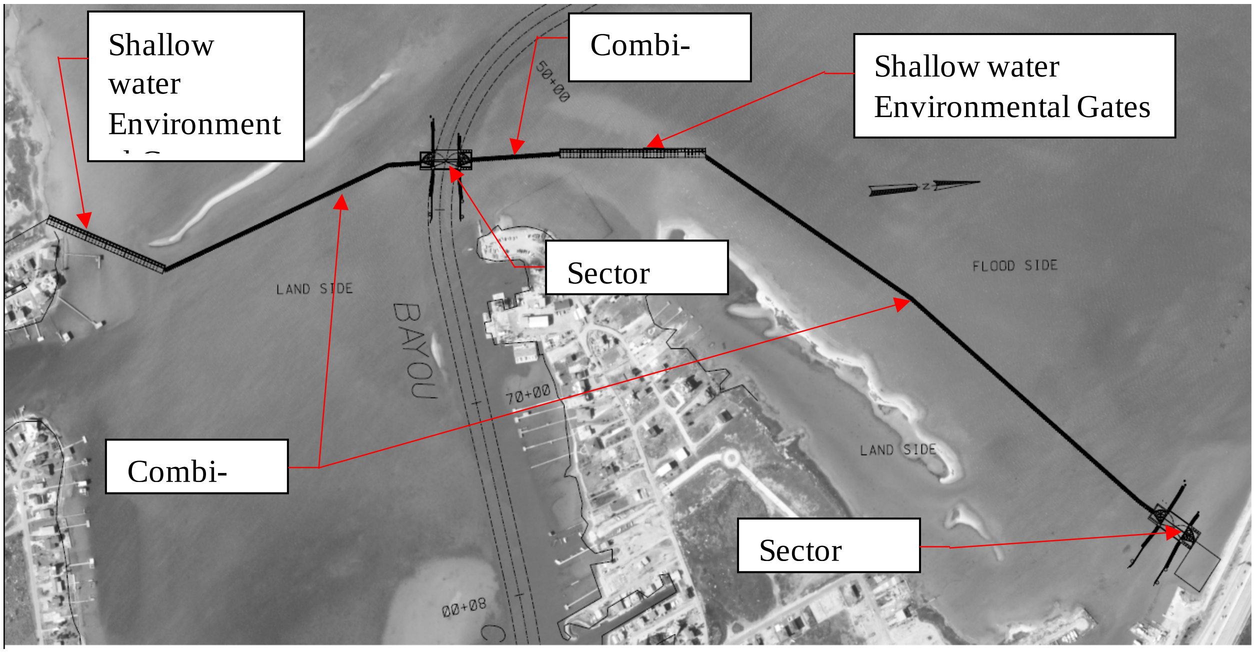

Figure 19. Offatts Bayou Crossing

Seawall Improvements

The Galveston seawall improvement feature is a future adaptation to provide additional storm surge and wave overtopping reduction along Galveston Island, which will connect to the storm surge gate at Bolivar Roads and the beach dune system. The recommendation is to increase the height of the existing 10-mile seawall to reach a uniform level of protection of 21.0 feet above mean sea level. (NAVD88). The extension would go from the San Jacinto levee seawall tie-in to the west end tie in of the GRBS.

Dickinson Bay Gate

Features at Dickinson Bay west of Highway 146 consist of sector gate, associated combi-wall, and pump station. The current authorized dimensions of the channel are a 60-foot width and a depth of –9 feet MLLW, which includes an advanced maintenance depth. The alignment of the gates and associated wall would be along the abandoned railroad ROW. The gate opening across Dickinson Bay is at 100-foot to allow for additional flow area. End points for the combi-wall will be further analyzed during future analyses. The elevation of the wall and gate is 18.0 feet.

Clear Lake Channel and Gate

Features at Clear Lake Channel west of Highway 146 consists of sector gate across the channel, associated barrier wall and pump station. The current authorized dimensions of the channel are a 75 feet width and a depth of -10 feet MLLW, which includes an advanced maintenance depth. The Clear Lake Channel is currently not maintained. The alignment of the gates and associated wall will be along the abandoned railroad right-of-way (ROW). The elevation of the wall and gate is 17.0 feet.

Mitigation Plan

In accordance with the mitigation framework established by Section 906 of the Water Resources Development Act (WRDA) of 1986 (33 US 2283), as amended by Section 2036 of WRDA 2007 and Section of the Water Resources Reform and Development Act (WRRDA) of 2014, the Council on Environmental Quality's (CEQ) National Environmental Policy Act (NEPA) regulations (40 CFR Sections 1502.14(f), 1502.16(h), and 1508.20) and Section C-3 of Engineering Regulation (ER) 1105-2-100, the Corps has prepared a mitigation plan (Appendix J of the EIS) to ensure that project-caused adverse impacts to ecological resources are avoided or minimized to the extent practicable, and that remaining, unavoidable impacts are compensated to the extent justified.

Mitigation planning is an integral part of the overall planning process. To complete mitigation planning, the same steps used for ER and CSRM plan formulation were followed including: identifying the problem/need and objectives and identifying, evaluating, and selecting measures. This process included close coordination with Federal and State resource agencies.

The very first step in mitigation planning is to determine the mitigation need. Practicable avoidance and minimization measures were considered where feasible and incorporated to reduce the amount of unavoidable impacts to the environment. Avoidance and minimization included: siting structures in areas of previous disturbance where practicable, limiting the footprint of the structures to the smallest extent required to function in a safe and effective manner, removal of levees and replacement of the measure with beach and dune nourishment, modification of the gate design to reduce the rate of constriction, seasonal timing and equipment restrictions, etc.

Compensatory mitigation is required for unavoidable impacts to the environment that are caused by the RP. No mitigation was determined to be required for any of the ER measures, the South Padre Island Beach Nourishment or the Bolivar Peninsula and West Galveston Island Beach and Dune Improvements because no net loss in AAHUs was realized in the HEP analysis. Implementation of the Bolivar Roads Gate Structure, Galveston Ring Barrier, Dickson Bay Surge Gate, and Clear Lake Surge Gate are expected to have unavoidable adverse impacts to various habitats as indicated by a net loss of 881.2 AAHUs (see "Project Impacts" section below). Impacted habitat types are estuarine emergent wetland, palustrine emergent wetland, oyster reef and open bay bottom.

The objective of wetland and oyster mitigation plan is to replace the significant net losses of affected wetland and oyster values and function that would be directly or indirectly impacted during construction or long-term operation of the Galveston Bay Storm Surge Barrier System.

The Corps and an interagency resource team made up of biologists, hydrologists, engineers, and planners from Texas Parks and Wildlife Department (TWPD), National Marine Fisheries Service, U.S. Fish and Wildlife Service (USFWS), Texas General Land Office (GLO), Natural Resource Conservation Service (NRCS), U.S. Environmental Protection Agency (EPA), Texas Water Development Board (TWDB) and others met numerous times to identify types of mitigation measures and alternatives, agree on specific locations where these mitigation alternatives could be located, discuss assumptions underlying the mitigation benefits, and select an evaluation array of mitigation alternatives.

The team identified a total of five potential measures to mitigate for wetlands including: mitigation bank credits, onsite wetland restoration, off-site wetland restoration, wetland creation, and wetland preservation. Each of these measures were considered for both estuarine and palustrine wetlands. Off-site wetland mitigation was carried forward because it was the only measure that was feasible.

A total of four methods were considered for oyster mitigation including: mitigation bank credits, restoration (placement of cultch directly on bay bottom or on elevated berm, oyster structures, or oyster seeding), creation, and protection/preservation. Oyster restoration involving placement of cultch directly on the bay bottom was the only measure carried forward due to other measures not being feasible or cost-effective.

Once the wetland and oyster mitigation measures were identified, the same interagency team met to identify potential restoration sites. The team came up with several screening criteria to identify the final array of potential restoration sites such as distance to the impact area, property ownership, potential for long-term protection, ability to be self-sustaining, etc. Based on the criteria, the interagency team narrowed the potential mitigation sites down to five estuarine wetland sites, one palustrine wetland sites, and three oyster restoration sites (Figure 20 and Table 7). Each of these sites have been determined to meet most of the screening criteria and are acceptable to the resource agencies as a way to mitigate the losses.

The same methodology for assessing habitat change for the ER measures was applied to the mitigation sites to determine habitat quality of the site. Each site has very low existing and without restoration condition HSI scores. After restoration of the site, lift is gained and a net increase in AAHUs is realized. **Error! Reference source not found.** Table 7 shows the net change in AAHUs that can be gained at each of the mitigation sites.

A combination of all of these sites will be required despite being able to achieve the needed total mitigation at one site. This is because it was prudent to mitigate for the loss as close as possible to the impact site, so being able to do one large mitigation project, which was likely a good distance removed from the impact site would not achieve the objective of the mitigation.

Potential locations for mitigation sites, will be refined further during future Tier Two assessments in coordination with the resource agency team. Ultimately, the final size of the mitigation measures (width, length, etc.) may change. However, the type of restoration proposed in the RP would not change. The location of the proposed restoration could change if significant time passes and these locations are developed in the meantime or restored as part of another non-Corps project.

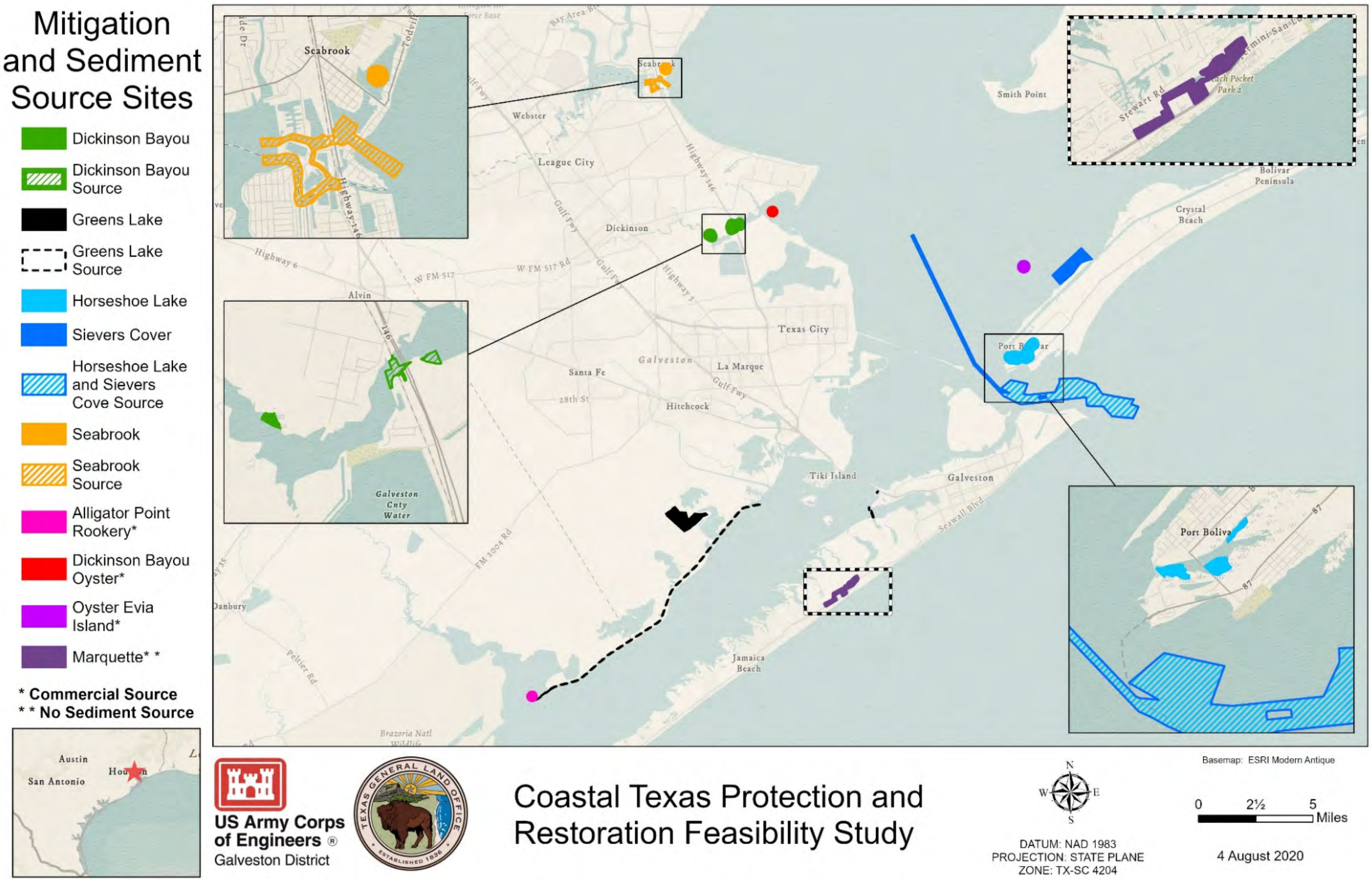

Figure 20. Potential Mitigation Sites

Table 7. Description of Mitigation Sites Being Considered

Mitigation Site	Description	Mitigating For	Net AAHUs
Estuarine Emergent Wetlands			
Sievers Cove	Establish a minimum of 667 acres of tidal wetland that is comprised of 80% *Spartina alterniflora* stands and 20% open water. The wetland would be established by pumping shoaled material from the GIWW, the HSC, or using material from the Coastal Texas Project.	Bolivar Roads Gate System (Direct and Indirect Impact)	491.8
Greens Lake	Establish a minimum of 562 acres of tidal wetland that is comprised of 80% *Spartina alterniflora* stands and 20% open water. The wetland would be established by pumping shoaled material from the GIWW or the Hitchcock/Highland Bayou Diversionary Canal.	Bolivar Roads Gate System (Indirect Impact)	453.1
Horseshoe Lake 1-3	Restore tidal wetland that is comprised of 80% *Spartina alterniflora* stands and 20% open water. The wetland would be established by pumping shoaled material from the GIWW, the HSC, or using material from the Coastal Texas Project.	Bolivar Roads Gate System (Direct Impact)	37.6
Seabrook	Establish a minimum of 4 acres of tidal wetland that is comprised of 80% *Spartina alterniflora* stands and 20% open water. The wetland would be established by pumping shoaled material from the Clear Creek Channel, the HSC, or using material from the Coastal Texas Project.	Clear Lake Surge Gate (Direct Impact)	2.1
Dickinson Bayou	Establish a minimum of 7 acres of tidal wetland that is comprised of 80% *Spartina alterniflora* stands and 20% open water. The wetland would be established by pumping shoaled material from the Dickinson Bayou, the HSC, or using material from the Coastal Texas Project.	Dickinson Surge Gate (Direct Impact)	4.0
Palustrine Emergent Wetlands			
Marquette	Restore 34.2 acres of dune swale freshwater wetlands and 127.6 native prairie vegetation by excavating material where necessary to bring them to within one-foot of the winter water table.	Galveston Island Ring Barrier (Direct Impacts)	12.2
Oyster Reef/Open Bay Bottoms			
Evia Island	28 acres of oyster reef constructed around the bird rookery at Evia Island.	Open Bay Bottom from Navigation Gates (Direct Impacts)	28
Dickinson Bayou	7 acres of oyster reef constructed in Dickinson Bay.	Dickinson Bayou Surge Gate (Direct Impact)	7
Alligator Point	10 acres of oyster reef constructed around the bird rookery at Alligator Island.	Open Bay Bottom from Ring Levee (Direct Impact)	4.9

Recommended Plan

The Recommended Plan includes a combination of ER and CSRM measures that function as a system to reduce the risk of coastal storm damages to natural and built infrastructure and to restore degraded coastal ecosystems through a comprehensive approach employing multiple lines of defense. Focused on redundancy and robustness, the proposed system provides increased resiliency along the Bay and is adaptable to future conditions, including relative sea level change. The Recommended Plan includes Alternative 1 – Coastwide ER plan (ER), the South Padre Island Beach Nourishment (Lower Coast CSRM), and Alternative A – Coastal Barrier (Upper Coast CSRM). In addition, the recommended plan includes a recommendation to mitigate for the net loss of 881.2 AAHUs.

Within the recommended plan, six ER measures have been identified as "actionable" measures meaning the measures have a sufficient level of site-specific detail to fully understand the context and intensity of the anticipated impacts of the measure. Therefore, the EIS has incorporated a site-specific analysis for these measures and are fully compliant with NEPA and all environmental laws and regulations, including FWCA. Measures identified as "Tier One" measures include all dune and beach restoration measures that were evaluated as ER measures (B-2 at Follet's Island and W-3 at North Padre Island/Port Mansfield Channel), and the Bolivar Peninsula and Galveston Island component of the Galveston Bay Barrier System. Tier One measures also included the Gulf and Interior surge gates and Galveston Island Ring Levee System and Seawall Improvements. Tier One measures were broadly reviewed in the Study EIS to document anticipated impacts; however, the designs are likely to change and may affect the potential impacts and therefore mitigation plan components. As a result of these uncertainties in the design plans, an additional separate independent NEPA analysis and environmental compliance will be completed on the Tier One measures once the designs are refined and the impacts are fully understood, at which time additional coordination with the Service would occur and one or more FWCARs would need to be issued for the Tier One measures. Table 8**Error! Reference source not found.** shows which measures are actionable and which are not.

Table 8. Actionable and Tier One Measures of the Recommended Plan

Recommended Plan Component	Actionable	Tier One*
G-28 – Bolivar Peninsula and West Bay GIWW Shoreline and Island Protection	X	
B-2 – Follet's Island Gulf Beach and Dune Restoration		X
B-12 – West Bay and Brazoria GIWW Shoreline Protection	X	
CA-5 – Keller Bay Restoration	X	
CA-6 – Powderhorn Shoreline Protection and Wetland Restoration	X	
M-8 – East Matagorda Bay Shoreline Protection	X	

Recommended Plan Component	**Actionable**	**Tier One***
SP-1 – Redfish Bay Protection and Enhancement	X	
W-3 – Port Mansfield Channel Dredging, Island Rookery, and Hydrologic Restoration, Beach and Dune Restoration Padre Island National Seashore		X
South Padre Island Beach Nourishment		X
Bolivar Roads Gate System		X
Bolivar and West Galveston Beach and Dune System		X
Galveston Seawall Improvements		X
Galveston Ring Barrier System		X
Clear Lake Surge Gate		X
Dickinson Surge Gate		X
Non-structural Measures		X

* Requires additional NEPA analysis and FWCA consultation

PROJECT IMPACTS

This section describes the potential project impacts of implementing the six ER measures that the Corps determined are actionable measures in the EIS. This section also describes the potential impacts of implementing the beach and dune measures proposed in the two ER measures (Follet's Island – B-2 and Port Mansfield Channel/Padre Island – W3) and the three CSRM measures (Galveston Bay Barrier System on Galveston Island and Bolivar Peninsula, and South Padre Island beach nourishment), which will be considered as Tier One measures in the EIS. Additional overview of the Galveston Bay Barrier System, which includes Gulf and interior surge gates and Galveston Ring Barrier (CSRM) measures and the restoration of hydrological connection to the Laguna Madre (W-3) is also discussed herein.

Actionable ER Measures and Tier One Beach and Dune Measures

The following is a general description of the benefits and adverse impacts the Corps anticipated with each of the ER measures including beach and dune measures at B-2 and W-3, and the South Padre Island Beach Nourishment (CSRM) measure that will be evaluated further in the Tier Two NEPA evaluation.

Breakwaters

Benefits: Breakwaters allow for the stabilization and protection of the existing shoreline and support the reestablishment of intertidal emergent vegetation along the shoreline through retention of sediments and reduced land loss. Under the existing condition, the rate of loss is approximately 4 feet per year, which translates to approximately 55.25 acres per year (about 2,763 acres over a 50-year period) of interior wetland that would be protected and improved with implementation of the breakwaters. Additionally, breakwaters are expected to improve overall water quality with reduced saltwater intrusion and turbidity and may decrease operations and maintenance costs of the GIWW by reducing the amount of dredging. Overall, emergent shoreline habitats and interior wetlands are expected to improve thereby supporting a more diverse and productive habitat for aquatic and terrestrial species. The breakwater structure itself can provide additional aquatic habitat by providing substrate for oyster larvae settlement and recruitment, and also supports a greater abundance and diversity of aquatic species that utilize this structure for foraging and refugia from predation.

Adverse Impacts: Direct and indirect impacts associated with constructing breakwaters are temporary in nature and limited in scope. Construction activities would contribute the greatest impacts to the environment and could include: localized effects to water quality, including increased turbidity and total suspended sediments, organic enrichment, reduced dissolved oxygen, elevated carbon dioxide levels, and decreased light penetration, among others; habitat removal and/or fragmentation; temporary habitat avoidance because of increased noise, vibrations, and overall temporary lower quality habitat; losses of slow moving and less mobile species (aquatic invertebrates, benthic species, mollusks, and smaller/juvenile fish); and temporary loss of recreation opportunities. The level and duration of the impacts is dependent on the final design the measure, type of equipment used, and duration of construction activities.

However, it is anticipated that if appropriate conservation measures are implemented during and after and construction is complete, temporary disturbances related to construction activities would cease.

Long-term impacts from placement of the breakwaters would permanently convert inland open water habitat to a hardened structure thereby reducing available habitat for aquatic species. This loss, which equates to only the footprint of the structure, is generally considered minimal when compared to the extent of inland open water habitat available and the ability of benthic organisms to recover in adjacent bottom sediments once construction has been completed. As well, the structures would be designed in such a way as to not hinder movement of aquatic species between open water areas and the adjacent existing wetland habitats. These impacts would have an overall minimal impact to fisheries and aquatic populations in the area and would in the long-term protect adjacent wetland and seagrass habitat that aquatic species depend on for survival that would be lost in the future if the measures were not implemented. Any long-term loss of open bay mud bottom is expected to be outweighed by the benefits the breakwater would provide as protection to existing or restored wetlands and seagrass habitats. The overall benefits of implementing the breakwater measure far outweigh any temporary or permanent loss of open water mud bottom habitat that displace infaunal species or those that require unvegetated open water areas that occurs during construction.

Wetland Restoration

Benefits: The unconfined placement of dredged material in wetland restoration units and along the shoreline of the GIWW would have a net relative benefit given the uncertainty in future sea-level rise and dynamic wetland response to current and future tidal conditions. A total of 2,052 acres of wetland complex habitat would be restored by reducing the extent of open water in these wetland restoration units to less than 35% in order to maximize the "edge-effect" of increasing the densities of both transient and resident aquatic species utilizing the first three meters of the wetland habitat (Peterson and Turner, 1994; Zimmerman and Minello, 1984). Additionally, increasing available sediment and detritus in these wetland restoration units is expected to increase the potential for future sediment accretion and adaptation to sea level rise by supporting a diversity of wetland plant species at higher elevations than are typically found in lower elevation, *Spartina alterniflora* monoculture wetlands.. The importance of estuarine wetlands as a source of detrital-based food chains is well documented (Darnell, 1967; Peterson and Turner, 1994). Once vegetative species composition and detritus is restored in these restoration units, the functional equivalency of these wetlands will provide increased primary productivity, soil development, nutrient cycling, food chain support, benthic biomass production, and fish and shellfish production (Peterson et al., 2007; Craft et al., 1999; Minello, 1999; Minello and Webb, 1997). These valuable resources are expected to provide higher quality nesting, foraging, roosting, and nursery habitat for resident and migratory fish and wildlife species

Adverse Impacts: Many of the same adverse temporary impacts associated with construction of the breakwaters can be expected for wetland restoration. Placement of dredged material into the restoration unit has the potential to: degrade water quality locally within the placement site; compact soils and mix soil horizons; smother, trample, and kill existing vegetation and slow moving or less mobile species (small mammals, aquatic invertebrates, benthic species, etc.); and create noise and vibrations that cause fish and wildlife to avoid the area. The level and duration of the impacts is dependent on the final design the measure, type of equipment used, and duration of construction activities, as well as the species ability to avoid the habitat during the construction period and until the habitat has recovered from the disturbance. It is anticipated that once construction is complete, temporary impacts related to construction activities would cease.

Although wetland restoration would result in the loss of approximately 65% of the open water in the restoration units, wildlife species currently utilizing this habitat would not be expected to be adversely affected over the long-term. Wildlife species currently utilizing the shallow open water and vegetated shoreline habitat in the restoration units are highly mobile allowing them to relocate into adjacent open water habitats outside the restoration units. The conversion of open water to wetland habitat is generally considered a benefit to aquatic species, but may displace infaunal species or those that require unvegetated mud bottom habitats (e.g. shrimp).

Island Restoration

Benefits: Restoration of islands would increase available nesting habitat by expanding the size of the islands and enhancing the quality of habitat for ground nesting birds such as skimmers, terns, reddish egret, and American oystercatcher, as well as shrub nesters like spoonbills and pelicans. The islands would likely serve as a source populations for recolonizing other sites and reduce issues associated with overcrowding on existing islands. They would be important in sustaining or increasing regional populations given the few nesting islands available along the coast.

The shoreline length of each of the islands would increase and provide for additional area for fringe wetland habitat to establish thereby increasing suitable habitat for a number of additional aquatic species. Additionally, the increase in nutrients to the water from bird defecation has been known to create conditions which promote seagrass meadow establishment. The islands would provide additional protection to these sensitive aquatic habitats (e.g. seagrass).

The islands would also be consistently susceptible to erosion, but would in turn be providing protection to intertidal wetlands and seagrass habitats from currents and wave energies from barge, tides, and storms. Habitat longevity would be increased by raising the island elevation and constructing protective features, such as breakwaters and oyster reefs. As erosion occurs, the islands would be prime sites for beneficial use of future sediment disposal rather than placing material into upland or offshore disposal sites.

Adverse Impacts: Placement of material onto remnant islands or on the bay bottom would have similar adverse impacts as described for breakwaters by permanently displacing infaunal aquatic species (e.g. polychaetes), and would not provide the benefits of providing hard structures for recruitment of benthic organisms (e.g. oysters) to or inhabit hard structures. Although it is unlikely any terrestrial species would be impacted by construction actions, there could be spatial and temporal adverse effects on migratory species that have previously used these areas for nesting, breeding or foraging habitats. Adverse effects are anticipated to be temporary disturbances to colonial waterbirds or migratory species if conservation measures recommended by the Service are implemented during construction activities, and will result in more suitable ground nesting habitat for future migratory bird species including colonial waterbirds. Under these types of circumstances, the benefits of bird island restoration would far outweigh any adverse effects from temporary displacement of migratory species and colonial waterbirds.

However, the long term adverse effects resulting from conversion of open bay bottom habitat into upland bird rookery islands would result in permanent displacement of infaunal species or those that require unvegetated mud bottom habitats (e.g. polychaete) is not considered a benefit to aquatic species. In addition, there may be long term adverse effects on migratory bird species that are unable to utilize existing islands and will result in permanent displacement of infaunal species or those that require unvegetated mud bottom habitats (e.g. shrimp). Any long-term loss of open bay bottom is expected to be outweighed by the benefits the island would provide as a rookery and protection to seagrass meadows and wetlands. As well, use of the islands by colonial waterbirds is expected to cause localized water quality degradation due to the extent of defecation that would occur into adjacent waters. To mitigate degraded water quality, oyster reefs would be constructed to filter the water and improve or maintain existing water quality.

Oyster Restoration

Benefits: Most of the beneficial impacts described for breakwaters would also apply to oyster reef restoration. However, oyster reef restoration would also restore the ecological function of oyster reefs in the action area. Oyster reefs provide a host of ecosystem services including: enhanced recruitment, growth and survival of oyster populations, water filtration and regulations of water column phytoplankton dynamics, enhanced nitrogen cycling between the benthic and pelagic system components, enhanced phosphorus burial in sediments, nursery and predation refuge habitat for a diverse community of invertebrates and small fish, and foraging habitat for transient piscivorous and bethivorous fish (Rodney and Paynter 2006; Newell et al. 2004).

Oysters can affect other organisms by changing the physical and chemical environment of the open water ecosystem. Oysters filter water while feeding, thereby removing sediment and other particles from the water and releasing these sticky pellets called pseudo-feces to the water column, which eventually settle to the bottom in adjacent areas. Filtration by large numbers of oyster can reduce the time that sediment remains suspended in the water column and increase the clarity of the filtered water. Oysters' pseudo-feces are rich in nutrient and, therefore, help support primary production among bottom-dwelling organisms in areas immediately surrounding oyster bars and reefs. Local nutrient enrichment from these pseudo-feces also stimulates the exchange of various forms of nitrogen and nitrogen compounds from one part of the system to another. (Newell et al. 2002)

Oyster reefs are also know to support a complex and extremely productive marine community. Total macrofaunal abundance (free living and sessile organisms) is typically an order of magnitude higher on restored reefs compared to unrestored areas, while free living macrofauna are twice as abundant on restored reefs and two orders of magnitude more abundant than on unrestored reefs. Epifaunal organism density is reported to be on average three times higher and demersal fish density is four time higher in restored reefs.

Adverse Impacts: The adverse impacts from construction and long-term operation of the oyster reefs is similar to those anticipated for the breakwaters, except that the long-term adverse impacts from conversion of the bay bottom to hard substrate would provide more available substrate for recruitment an oyster reef than as a breakwater.

Dune and Beach Restoration/Nourishment

Benefits: Beach restoration/nourishment involves placing sand on an eroding beach to create a wider beach that is more resilient during seasonal cycles and erosion events. A wide, nourished beach system absorbs wave energy, protects upland areas from flooding, and mitigates erosion. The beach provides a buffer between storm waves and landward areas, and it can prevent destructive waves from reaching the dunes and upland developments. When sediment is naturally moved offshore from a nourished beach, it causes waves to break farther from the shoreline, which weakens their energy before reaching the shore. The wide, relatively flat beach berm with a sufficient volume of sand keeps the erosive power of the waves from reaching and eroding the dune or hardened structures and can reduce damages caused by waves, inundation, and erosion. Without the beach nourishment, the starting point for damage would be farther onshore.

Beach restoration measures include construction of dune system. By acting as a protective barrier, dunes help prevent flooding and storm damage caused by storm surge, wave run-up, and overtopping into areas behind the dune. For W-3, wetland habitat would not be subjected to storm surge inundation, except under the most extreme events, which then reduces the extent of wetland degradation when saltwater or high energies over top the dune.. For areas behind the Bolivar Peninsula, Galveston Island and South Padre Island action area, a healthy beach can protect shoreline development from the impacts of coastal erosion and flooding, which are increasing with climate change and RSLC.

The proposed beach and dune nourishment design allows for natural processes to continue to work without hindering long-shore sediment transport or modifying circulation patterns, which can often be seen with jetties, groins, or revetment type hardened structures.

Adverse Impacts: The proposed beach nourishment projects are designed and engineered to function like natural beaches, allowing sand to shift continuously in response to changing waves and water levels. However, there are short- and long-term impacts that could occur, particularly if the beach profile or sediment is not compatible with existing shorelines or reference shorelines. Potential adverse effects include: disturbance of species' feeding patterns; disturbance of species' nesting and breeding habitats; temporary elevated turbidity levels; changes in near shore bathymetry and associated changes in wave action; burial of intertidal and bottom plants and animals and their habitats in the surf zone; and, increased sedimentation in areas seaward of the surf zone as the fill material redistributes to a more stable profile (National Research Council, 1995). Of particular concern are the effects to endangered species such as sea turtles and shorebirds which use the beach as nesting, foraging, or loafing areas.

Hydrologic Connections

Benefits: Dredging Mansfield Pass would facilitate water exchange between the Lower Laguna Madre and the Gulf of Mexico. The Lower Laguna Madre is a hypersaline lagoon that has become accustomed to salinity levels in the range of 40-50 ppt. However, as the pass continues to close from shoaling, the exchange of lower saline Gulf of Mexico water (near 35 ppt) decreases and the salinity in the lagoon increases. By maintaining the pass, the wind-driven circulation patterns in the lagoon system (flow counterclockwise in winter and clockwise in summer) will help to maintain lower salinity levels by replacing hypersaline lagoon with lower salinity water from the Gulf of Mexico. The current would also flush pollutants and low oxygen water from the lagoon, while also bringing in more nutrients and facilitating continued movement of marine species of various life stages between the Gulf of Mexico and the Lower Laguna Madre, including spotted seatrout, red drum, and juvenile green and hawksbill sea turtles. Restoring the hydrologic connection would maintain or improve 112,864.1 acres of the Lower Laguna Madre including maintaining or improving existing species diversity and habitats, and reverse the projected loss of seagrass meadows and fringe wetlands if no action is taken.

Adverse Impacts: Potential adverse impacts resulting from dredging would be mostly temporary in nature and only occurring as long as dredging operations are underway in areas that have been previously disturbed by recurring maintenance dredging in the past.

Water quality adverse impacts are expected to be minor and include increases in turbidity that would be monitored and remain below levels mandated by the Clean Water Act Section 401 water quality certifications issued by TCEQ and water column degradation from slurry releases at the outfall of the dredge. Anaerobic sediment will likely be a minor fraction, if any, of the material dredged therefore, it is anticipated that there would likely be little to no reduction in ambient DO during dredging. Maintenance dredging is accumulated sediment that has not become hard packed and resistant to being “churned up” by infaunal and benthic organisms, thus the potential for finding much anaerobic sediment is small.

Effects on the biological environment are a direct result of removing sediment from the action area and the presence of dredging operations. In general, the literature suggests that dredging causes reductions in biomass, abundance, and species diversity for varying lengths of time, depending on surrounding conditions. Marine mammals and pelagic species are likely to compensate for small-scale changes in prey abundance by switching precise, moving to alternative foraging grounds, or increasing time spent foraging.

For infaunal communities, all but the deepest burrowing organisms would be lost; although communities typically recover in six to 18 months (Desprez 2000) with colonization coming from adjacent areas. Epibenthic organisms may undergo mortality due to entrainment; however, many of these species are capable of avoiding the disturbance area. The temporary loss or decrease in benthic organisms is not expected to have detectable effects on local species that prey on infauna or epibenthic organisms and the effect would be minor in relation to the entire benthic community available in the local area.

Quantified Benefits of ER Measures

Each of the eight alternatives presented in the section titled “Description of Recommended Plan and Alternatives Considered” contain one or more of eight measures. Table 9 shows a summary of the net change in AAHUs of all models for each measure, while Table 10 shows the AAHUs and Table 11 shows the acres for selected Target Years for each measure by species model.

Table 9. Net Change in AAHUs by Measure

Measure	FWOP AAHUs	FWP AAHUs	Net Change in AAHUs	Acres (2085 FWP)
G-28	20,327	30,339	10,012	1,144
B-2	54	608	554	216
B-12	30,357	31,618	1,261	1,993
M-8	10,769	10,992	223	2,526
CA-5	1	266	265	1,176
CA-6	901	919	18	620
SP-1	11	2,201	2,190	3,679
W-3	14,911	22,307	7,396	41,883

Table 10. Modeling Results for Each ER Measure at Selected Target Years in HUs

Target Year (TY)	Existing Condition	TY 1 (2035)			TY 31 (2065)			TY 51 (2085)		
		FWOP	FWP	Change	FWOP	FWP	Change	FWOP	FWP	Change
G-28 Bolivar Peninsula and West Bay GIWW Shoreline and Island Protection										
American Oyster	0	0	10	10	0	8	8	0	7	7
Brown Pelican	15	7	194	187	0	186	186	0	182	182
Brown Shrimp	45,707	49,182	50,427	1,246	13,966	14,789	823	0	62	62
B-2 Follets Island Gulf Beach and Dune Restoration										
Kemp's Ridley Sea Turtle	98	58	608	550	49	442	393	46	437	390
B-12 Bastrop Bay, Oyster Lake, West Bay, and GIWW Shoreline Protection*										
American Oyster	0	0	1	1	0	1	1	0	1	1.14
Brown Shrimp	63,493	67,926	68,859	933	23,872	25,335	1,463	0	147	147
M-8 East Matagorda Bay Shoreline Protection										
American Oyster	0	0	8	8	0	7	7	0	5	5
Brown Pelican	0	0	68	68	0	62	62	0	56	56
Brown Shrimp	16,394	17,997	18,106	109	11,359	11,553	194	467	558	91
CA-5 Keller Bay Restoration										
American Oyster	0	0	2	2	0	2	2	0	2	2
Spotted Seatrout	80	80	1,198	1,118	0	1,198	1,198	0	9,825	9,825
CA-6 Powderhorn Shoreline Protection and Wetland Restoration										
Brown Shrimp	611	1,136	1,197	61	1,137	1,137	0	124	124	0
SP-1 Redfish Bay Protection and Enhancement										

Target Year (TY)	Existing Condition	TY 1 (2035)			TY 31 (2065)			TY 51 (2085)		
		FWOP	FWP	Change	FWOP	FWP	Change	FWOP	FWP	Change
American Oyster	0	0	1	1	0	1	1	0	0	0
Brown Pelican	74	0	268	268	0	266	266	0	265	265
Spotted Seatrout	1,009	1,009	3,143	2,134	0	97,737	97,737	0	65,158	65,158
W-3 Port Mansfield Channel, Island Rookery, and Hydrologic Restoration										
Brown Pelican	2	0	18	18	0	18	18	0	18	18
Kemp's Ridley Sea Turtle	143	42	437	395	18	225	208	15	152	137
Spotted Seatrout	38,039	38,039	42,554	4,515	931,287	1,290,480	359,193	423,002	699,550	276,548

* B-12 does not include port-owned land tracts near Port Freeport.

Table 11. Acres of Habitat at Selected Target Years for Each ER Measure

Target Year (TY)	Existing Condition	TY 1 (2035)	TY 31 (2065)	TY 51 (2085)
G-28 Bolivar Peninsula and West Bay GIWW Shoreline and Island Protection				
American Oyster	0	18	18	18
Brown Pelican	23	298	286	280
Brown Shrimp	49,033	52,551	25,185	846
B-2 Follets Island Gulf Beach and Dune Restoration				
Kemp's Ridley Sea Turtle	850	691	502	216
B-12 Bastrop Bay, Oyster Lake, West Bay, and GIWW Shoreline Protection*				
American Oyster	0	2	2	2
Brown Shrimp	70,759	74,422	40,794	1,991
M-8 East Matagorda Bay Shoreline Protection				
American Oyster	0	15	15	15
Brown Pelican	3	96	88	79
Brown Shrimp	17,852	19,524	14,796	2,432
CA-5 Keller Bay Restoration				
American Oyster	0	4	4	4
Brown Shrimp	1,110	1,613	1,613	876
Spotted Seatrout	296	296	296	296
CA-6 Powderhorn Shoreline Protection and Wetland Restoration				
Brown Shrimp	1,615	2,416	2,335	620
SP-1 Redfish Bay Protection and Enhancement				
American Oyster	0	2	2	2
Brown Pelican	118	423	421	419
Spotted Seatrout	3,028	3,258	3,258	3,258
W-3 Port Mansfield Channel, Island Rookery, and Hydrologic Restoration				
Brown Pelican	4	23	23	23
Kemp's Ridley Sea Turtle	979	497	256	173
Spotted Seatrout	46,810	56,333	47,320	41,687

Galveston Bay Storm Surge Barrier System (Tier One Measure)

The Galveston Bay Storm Surge Barrier System (Alternative A) is expected to have adverse direct and indirect impacts, to aquatic and terrestrial organisms in the project area through behavioral changes, loss of habitat and changes in habitat quality. These measures would result in permanent loss of estuarine water column, estuarine mud and sand bottoms, marine water column, unconsolidated marine water bottoms, estuarine hard bottom substrate, estuarine emergent wetlands, and possibly seagrasses. Long-term effects on prey species and on individuals are anticipated due to the reduced flow, reduced tidal amplitude, and periodic high velocities through the navigation and environmental gates. These long term effects also include a reduction in prey due to the mortality or displacement of benthic species associated with dredging, placement, and construction activities. The exact long-term impacts to the Galveston Bay system are uncertain, and additional studies will be required to best predict the impacts the structures may cause. These studies would completed during the Tier Two analyses, at which time additional FWCA coordination with the Service would be sought to ensure compliance with ESA.

Tidal Exchange/Amplitude and Velocities

A 3D Adaptive Hydraulics (AdH) model for the Galveston Bay Storm Surge Barrier System was completed for the 2018 design (McAlpin et al. 2019) and updated it for the 2020 design (Lackey and McAlpin 2020). All model input conditions for this updated modeling match those for the present condition as referenced in McAlpin et al. (2019). The updated AdH modeling showed that the 2020 design for the System would have lower changes to tidal prism, water velocities, and salinities in the Galveston Bay System. Using the present conditions (2019 water elevations/tides) with the 2020 Surge Barrier design, the model showed potential changes in tidal prism of 2.4-5.7% across all of the stations in Galveston Bay, which was equivalent to a 0.01-0.02 meter (0.4-0.8 inch) change (Lackey and McAlpin 2020).

The velocity magnitudes for the with-project condition do not vary greatly from the without-project condition at different locations in the bays. The velocity magnitudes do drop at most locations for both surface and bottom but the reduction in the mean velocity magnitude is less than 0.1 m/s and more typically 0.05 m/s or less. Locations in West Bay and on the western perimeter of Galveston Bay show a slight increase in velocity magnitude for surface or bottom but, again, the change in the mean velocity magnitude is less than 0.1 m/s.

To analyze the hydrodynamics of the 2020 Galveston Bay Storm Surge Barrier System design at the barrier location, a new arc was located within the proposed location of the outbound 650-foot-wide sector gate. Instead of running the analysis for the full time series the researchers choose the strongest tide cycle that was observed in the two year analysis. The transition between low and high tide showed the greatest jump in predicted velocities through the navigation structure can reach 2 m/s (6.6 ft/s) in places. This could result in the formation of eddies on the backside of the structures, which may have impacts on navigation and could adversely impact organisms. The analysis does show that with this particularly strong tide cycle, once the transition period between low and high tide moves to the full incoming tide, the maximum velocities 0.75 m/s (2.5 ft/s) which was less than the 1.3 m/s (4.3 ft/s) seen in the without project condition during the tidal transition.

Larval Impacts from Tidal Exchange/Amplitude and Velocities

Eggs and larval stages of aquatic organisms can be affected by changes to tidal exchange/amplitude and velocities. These life stages are transported by currents, moving into the bay by the incoming tides. Larval forms of some species drop near the bottom on outgoing tides, particularly in the shallow areas of the nearshore to reduce transport out of the bay. Shallow water Environmental Gates (SWEG) along the shoreline of Bolivar Roads may help alleviate some of the potential impacts to aquatic organisms that utilize shallow edge habitats but may also provide a barrier for species that utilize bottom currents to enter Galveston Bay.

With input from the resource agencies, the Corps used the Particle Tracking Model (PTM) to show indirect impacts, and the extent of those impacts, from constructing the storm surge barrier system at Bolivar Roads on the larval stages of the marine life that travel in and out of Galveston Bay. The PTM simulates the transport of particles, or local marine larval species, using environmental inputs such as circulation, salinity, currents, and water surface elevation from the 3D Adaptive Hydraulics Model and local marine species' transportation characteristics (e.g. bottom dwellers, top dwellers etc.). The particle movements represent a multitude of aquatic species including shrimp, blue crabs, and commercially and recreationally important finfish (e.g. spotted sea trout and flounder).

Based on the Service's evaluation of the PTM developed by Lackey and McAlpin (2020), the model domain does not extend to San Luis Pass to determine the impacts to larvae movement transferred in the near shore waters down current of the surge gate due to restricted tidal exchange/amplitudes or velocities at the Bolivar Road surge gates. The Service recommends the model be updated to include direct and indirect impacts of the Bolivar Road surge gates on down current transfer of larvae to tidal passes such as San Luis Pass.

An additional concern is that the actual PTM developed by Lackey and McAlpin (2020) does not reflect the same conclusions stated in the Draft EIS: "the Bolivar Road gates did not appear to have a significant impact on all six biological larvae types (tidal lateral, diel vertical, tidal vertical, bottom movers, surface movers and passive neutrally buoyant particles)." The actual documentation for the model, not included in the Draft EIS shows that out of thousands of particles released at multiple locations outside the gate, only a fraction of them reach their specific recruitment locations (Lackey and McAlpin 2020). Most of the returning larvae (all six types) pile up behind the Gulf side of the gate structures, or are swept back into the Gulf where they are transported by currents along the shoreline. An additional concern is that those particles representing different fish, shrimp or blue crabs making it through the pass to reach the bay have very limited transport to East Bay while most of the particles are transported to West Bay or the west side of Galveston Bay. It is also unclear whether the higher velocity going through the pass (due to a narrower restricted opening or the deeper waters through the main channel) have an influence on where larvae are deposited in Galveston Bay. Although the model results show tidal vertical larvae may have the most advantage in reaching Galveston Bay, those tidal vertical larvae that make it through the gates are also among the few particles reaching East Bay. Other larvae with surfacing moving or bottom dwelling characteristics appear to be delayed from moving through the gates or are swept back out into the Gulf into near shore waters and transferred down current. The Service recommends the Corps provide additional particle transport modeling to assess the environmental consequences of the Upper Coast CSRM measures impact on tidal exchanges, fish migration, and larvae recruitment through Bolivar Roads and San Luis Pass. The FWS also recommends the model documentation is included in an Appendix of the Final EIS.

Environmental Consequences to Key Species from Bolivar Roads Surge Gates

The Service has concerns that the cumulative impacts of this Tier One measure has not been fully evaluated for key species such as the blue crab (*Callinectes sapidus*) that may be more likely to be affected by the restricted tidal exchange or concrete sills of the shallow water gate structures than other species migrating through this pass. Blue crabs are the preferred food for whooping cranes during their fall migration to Texas (Olsen and Derrickson 1980; Canadian Wildlife Service and U.S. Fish and Wildlife Service 2005). In December and January, when the tidal flats and sloughs drain the marshes, these birds move into the shallow bays and channels to forage for blue crabs. Blue crabs provide the much needed nutrition for over-wintering foraging and survival of whooping cranes (Olsen and Derrickson 1980). Blue crabs have continued to show a downward trend in abundance and relative biomass according to TPWD resource monitoring data (Sutton and Wagner 2007; Martinez-Andrade 2018). Over the period 1982-2005, there was a 70% reduction in blue crab biomass in the TPWD data, which has continued to decline over the last decade. While males and females mate in the shallow parts of estuaries, there is spatial partitioning of the two sexes during in their life stages. Females usually mate once in the fresher upper bays, acquiring a lifetime supply of semen. Once inseminated, female crabs begin their migration to higher-salinity waters in lower Galveston Bay near tidal passes, and the immediate Gulf offshore waters to incubate their eggs, while males remain in the estuary to spawn again (Ward 2012). The spawning season for mature blue crabs is from December to the following October, with peaks generally occurring in March-April and June-July. TPWD regulations specifically prohibiting harvest of “sponged” crabs, or those observed to be carrying eggs on their abdomen in order to protect existing stock and future year classes (Sutton and Wagner 2007). However, as the female crabs utilize the immediate lower Galveston Bay waters or immediate Gulf waters surrounding the gate structures during this critical stage in their eggs incubation period, they may be subject to higher velocity flow conditions or restricted tidal exchanges, and thus suffer greater mortalities.

Temperature is also in an important variable in the life stages of blue crabs. Temperature influences mating, spawning, egg development, zoeal development, intermolt duration and growth rate, and a number of underlying metabolic functions (Ward 2012). The AdH model results indicate that the Bolivar Roads surge gates appear to increase bay water temperatures due to the restricted opening and tidal exchanges. These increased temperatures in the pass and inner bay waters near the pass may also prohibit female blue crab egg production, incubation and survival. As female blue crabs migrate to the immediate area surrounding the gates, it unknown what impacts may occur to affect their survival or the larvae that hatch and must reach Gulf waters to grow and mature offshore. The impacts of increased temperatures and tidal restrictions to mature female adult blue crabs has not been adequately evaluated in this study to understand the long term environmental consequences of the Bolivar Roads surge gate structures.

An additional concern is that blue crab larvae once hatched and released near Bolivar Roads may not be able to pass through the shallow water gate structures to reach nearshore waters of the inner continental shelf for the one to two months required to grow offshore. Equally important factors to blue crab larvae survival is the ability to pass back through the gates into the bay so they can mature and spawn in fresher waters. The post-larvae return to the near shore areas adjacent to passes and have a directed migration into the bays that is a combination of deliberate vertical movements between seabed and water column, and horizontal transport by currents through the pass (PTM tidal vertical and tidal lateral characteristics). Although the results of the PTM show this species larvae characteristics are one of the few types that might make it through the gate structures to specific recruitment areas, the long term impacts of restricted tidal exchanges may interrupt or deter these crab larvae from passing over the concrete sills of the shallow water gate structures.

The Service recommends that additional evaluation of environmental consequences of the Bolivar Roads surge gates on mature female blue crabs, eggs, and larvae is included in future Tier Two evaluations.

Salinity

During normal flow conditions, average salinities in the Galveston Bay System range from less than 10 ppt in upper Trinity Bay to 30 ppt at Bolivar Roads (Lester and Gonzalez, 2011). The updated modeling also showed that the predicted changes in salinity using the present conditions with the 2020 Galveston Bay Storm Surge Barrier design, were almost identical near the HSC entrance, they begin to diverge further into the system at Mid Bay and Morgan’s Point. However, the change in the mean salinity between with and without project remains within 2 ppt and in most instances in the time series, the difference is less than 1 ppt for all of the stations across the bay.

Most organisms occupying these environments are ubiquitous along the Texas coast and can tolerate a wide range of salinities (Pattillo et al., 1997). Therefore, no adverse effects to aquatic species are anticipated from the 1-2 ppt change in salinity. However, changes in temperature have not been fully evaluated and need further consideration.

Habitat Loss

With the proposed Galveston Bay Storm Surge Barrier System, the Bolivar Roads Gate System, Clear Lake Gate System, Dickinson Bay Gate System, and the Galveston Ring Barrier System would have unavoidable habitat impacts to 128 acres of palustrine wetlands, 134 acres of estuarine wetlands, 161.6 acres of open bay bottom habitat, and 6 acres of oyster habitat which would require mitigation. The majority of open water bay bottom habitat impacts would occur at Bolivar Roads, which would be covered by the support structures and gates. The current design of the Bolivar Roads Gate System indicates the support structures and gates would be 60 feet deep and 15 to 30 feet deep through the environmental gates. The Galveston Bay complex contains approximately 378,063 acres of open-bay habitat (Pulich, 2002). The 167.6 acres impacted is a very small fraction of the total available habitat within the entire Galveston Bay system, which if sea level rise continues at current rate will be replacing wetland habitats along the shoreline of Galveston Bay. However based on the amount of impact and methods for mitigating with equivalent units of oyster habitat, these losses will be appropriately compensated.

In addition to habitat impacts, there would also be adverse temporary and permanent impacts on wildlife and terrestrial vegetation during mechanized land clearing for tying in the structures to existing CSRM features and construction access work spaces. If preventative measures are implemented wildlife in the area may avoid these areas during construction. However specific and best management practices to avoid impacts to threatened and endangered species and migratory bird species during specific nesting or overwintering season would be required in addition to restrictions for night construction activities, transiting to the beach, or storing equipment on the beach.

HEP Analysis Results

The HEP analysis for post-Tentatively Selected Plan (TSP) for CSRM measures was performed on Alternative B, which was modified in February/March 2020 to evaluate impacts to ecological resources under baseline, FWOP, and FWP conditions. Based on this analysis, the Galveston Seawall Improvements and the non-structural features of the alternative would not have any impact to habitats found within the study area, since all work would be completed within urbanized areas and where existing hardened structures exist. However, the Bolivar Roads Gate Structure, Galveston Ring Barrier, Dickinson Bay Surge Gate and Clear Lake Surge Gates would have multiple habitat impacts. Table 12 shows the net change in AAHUs by each measure while Table 13 shows the modeling results in selected target years for each measure.

Table 12. Net Change in AAHUs by CSRM Measure

	FWOP (AAHUs)	FWP (AAHUs)	Net Change (AAHUs)	Acres
Bolivar Roads Gate Structure	25,634	25,044	-590	38,696
Galveston Ring Barrier	44	7	-38	55
Dickson Bay Surge Gate	5	1	-4	8
Clear Lake Surge Gate	2.6	0.6	-2	4

Table 13. Modeling Results for Each CSRM Measure at Selected Target Years in HUs

Target Year (TY)	Existing Condition	TY 1 (2035)			TY 31 (2065)			TY 51 (2085)		
		FWOP	FWP	Change	FWOP	FWP	Change	FWOP	FWP	Change
Direct Impacts										
Bolivar Roads Gate Structure										
Brown Shrimp	7.5	12.5	0	-12.5	25	0	-25	7.5	0	-7.5
American Alligator	14.4	18.1	0	-18.1	1.85	0	-1.85	1.66	0	-1.66
Galveston Ring Barrier										
Brown Shrimp	14	41.5	0	-41.5	53.2	0	-53.2	3	0	-3
American Alligator	9.29	12.12	0	-12.12	1.9	0	-1.9	1.6	0	-1.6
Dickson Bay Surge Gate										
Brown Shrimp	4.56	4.23	0	-4.23	3.5	0	-3.5	3.24	0	-3.24
American Oyster	1.3	1.14	0	-1.14	0.9	0	-0.9	0.82	0	-0.82
Clear Lake Surge Gate										
Brown Shrimp	2.34	2.17	0	-2.17	1.79	0	-1.79	1.66	0	-1.66
American Oyster	2.41	2.1	0	-2.1	1.67	0	-1.67	1.52	0	-1.52
Indirect Impacts										
Tidal Amplitude										
Brown Shrimp	229.6	229.6	0	-229.6	1,070.1	0	-1,070.1	989.3	0	-989.3

As previously discussed, a net loss in AAHUs from implementing the Galveston Bay Barrier Storm Surge System would have unavoidable habitat impacts to palustrine and estuarine wetlands, open bay bottom habitat, and oyster habitat, which would require mitigation. Long-term unavoidable habitat impacts include the loss of 128 acres (11.8 average AAHUs) of palustrine wetlands, 134 acres (59.9 AAHUs) of estuarine wetlands, 161.6 acres (18.1 AAHUs) of open bay bottom habitat, and 6 acres (2.8 AAHUs) of oyster habitat (**Error! Reference source not found.Error! Reference source not found.**).

All measures that have resulted in a net loss of AAHUs require further refinement in design and future NEPA analysis to confirm and/or add to the assessment of impacts. This would be completed in a Tier 2 Analysis at some point in the future. It is fully anticipated that when refinements are made and more information is available to better understand the impacts, these values are going to change. However, due to the conservative nature of engineering and economic assumptions used in the development of the Recommended Plan, it is anticipated that design refinements of the proposed structures will result in equal or lesser environmental impacts than estimated here.

Table 14. Impacts from Implementing the Galveston Bay Storm Surge Barrier System

Impact	Acres	AAHUs
Direct		
Palustrine Wetlands	128	-11.8
Estuarine Wetlands	134	-59.9
Open Bay Bottom	161.6	-18.1
Oyster	6.0	-2.8
Total Direct Impacts	429.6	-92.6
Indirect		
Tidal Prism Change	1,148	-789
Total Indirect Impacts	1,148	-789
Total Impacts	1,577.6	-881.6

As previously discussed, based on model analysis, a total of 17.4 AAHUs of equivalent oyster reef AAHUs would be required to mitigate for open bay bottom losses (AAHUs) for the CSRM measures included in the Galveston Bay Barrier Storm Surge System, Galveston Ring Barrier System, Clear Lake and Dickinson Bayou Interior Surge Gates (Table 15).

Table 15. Conversion of Open Bay Bottom Habitat Loss AAHU to Equivalent Oyster AAHUs for FWP Conditions

Measure	Open Bay Bottom Loss (Net AAHU)	Conversion Ratio (Open Bay Bottom : Oyster Reef)	Equivalent Oyster Reef (Net AAHU)
Bolivar Roads Gate System	-117	8.9:1	-13.1
Galveston Ring Barrier System	-16.7	8.9:1	-1.9
Clear Lake Gate System	-6.1	8.9:1	-0.7
Dickinson Bayou Gate System	-15.5	8.9:1	-1.7
Total:	**-155.3**		**-17.4**

A Draft Mitigation Plan, which is included as Appendix J of the EIS, details proposed plans to replace the lost functions and values of the impacted areas through restoration activities that increase and/or improve the habitat functions and services within tentatively selected mitigation sites. The mitigation plan is also summarized in the section above titled "Description of Recommended Plan and Evaluation of Alternatives."

Fish and Wildlife Species

Temporary and permanent adverse effects to fish and other aquatic organisms are expected as a result of construction of the all the features of the Galveston Bay Storm Surge Barrier System. During construction, noise and temporary minimal sedimentation due to disturbance of the bottom is expected, which could disrupt foraging, reproduction, and passage of fish and wildlife species. Once completed, the storm surge barrier gates would remain open except during major storm events requiring closure. When the gates are open, the Corps current model estimates there would be 7 to 10% restricted flow through the pass, resulting in reduced passage of aquatic organisms including adult spawners moving offshore, or larvae fish and shellfish returning to the bay's recruitment and nursery areas. There would also be reduced prey species (e.g. blue crabs) available for foraging by trust species including migratory birds, and threatened and endangered species due to restricted tidal exchange conditions. According to the Corps BA, impacts to aquatic species during closures would be mitigated to the greatest extent possible by constructing bypass channels, but the impacts of reduced or restricted tidal exchanges have not been fully evaluated in the current EIS, or mitigation requirements determined.

If an extreme storm event were to occur, tide gates and surge barriers would be closed. During tide gate and surge barrier closures, tidal exchanges through Bolivar Roads would cease for a period of time, potentially reducing water quality, salinity, and dissolved oxygen (DO), while increasing the number of harmful nutrients in the water and increasing bay temperatures. The changes in water quality, salinity, DO, and nutrients could cause increased stress levels to benthic resources, shellfish and fish populations, which may lead to increased susceptibility to disease or even a mortality event (Tietze, 2016; Bachman and Rand, 2008). In the event there is extreme flooding resulting from an extreme storm and the gates were closed or were opened immediately after storm surge, the restricted flow through the gates could potentially result in a freshwater pulse that reduces salinities and temperatures of the bay for an extended time period resulting in adverse effects to benthic and pelagic fish and shellfish species, and limiting foraging opportunities for aquatic and terrestrial organisms trapped behind the storm surge barriers. Additionally, closure of the storm surge barriers and tide gates could result in a trapping effect by impeding passage of aquatic species that could be moving in and out of upstream estuarine areas to feed, spawn or grow.

EVALUATION OF THE RECOMMENDED PLAN

The Service has reviewed all Corps supplied documents and Service files relevant to the Study and the identified recommended plan measures. As the project footprint has not been finalized, and staging and construction areas have not been identified, we recommend that all construction and staging areas be limited to right-of-ways or previously impacted areas to avoid and minimize impacts to all fish and wildlife species.

The Service has concerns with the limited information provided about project specifics and an incomplete NEPA analysis of Tier One measures. The study's RP identifies a series of structural and non-structural improvements (e.g. navigation gates, levees, floodwall structures, seawall improvements, breakwaters, reef domes, and natural restoration improvements). There are multiple fish and wildlife resources impacted in addition to ecosystem-wide hydrologic alterations associated with construction of major navigation channels and gates within the study area. Although the proposed ER measures may restore wetlands, oyster, and beach habitats along the Texas Coast, there will be continued loss of coastal wetlands, oyster, and beach habitat due to increasing population levels and development along the coast, dredging of navigation channels, installation of utility and energy pipelines, and natural factors such as RSLR and climate change. The Service remains concerned with water quality degradation from the hydrological changes in salinity and flow from these structural modifications to a natural pass in Galveston Bay resulting in potentially excessive environmental impacts.

Although the six ER measures selected in the currently proposed RP may address these ecosystem restoration needs by enhancing existing natural barriers to storm surges, there remains many unanswered questions about the overall impacts of the remaining two ER and CSRM measures proposed.

The Corps identified sea level rise as a contributing factor to habitat degradation in the Study area. Consistent with the IPCC, the Corps adopted the intermediate sea level rise curve to assess impacts within the study area. We concur with this decision, but recommend where possible to consider designs which would also facilitate greater protection under the higher elevation scenarios, so long as those designs do not cause adverse effects to these habitats in their current conditions.

Threatened and Endangered Species

The following Federally-listed threatened (T) and endangered (E) species and/or their designated critical habitat (CH) were previously discussed in Section "Existing Conditions" that may occur within the study area including: piping plover (T) and its designated critical habitat, rufa red knot (T), whooping crane (E), eastern black rail (T), Northern Aplomado Falcon (E), West Indian manatee (T), loggerhead sea turtle (T), Kemp's ridley sea turtle (E), green sea turtle (T), leatherback sea turtle (E), and hawksbill sea turtle (E). The Service has coordinated with the Corps regarding the final determination of the Biological Assessment (BA) for the six ER measures that will be included in Appendix B of the EIS, in accordance with requirements outlined under ESA Section 7. The Service recommends the Corps coordinate with the Service on Section 7 consultations for all beach and dune restoration measures and the Galveston Bay Barrier System measures that affect threatened and endangered species and their habitats during the Tier Two Assessment.

Piping Plover Critical Habitat

Critical habitat units (CH) designated for the piping plover were included within the BA in Appendix B of EIS under Endangered Species Act Compliance for upper and lower coast measures. Table 16 shows the measures that are in close proximity to or that overlap piping plover CH. All other measures are greater than 1.0 mile from designated CH and would not be expected to be adversely effected by any proposed action. Designated CH habitat in these areas includes the land from the seaward boundary of mean low low water (MLLW) to where densely vegetated habitat begins and where the constituent elements no longer occur.

Wetland restoration and GIWW breakwater protection planned for G-28 (ER measure) is located within designated piping plover CH unit TX-37 near Rollover Bay (Figure 21). All other non-structural and structural improvements within G-28 measure are less than one mile from any other CH. This designated CH could be avoided if restrictions were made so that no wetland restoration or GIWW armoring would be placed within the tidal mud flats of the action area and all work would be restricted to existing degraded wetland areas.

The Bolivar Peninsula beach and dune improvements within the Galveston Bay Barrier System (Upper Coast CSRM measures) are located within piping plover CH TX-37 (Figure 21) and TX-36 (Figure 22). The Tie-in features of Galveston Bay Barrier System levee and combi-walls with the Bolivar beach and dune restoration project, has the potential to adversely affect 35 acres of critical habitat in TX-36 (Bolivar Flats) on the north side of Bolivar Roads Pass (Figure 22). The Corps has determined that the Tie-in levee through Bolivar Flats will require mitigation for adverse effects to piping plover critical habitat that will be further evaluated during the Tier Two assessment.

Continuation of the Galveston Bay Barrier System surge gates (Upper Coast CSRM measure) for Alternative A on the south side of Bolivar Roads on Galveston Island also passes through CH TX-35 ((Big Reef) Figure 22), which will require further evaluation during the Tier Two assessment.

Beach and dune improvements on Galveston Island that extends 3 miles to west side of San Luis Pass (B-2, ER measure) is also planned through CH TX-34 (Figure 23).

Beach and dune improvements on North Padre Island (Padre Island National Seashore) and the Port Mansfield Channel dredging activities (W-3, ER measure) is in close proximity to CH TX-3A, TX-3B, and TX-3C (Figure 24).

Beach and dune improvements (Lower Coast CSRM measure) at South Padre Island is located in close proximity to piping plover CH in TX-3A (Figure 25).

Although coordination with the Service under Section 7 consultation will address any short and long term conservation measures needed to be implemented prior to, or during construction of beach and dune restoration project to avoid or minimize adverse effects to piping plover CH, there may be some long term adverse effects to CH that have not been fully evaluated, which should be addressed in the Tier Two assessment.

Table 16. Piping Plover Critical Habitat In and Near the Action Area

Measure	Piping Plover CH Designation	Proximity
G-28	TX-37	OVERLAPS TX-37: Marsh restoration and GIWW armoring would overlap CH at Rollover Bay. All other areas are <1 mile from any CH.
W-3	TX-3A, TX-3B,TX-3C	CLOSE PROXIMITY TX-3A: Dredging occurs in the break between CHs (CH boundaries end at the channel) and beach nourishment actions occur north (channel width) of TX-3A, TX-3B and TX-3C.
Bolivar Peninsula and Galveston Island Beach and Dune Improvements	TX-34, TX-37, TX-36	OVERLAPS TX-34: Beach nourishment would occur from the most western boundary of nourishment near San Luis Pass eastward for 3 miles through CH. CLOSE PROXIMITY to TX-37: <0.15 miles south of the Rollover Pass CH location. OVERLAPS TX-36: Beach nourishment would occur from Bolivar Beach eastward for 0.33 miles through CH.
South Padre Island Beach and Dune Improvements	TX-3A	CLOSE PROXIMITY TX-3A: The north edge of the nourishment project terminates at the boundary of CH.
Bolivar Roads Surge Gates	TX-36, TX-35	OVERLAPS TX-36: Approximately 40 acres of the tie-in structure would be constructed within CH at Bolivar Flats and near Beacon Bayou.

Figure 21. *Piping Plover Critical Habitat on Bolivar Peninsula in Rollover Bay (G-28).*

Figure 22. Piping Plover Critical Habitat at Bolivar Roads in Galveston Bay Storm Barrier System – CSRM Measure.

Figure 23. Piping Plover Critical Habitat on Galveston Island at San Luis Pass (B-2).

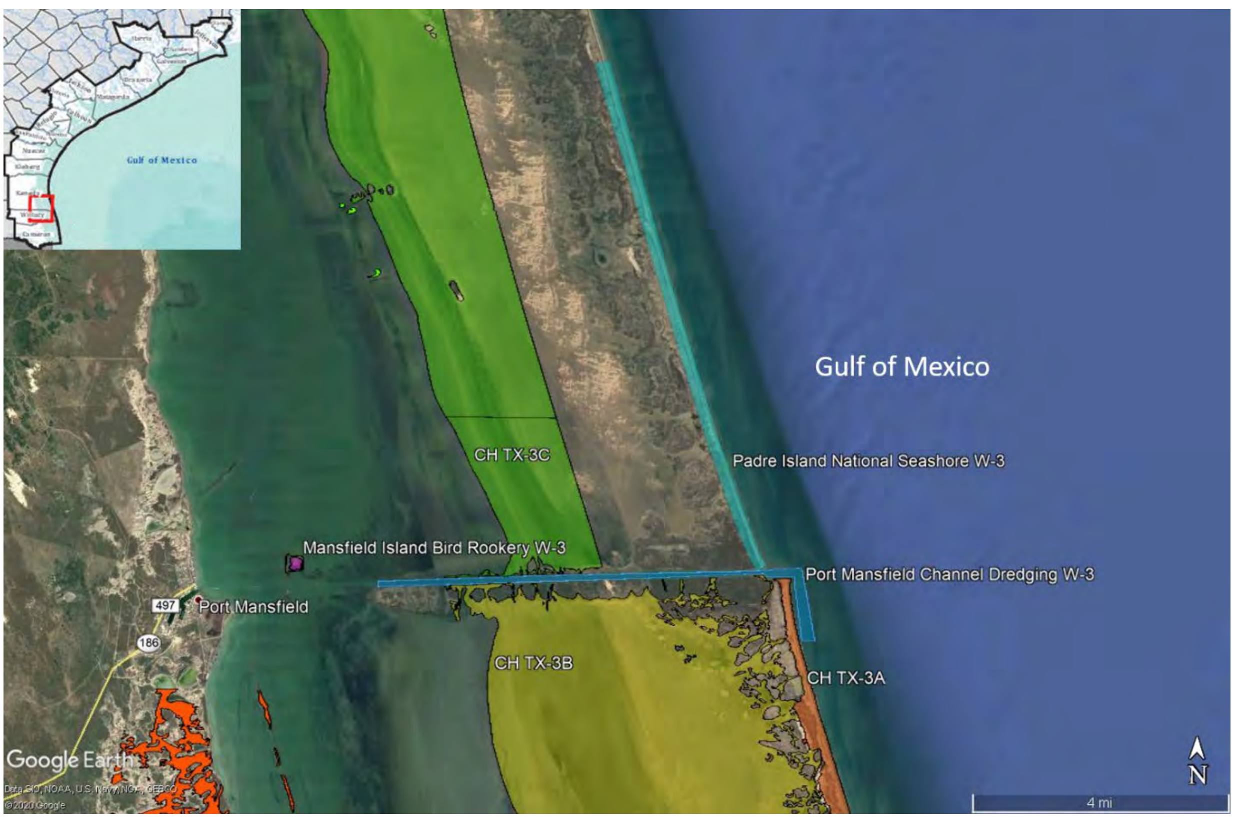

Figure 24. Piping Plover Critical Habitat at Port Mansfield Channel and North Padre Island (W-3)

Figure 25. Piping Plover Critical Habitat on South Padre at CSRM Measure.

Mitigation Recommendations

Although the actionable measures in this study were determined to not require mitigation, the Service recommends the Corps seek technical expertise during PED and construction phases to avoid and minimize impacts to aquatic habitats. Should the Corps identify long-term or permanent impacts during PED or construction phases for the actionable measures, we recommend full compensation of functions and values of impacted habitats and request coordination with the resource agencies regarding any such proposals to ensure adequate compensation is achieved.

Despite the Corps' identification of mitigation needs for Tier One measures, the Service does not have enough information regarding staging areas, best management practices, ingress and egress routes, construction methods, etc. to understand the true mitigation needs and requirements for the Galveston Bay Barrier System. We recommend the Corps seek the Service's technical expertise during the Tier Two analysis for the Tier One measures to identify additional information that is needed to understand the overall mitigation needs from all construction activities and long-term operation of the measures.

During the next phase of the study, the Service recommends that Tier One mitigation plans should be developed and coordinated with the natural resource agencies. At a minimum, the mitigation plan components should contain:

1. Criteria for determining ecological success.
2. Monitoring until after successful completion.

3. Description of available lands for mitigation and basis for determination of availability.
4. Identification of entity responsible for monitoring success criteria and invasive species removal.
5. Development of adaptive management strategies to ensure success criteria are met.
6. Establish consultation process with appropriate Federal and State agencies to determine acceptable methods for achieving mitigation and success criteria.
7. Mitigation should be implemented concurrent with or prior to construction as required to protect threatened and endangered species and species of concern.

Mitigation measures that would provide habitat or address recovery goals for at-risk species or threatened and endangered species in the study area should be included in any mitigation plan that would help conserve and protect these species. The Service can assist in development of such measures. If mitigation is not implemented concurrent with construction, the amount of mitigation needed should be reassessed, and adjusted to offset temporal habitat losses.

For estuarine or palustrine wetland mitigation, the acreage of wetlands created or restored to mitigate for wetlands impacts in the study area impacts should meet or exceed the wetland acreage projected for target year 10. If deficiencies occur in year 5, additional wetland mitigation should be provided.

The Corps should remain responsible for estuarine and palustrine wetland and oyster mitigation until the mitigation plan is demonstrated to be fully compliant with success and performance criteria.

Monitoring and Adaptive Management Plan for Mitigation Requirements

Overall, the monitoring regime and quantitative analysis outlined in the Monitoring Plan (U.S. Army Corps of Engineers, 2020), in general, would be acceptable to the Service if an Adaptive Management Team (including resource agencies) is convened, has oversight of the monitoring process, and is capable of recommending adaptive measures that would be implemented to rectify any deficiencies. The Service recommends that the same adaptive management team (AMT) described previously for the ER measures is officially established and made up of Corps staff, the non-federal sponsor, interested resource agencies and other stakeholders during the PED phase of the project. Pre-construction/baseline data, during construction, and post-construction monitoring will be utilized to determine the restoration of success. Monitoring will continue until the trajectory of ecological change and/or other measures of project success are determined as defined by project-specific objectives. Section 2039 of WRDA 2007 allows ecological success monitoring to be cost-shared for up to ten years post-construction.

The Service strongly encourages extended monitoring beyond the ten-year post construction period given the uncertainty of coastal and climatic conditions and the significance and vulnerability of natural resources in the Study Area. Data obtained from this monitoring effort will provide valuable information to meet current and future habitat management goals on a landscape level for managers and landowners along the coast, address restoration uncertainties, and fill information gaps. If ecological success cannot be determined within the ten-year post construction period of monitoring, any additional required monitoring should be the responsibility of the non-federal sponsor.

The Service encourages the Monitoring and Adaptive Management Plan for the Tier One measures be a fluid document that can be changed as the need arises, such as when new or modified monitoring techniques better meet the need or success criteria that was not accounted for but is later found to be prudent. With resource agency coordination, the Monitoring and Adaptive Management Plan should be revisited and confirmed or revised during PED. The monitoring results post-construction should also be coordinated with the AMT at which time recommendations would be made that the project is on track to meet the success criteria or recommendations would be made to conductive adaptive management to get the project on a path toward success.

FISH AND WILDLIFE CONSERVATION MEASURES

The President's Council on Environmental Quality defined the term mitigation in the National Environmental Policy Act regulations to include:

a) Avoiding the impacts altogether by not taking certain actions or parts of an action:
b) Minimizing impacts by limiting the degree or magnitude of the action and its implementation;
c) Rectifying the impacts by repairing, rehabilitating, or restoring the affected environment;
d) Reducing or eliminating the impacts over time by preservation and maintenance operations during the life of the action; and,
e) Compensation for the impacts by replacing or providing substitute resources or environment.

The Service's mitigation policy (Federal Register, Volume 46, Number 15, pages 7656-7663, January 23, 1991) provides guidance to help ensure that the level of mitigation recommended by the Service is consistent with the value and scarcity of the fish and wildlife recourses involved. In keeping with that policy, the Service usually recommends that losses of high-value habitats which are becoming scarce be avoided or minimized to the greatest extent possible. Unavoidable losses of such habitats should be fully compensated by replacement of the same kind of habitat value; this is called in-kind mitigation. The mitigation planning goals and associated Service recommendations should be based on the four categories as shown in Table 17. .

Table 17. U.S. Fish and Wildlife Service Resource Categories

FWS Resource Categories
<u>Resource Category 1-</u> Habitat to be impacted is of high value for evaluation species and is unique and irreplaceable on a national basis or in the ecoregion section. The mitigation goal for this Resource Category is that there should be no loss of existing habitat value.
<u>Resource Category 2-</u> Habitat to be impacted is of high value for evaluation species and is relatively scares or becoming scares on a national basis or in the ecoregion section. The mitigation goal for habitat placed in this category is that there should be no net loss of in-kind habitat value.
<u>Resource Category 3-</u> Habitat to be impacted is of high to medium value for evaluation species and is relatively abundant on a national basis. FWS's mitigation goal here is that there be no net loss of habitat value while minimizing loss of in-kind habitat value.
<u>Resource Category 4-</u> Habitat to be impacted is of medium to low value for evaluation of species. The mitigation goal is minimize loss of habitat value.

The Service finds the estuarine and palustrine wetlands, seagrass, oyster, bird rookery islands, and beach and dune habitats along the Texas coast to be aquatic resources of national importance due to their increasing scarcity and high habitat value for fish and wildlife within Federal trusteeship (i.e. migratory waterfowl, wading birds, other migratory birds, threatened and endangered species and interjurisdictional fisheries). Therefore the Service recommends that unavoidable losses of those habitats should be compensated via in-kind habitat replacement value.

Based on current project plans there would be no net adverse impacts to the aquatic resources of national importance by the six ER measures of the RP considered actionable measures, and hence there is no need to mitigate for adverse impacts. These proposed ecosystem resource measures would instead, increase the quantity of those valuable habitats. However, due to the uncertainty of the proposed plans for beach and dune improvements in addition to the Galveston Bay Barrier Storm System CSRM measures, the Service recommends there is additional coordination with the Corps to explore the least environmentally damaging coastal storm risk plans during the Tier Two Assessment in order to accomplish the same goals and purpose of this study.

SERVICE POSITION AND RECOMMENDATIONS

Although the proposed ecosystem restoration measures will provide a substantial benefit to wetlands and associated fish and wildlife resources, future design details of certain measures could have some unintended adverse effects to adjoining wetlands, and/or fish and wildlife resources. Because submerged aquatic vegetation (seagrass) provides valuable food source for migratory waterfowl, and provides high quality nursery habitat for estuarine dependent fisheries (Castellanos and Roza 2001 and Kaouse et al., 2006), the open water areas with dense submerged aquatic vegetation, targeted for wetlands creation or breakwater protection measures should be considered equally valuable habitat and avoided to the greatest degree possible. The recommendations provided below address ways to avoid such unintended impacts and to improve fish and wildlife habitat quality in and adjacent to these ecosystem restoration areas. The Service supports implementation of the six ER measures in the RP provided the following conservation measures are included as part of the RP in the EIS, and are implemented concurrently with construction of these measures.

1. To the greatest extent practical, borrow sources or dredge material for beneficial use wetland creation measures should be located to avoid and minimize direct and indirect impacts to densely vegetated wetlands, submerged aquatic vegetation, tidal mud flats at low tide, and oyster reefs.
2. No tidal connections with the GIWW may be restricted such that flow and salinity regimes are modified by breakwater alignments or wetland creation measures.
3. The Corps should continue to coordinate with the Service throughout the planning (PED) and construction process to ensure that the six proposed ER measures do not disturb nesting, breeding and foraging areas of migratory birds, threatened and endangered species, or species that may be listed in the future.
4. The Corps should ensure the following avoidance and minimization measures are implemented for all future ER construction activities for bird rookery islands, breakwaters, or wetland creation:
    a. All temporary workspaces shall be restored to preconstruction contours and elevations to the fullest practicable extent so that it does not adversely impact the surrounding aquatic habitats (including wetlands, seagrass beds, oysters, etc.).
    b. Incorporate conservation measures developed by the Service to reduce effects to at risk species, monarch butterflies and other pollinators (see Cardno 2020).
    c. Provide Clean Water Act Section 404 (b)(1) guideline analysis (40 CFR 230) to demonstrate all projects have provided avoidance of wetlands and special aquatic sites.
    d. Conduct pre-construction nesting surveys if any habitat will be cleared by mechanical or hydraulic devices between February 14 and September 15 to determine active nesting conditions.
    e. Adjust authorized work timelines to avoid disturbances during peak nesting seasons between February 14 and September 15.

f. Work areas or project boundaries should maintain a buffer of vegetation at least 100 feet (30 meters) around nests of Passerines (i.e., songbirds) until young have fledged or the nest is abandoned.
g. Maintain equipment and activity setback distance of 1,000 feet (304 meters) near active colonial waterbird rookeries during peak nesting seasons between February 15 and September 1.
h. Equipment and activity set-back distances should be at least 0.25 miles (400 m) for nesting raptors (USFWS 2015); with special provisions for Northern Aplomado falcons and bald eagles which require two miles (3.2 kilometers) for buffers around their nests based upon their home range sizes (USFWS 1990; Garrett et al. 1993; USFWS 2020) and their protected status under the Endangered Species Act and/or the Bald and Golden Eagle Protection Act.
i. Report any injured birds encountered during project operations to state and federal permitted rehabilitation centers.

5. No wetland construction will occur in G-28, B-12, M-8 and CA-6 between March 1 through September 30 during eastern black rail breeding, nesting, chick rearing, and molting season. If this timing cannot be achieved due to construction schedules, then the Corps should ensure the avoidance and minimization measures recommended specifically under Threatened and Endangered Species Section below are implemented during construction activities.
6. The Corps should monitor ER measures using methods developed by the Service and other interested natural resource agencies to document the degree of success achieved and any adaptive management measures that may be required to be implemented.
7. The Corps should obtain a right-of-way from the Service prior to conducting any work on refuge lands, in conformance with National Wildlife Refuge System Act (NWRSA) of 1997 (PL 105-57) and 50 CFR Section 29.21-1, Title 50, Right-of-Way Regulations. Issuance of a right-of-way will be contingent on a determination that the proposed work will be compatible with the purposes for which the refuge was established.
8. All planning, design, or other construction-related activities (e.g. surveys, surveys, geotechnical borings, etc.) conducted on NWRs will require the Corps to obtain a Special Use Permit from the Refuge Manager of the Texas Chenier Plains Complex (Tim Cooper at (409) 267-3337; and Refuge Manager of the Mid-Coast Refuge Complex (Jennifer Sanchez at 979 964-4011 x25). We recommend that the Corps request issuance of a Special Use Permit well in advance of conducting any work on these refuge complexes. Close coordination by both the Corps and its contractor must be maintained with the appropriate Refuge Manager to ensure that construction and maintenance activities are carried out in accordance with provisions of any Special Use Permit issued by the NWR.
9. The footprint of currently planned breakwaters along the shorelines of NWRs should be moved further away from the shoreline to create additional space for wetland habitat enhancement through natural sedimentation or beneficial use of dredge material.
10. The B-12 ER measure should be revised to extend the current breakwater alignment to include the Big Slough opening in order to protect the wetland around the terminus of Big Slough on Brazoria NWR.

11. The B-12 ER measure to place breakwaters and wetland creation on the inside west portion of Cow Trap Lake within the San Bernard NWR should be modified to protect both sides of the opening to Cow Trap Lake from the existing Corps Dredge Material Placement Areas along the GIWW to the interior wetland shorelines within the boundaries of NWR.
12. The M-8 ER measure to place breakwater alignments within the historic GIWW channel footprint should not encroach on NWR lands. The Service supports the construction of a breakwater on the East Matagorda Bay side of the GIWW, but requests that the proposed alignment is verified or revised to minimize impacts to existing spoil islands utilized by many migratory species.

The Service supports the proposed beach and dune restoration measures in the RP, which could provide positive benefits to fish and wildlife resources, based on the condition that there is an opportunity for the Service to provide additional input to the Corps through the tiered NEPA process. Although these beach and dune measures could result in some unintended minor adverse impacts to adjacent habitats, and may affect but are not likely to adversely affect some federally listed species, the Service believes these measures will improve fish and wildlife habitat quality on Texas barrier islands, provided the following recommendations are included in the Final EIS and are implemented concurrently with construction of the project.

1. To the extent feasible all sand sources for beach nourishment and dune construction on barrier islands should be reviewed by the resource agencies for appropriate site specific characteristics and quality (e.g.' grain size, color, composition, and mineralogy).
2. The Corps should enter into any necessary Section 7 consultation procedures with the Service analyze effects of the beach and dune improvement measures on federally listed nesting sea turtles, wintering piping plovers, and rufa red knots and their habitats within the study area. Survey data, analyses, and any other information should be coordinated and provided to the Service for review and concurrence during the Tier Two NEPA process for these specific beach and dune improvement measures.
3. The Corps and non-federal sponsor should coordinate with the Service, NWRs, National Park Service (NPS), National Marine Fisheries Service (NMFS), and other natural resource agencies during the planning phases on the timing for construction activities, duration of activities, locations for work space and placement areas, methods used, dimensions of all proposed beach nourishment and dune restoration footprints, temporary easements, federal property boundaries, appropriate compatibility determinations and Special Use Permits as previously referenced.
4. The Corps should provide frequent and consistent coordination with the Service, NWRs and NPS immediately prior to and during project work on federal property throughout the year.
5. Mitigation measures and evaluation of adverse effects on trust resources and values within federal lands should be considered separate from mitigation measures planned to compensate for habitat impacts on non-federal lands.

6. Land acquisition, habitat development, maintenance, and management of mitigation lands should be allocated as a first cost expense of the project to ensure mitigation obligations are met on behalf of public interest.

However, the Service finds the Tier One CSRM measure collectively referenced as Galveston Bay Storm Surge Barrier may create permanent disturbance to fish and wildlife species over such a large geographic area, with adverse effects on trust species and their breeding, nesting, and foraging areas along the Texas coast, nationally, and in other countries. Our concerns and recommendations for future coordination on the Galveston Bay Storm Surge Barrier are summarized below.

1. The current design of the Bolivar Roads surge gates will cause increased retention times of floodwaters or seasonal high tides over the adjacent wetlands. The Service requests that the adverse effects of displacing migratory birds, or ground nesting birds such as the eastern black rail, due to retention of higher water levels in the wetlands surrounding Galveston Bay, is more fully evaluated in the Tier Two assessment for this CSRM measure.
2. The 3D Adaptive Hydraulics (AdH) model for the Galveston Bay Storm Surge Barrier System should extend to San Luis Pass to identify all potential direct and indirect impacts of constructing the gates on tidal flow, tidal amplitude, salinity, temperature, and sediment and organism movement within the Galveston Bay estuary and adjacent passes. The Service requests that additional AdH modeling is conducted to assess the environmental consequences of the elevated tidal amplitude from the surge gates on land forms on either side of San Luis Pass resulting in potential loss of critical habitat for piping plover.
3. The combined structural (ring levee) and non-structural (dune and beach restoration) barriers proposed in the Galveston Bay Storm Surge Barrier System measures may prevent sediment overwash during storms, and interrupt natural wind driven transport of sediment to the bay sides of Bolivar Peninsula and Galveston Island, which are crucial in sediment accretion by tidal wetlands in prohibiting landward migration from relative sea level rise. The Service recommends the Corps conduct comprehensive bathymetric, hydrodynamic, and sediment transport studies to evaluate the short-and long-term adverse effects of sediment and nutrient losses caused by the proposed RP on the bay sides of Bolivar Peninsula and Galveston Island that may reduce the available nesting, breeding and foraging areas for migratory birds and endangered species.
4. The combined Galveston Bay Storm Surge Barrier System measures may also cause greater sediment deposition in San Luis Pass resulting in tidal restrictions into West Bay and Christmas Bay. Tidal exchange restrictions due to sediment accelerated accretion could also influence salinity gradients and water quality in the lower reaches of West Galveston Bay. These tidal restrictions could also result in limited fish migration or larvae transport into West Bay and Christmas Bay. The Service recommends the Corps evaluates the short-and long-term adverse effects of potential increased sediment accretion and tidal restrictions within the San Luis Pass on West Bay, Cold Pass, Moody’s Island, Mud Island, and Christmas Bay.

5. The combined Galveston Bay Storm Surge Barrier System measures may also cause reduced tidal exchange, reduced circulation, increased nutrient levels, and increased retention times that will likely increase eutrophication and contaminant levels within Galveston Bay and its tributaries, which could adversely affect trust resources such as colonial waterbirds that forage on the fish and shellfish directly impacted by lower dissolved oxygen levels or contaminants. Reduced tidal exchanges may also cause longer bay retention times of freshwater inflows from floods, or Gulf waters from higher tides due to relative sea level rise. Longer retention of nutrient loaded waters may also promote toxic algal blooms (e.g., *Karenia brevis*) (Brand and Compton 2007), as well as promote the production of other pathogens which adversely affect fish, shellfish, colonial waterbirds that forage on fish and shellfish, and the federally listed West Indian manatee (*Trichechus manatus*), which is susceptible to toxic algae blooms. Reduced tidal exchange and increased bay retention times may also lead to extended impacts from oil or chemical spills on colonial waterbirds, West Indian manatee, and other marine mammals, and sea turtles.
6. The Galveston Bay Larvae Transport Model or particle transport model developed by Lackey and McAlpin (2020) does not appear to provide an evaluation of the impacts to larvae movement restricted at the gates or transferred downstream of the Bolivar Roads surge gate along the shoreline of Galveston Island to San Luis Pass. The Service recommends that additional particle transport modeling be conducted to assess the environmental consequences of surge gate's impact on tidal exchanges, fish migration, and larvae recruitment through Bolivar Roads and San Luis Pass.
7. The environmental consequences of the Bolivar Road surge gates on key species such as the blue crab (*Callinectes sapidus*) may be more likely to be affected by the Bolivar Roads surge gates than other species migrating through this pass. Blue crabs provide much needed nutrition and preferred food for the federally listed Whooping Cranes during their fall migration to Texas. Mature female blue crabs utilize the immediate lower Galveston Bay waters near Bolivar Roads pass during a critical stage in their egg incubation period and may be adversely affected by increased tidal velocities in the narrow deeper channel between the main surge gates. Water temperature related changes caused by tidal restrictions from the shallow water surge gates could also delay egg incubation periods resulting in greater mortalities to the eggs. An additional concern is any surviving larvae released into lower Galveston Bay may not be able to pass through the shallow water gate structures and concrete sills to reach the inner continental shelf for offshore growth, or the larvae's subsequent return to the estuary for growth and reproduction into mature adults. The Service recommends the Corps evaluate the direct and indirect impacts of changes in tidal velocities, tidal restrictions and water temperatures related to the Bolivar Roads surge gates on the mature female blue crab, her eggs, and larvae; and the overall consequences to trust species dependent on blue crabs in their diets.
8. Recommend the Corps fully compensate for any unavoidable losses of estuarine wetland, oyster, mud flat, submerged aquatic or open water habitat caused by project features as dictated by the Habitat Evaluation Procedure (HEP) model used for each habitat.

9. The Service encourages additional monitoring and adaptive management measures are incorporated at the mitigation sites (including preservation and rehabilitation of existing habitats) and be included in the subsequent NEPA Tier Two analysis for all Tier One measures. Monitoring is an essential component of restoration and mitigation projects for understanding species use and composition of the newly rehabilitated sites and will provide a basis for future recommendations to ensure successful implementation and continued usage by all fish and wildlife species.

Threatened and Endangered Species

Although the Service has coordinated with the Corps regarding the final determination of the Biological Assessment (BA) for the six ER measures that will be included in Appendix B of the EIS, in accordance with requirements outlined under ESA Section 7, we also recommend conservation measures be implemented for each threatened and endangered species found within the action areas of the ER and CSRM measures in the Tier Two Assessment. Specifically, the Service recommends the Corps coordinate with the Service on Section 7 consultations for all beach and dune restoration measures and the Galveston Bay Barrier System measures that affect threatened and endangered species and their critical habitats in the future.

The Service recommends the following conservation measures be incorporated into operations for the protection of all listed species:

1. All personnel (contractors, workers, etc.) will attend training sessions prior to the initiation of, or their participation in, project work activities. Training will include:
    a. Recognition of piping plovers, rufa red knot, whooping cranes, eastern black rail, West Indian manatee, and sea turtles, each of the species' habitat, and signs of presence;
    b. Avoidance measures;
    c. Reporting criteria;
    d. Contact information for rescue agencies in the area; and 5) penalties of violating the ESA.
2. Project equipment and vehicles transiting between the staging area and restoration site will be minimized to the extent practicable, including but not limited to using designated routes and confining vehicle access to the immediate needs of the project.
3. The contractor will coordinate and sequence work to minimize the frequency and density of vehicular traffic within and near the restoration unit(s) and limit driving to the greatest extent practicable.
4. Use of construction lighting at night shall be minimized, directed toward the construction activity area, and shielded from view outside of the project area to the maximum extent practicable.
5. A designated monitor(s) will be identified who will act as the single point of contact responsible for communicating and reporting endangered species issues throughout the construction period.

Piping Plover and Rufa Red Knot

The Service recommends these specific conservation measures be implemented to minimize the potential for adverse effect to piping plover and rufa red knot:

1. No breakwaters or dredged material would be placed in any tidal flats exposed at low tide (specifically applies to G-28).
2. Time of construction will be restricted during piping plover wintering seasons.
3. A monitoring plan would be developed in coordination with USFWS during pre-engineering design (PED) phase to avoid disturbance to individuals.

Piping Plover Critical Habitat

Although the Corps has coordinated with the Service under an informal Section 7 consultation on ER measures not involving beach and dune restoration, the Service recommends the Corps address any short and long term conservation measures needed to be implemented prior to, or during construction of beach and dune restoration projects that adversely affect piping plover CH. We have concerns there may be additional affects to piping plover CH that have not been fully evaluated, which should be addressed in the Tier Two assessment. Artificially increased amounts of sediment deposited on beaches within the study area would be more available for erosion and transported down current onto existing piping plover CH, where it could help maintain that beach’s profile, or it could be deposited in the tidal passes adjacent to CH. Increased sediment deposition in tidal passes will impede tidal exchanges and aquatic organisms from moving into sub-bays and adjacent shorelines, resulting in loss of preferred food items formerly available in piping plover CH.

Another concern is that hard structures such as the Galveston Bay Storm Surge System gates could reflect wave and wind energy down current washing away piping plover CH located adjacent to these tidal passes into sub-bays. Although complete avoidance of piping plover CH during construction of the RP is recommended, there may be adverse effects from the Gulf gate’s reflection of down current wind and wave energy on piping plover CH at San Luis Pass that may need to be assessed for additional conservation measures or mitigation for impacts to the CH.

When evaluating the effects of the RP on piping plover CH for Section 7 purposes, we recommend the Corps consider cumulative and indirect effects in addition to effects from direct dredging or placement of structural and non-structural components of the proposed CSRM and ER measures on piping plover CH. However, if the Corps deems it necessary to adversely affect piping plover CH, consultation procedures pursuant to Section 7 of the Act should be initiated with the Texas Coastal Ecological Field Office, Houston, Texas.

Whooping Cranes

If construction is necessary during the whooping crane wintering season (November 1 to April 30), all work crews will be trained in whooping crane identification prior to the start of construction.

1. If a whooping crane is identified within 1,000 feet of an active construction area, all work should immediately stop. When the crane has left the 1,000-foot area on its own accord, work may continue.
2. All equipment (permanent or construction) greater than 15 feet high should be laid down at dusk and overnight, so as to avoid whooping crane strikes during times of low visibility.
3. If equipment cannot be laid down at dusk or overnight, then such equipment will be marked using surveyors reflective flagging tape, red plastic balls or other suitable marking devices and lighted during inclement weather conditions when low light and/or fog is present.
4. All whooping crane sightings should be immediately reported to the Texas Coastal Ecological Services Field Office at (361) 533-6765 or (361) 676-9953.

Eastern Black Rail

The Service has concerns the proposed project may affect this species. Based on our review of the project plans, aerial photos, and National Wetlands Inventory Maps, wetland habitat suitable for the eastern black rail appears to occur within the action area of the study area ([USFWS], 2020) This species was also identified within the Anahauc NWR, Brazoria NWR, San Bernard NWR, and Powderhorn Ranch. Adult eastern black rail undergo a complete post-breeding molt each year between July and September (Pyle 2008, Hand 2017). Individuals simultaneously lose all of their remiges (wing flight feathers) and rectrices (tail flight feathers), and are temporarily unable to fly for approximately three weeks (Flores and Eddleman 1991, Eddleman et al. 1994). A drop in body weight may occur during this time, indicating that the metabolic costs of performing a complete molt may outweigh an individual’s ability to replenish energy reserves (Flores and Eddleman 1991). Eastern black rail are particularly vulnerable to construction affects during this period of flightlessness and lower body weight. Because eastern black rail occupy drier areas in wetlands and require dense cover, they may be more susceptible to disturbances than other rallids (Eddleman et al. 1994). However, areas where vegetation and soils are trampled or soils are compacted is likely to have negative effects on eastern black rails and the quality of their habitat (Richmond et al. 2010).

The Service recommends that no wetland construction occur in G-28, B-12, M-8 and CA-6 between March 1 through September 30 during eastern black rail breeding, nesting, chick rearing, and molting season. If this timing cannot be achieved then the Corps should ensure the following avoidance and minimization measures are implemented during construction activities:

1. On site vegetative field surveys will be conducted before work begins to identify eastern black rail habitat types along the GIWW adjacent to the proposed breakwater structures and wetland creation sites.
2. No material for wetland restoration will be placed in higher elevated wetlands dominated by Gulf cordgrass (*Spartina spartinea*), saltmeadow cordgrass (*S. patens*), sea-oxeye (*Borrichia frutescens*), and/or saltgrass (*Distichlis spicata*) or dense overhead cover that meets the target wetland elevation for eastern black rail habitat.

3. If temporary access routes, dredge pipeline routes, or staging areas occur within identified eastern black rail habitat the contractor must minimize traffic in these areas therefore minimizing the construction foot print, (i.e., limited paths, etc.).
4. In addition to minimizing access routes through high wetland habitat, these areas should be left intact to provide refugia for the eastern black rail to ensure escape access routes remain available. The Corps should work with the Service to identify refugia areas once site specific planning begins.
5. Monitors will be needed to assist construction crews with avoidance and minimization to eastern black rail higher elevation wetlands and densely vegetated habitats once work begins.
6. Use of construction lighting at night shall be minimized, directed toward the construction activity area, and shielded from view outside of the project area.

Northern Aplomado Falcon

This species has been reported to occur in the Big Boggy NWR, Aransas NWR, and the Laguna Atascosa NWR within the study area. Its potential presence was also reported in IPAC for ER measures B-12 (Bastrop Bay, Oyster Lake and Cow Trap Lake), M-8 (GIWW and East Matagorda Bay), CA-5 (West Matagorda and Keller Bay), CA-6 (West Matagorda Bay and Powderhorn Lake), and SP-1 (GIWW and Redfish Bay); and for the CSRM measure at South Padre Island.

The Service recommends maintaining equipment and activity set-back distances of at least two miles (3.2 kilometers) for buffers around their nests based upon their home range sizes (USFWS 1990).

West Indian Manatee

The construction of the proposed Galveston Bay Barrier System surge gates may affect the West Indian manatee (*Trichechus manatus*), federally listed species, which may be found within the Houston Ship Channel or Galveston Bay. Although a rare visitor to the Texas coast, additional conservation measures to avoid adverse effects to West Indian manatees should be incorporated in the RP to be implemented during construction of the Bolivar Roads surge gates, interior bay surge gates, or ring levee around City of Galveston.

1. All personnel associated with the project shall be instructed about the presence of manatees and manatee speed zones, and the need to avoid collisions with and injury to manatees. The permittee shall advise all construction personnel that there are civil and criminal penalties for harming, harassing, or killing manatees, which are protected under the Marine Mammal Protection Act and the Endangered Species Act.
2. All vessels associated with the construction project shall operate at "Idle Speed/No Wake" at all times while in the immediate area and while in water where the draft of the vessel provides less than a four-foot clearance from the bottom. All vessels will follow routes of deep water whenever possible.

3. Siltation or turbidity barriers shall be made of material in which manatees cannot become entangled, shall be properly secured, and shall be regularly monitored to avoid manatee entanglement or entrapment. Barriers must not impede manatee movement.
4. All on-site project personnel are responsible for observing water-related activities for the presence of manatee(s). All in-water operations, including vessels, must be shut down if a manatee(s) comes within 50 feet of the operation. Activities will not resume until the manatee(s) has moved beyond the 50-foot radius of the project operation, or until 30 minutes elapses if the manatee(s) has not reappeared within 50 feet of the operation. Animals must not be herded away or harassed into leaving.
5. Any collision with or injury to a manatee shall be reported immediately to the Texas Marine Mammal Stranding Network (TMMSN) Hotline at 1-888-9-MAMMAL and also reported to the U.S. Fish and Wildlife Service (1-281-212-1516).

Migratory Birds

The proposed ER measures could positively contribute to enhancement of the colonial waterbird populations across the Gulf of Mexico. The Service recommends ER measures and any mitigation measures for bird or habitat enhancement projects for unavoidable impacts be constructed outside of colonial waterbird breeding and nesting season (February 1 through September 1). The Corps should also continue to coordinate with the Service throughout the planning (PED) and construction process to ensure that the six proposed ER measures do not disturb nesting, breeding and foraging areas of migratory birds. The Corps should ensure the following avoidance and minimization measures are implemented for all future ER construction activities for bird rookery islands, breakwaters, or wetland creation:

1. All temporary workspaces shall be restored to preconstruction contours and elevations to the fullest practicable extent so that it does not adversely impact the surrounding aquatic habitats (including wetlands, seagrass beds, oysters, etc.).
2. Any temporary structures and/or work necessary for construction activities to facilitate utility line installation or removal (i.e. cofferdams, dewatering) be coordinated with state and federal agencies.
3. Use only native plants in restoration of rookery islands or temporary work areas.
4. Incorporate conservation measures developed by the Service to reduce adverse effects to at risk species, monarch butterflies and other pollinators (see Cardno 2020).
5. Provide Clean Water Act Section 404 (b)(1) guideline analysis (40 CFR 230) to demonstrate all projects have provided avoidance of wetlands and special aquatic sites.
6. Conduct pre-construction nesting surveys if any habitat will be cleared by mechanical or hydraulic devices between February 14 and September 15 to determine active nesting conditions.
7. Adjust authorized work timelines to avoid disturbances during peak nesting seasons between February 14 and September 15.

8. Work areas or project boundaries should maintain a buffer of vegetation at least 100 feet (30 meters) around nests of Passerines (i.e., songbirds) until young have fledged or the nest is abandoned.
9. Maintain equipment and activity setback distance of 1,000 feet (304 meters) near active colonial waterbird rookeries during peak nesting seasons between February 15 and September 1.
10. Equipment and activity set-back distances should be at least 0.25 miles (400 m) for nesting raptors (USFWS 2015); with special provisions for Northern aplomado falcons and bald eagles which require two miles (3.2 kilometers) for buffers around their nests based upon their home range sizes (USFWS 1990; Garrett et al. 1993; USFWS 2020) and their protected status under the Endangered Species Act and/or the Bald and Golden Eagle Protection Act.
11. Report any injured birds encountered during project operations to state and federal permitted rehabilitation centers.

This final report is submitted in fulfillment of the requirements of the Fish and Wildlife Coordination Act (48 Stat. 401, as amended; 16 U.S.C. 661 et seq.), and constitutes the final report of the Secretary of the Interior as required by Section 2(b) of that Act.

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ANNEX A:

USFWS Planning Aid Letter dated November 20, 2017

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↳ PPMD

United States Department of the Interior
FISH AND WILDLIFE SERVICE
Texas Coastal Ecological Services Field Office
17629 El Camino Real, Suite 211
Houston, Texas 77058
281/286-8282 / (FAX) 281/488-5882

In Reply Refer To:
FWS/R2/02ETT
XX0-2016-CPA-0057

November 20, 2017

Colonel Lars Zetterstrom
District Commander
Attention: Janelle Stokes
Galveston District, U.S. Army Corps of Engineers
Post Office Box 1229
Galveston, Texas 77553-1229

Dear Colonel Zetterstrom:

The U.S. Fish and Wildlife Service (Service) is collaborating with the U.S. Army Corps of Engineers (Corps) on the evaluation of the "Coastal Texas Storm Surge Protection and Restoration Study (Coastal Texas Study)". The study was authorized as part of the Water Resources Development Act of 2007 which directs the Corps to develop a comprehensive plan to determine the feasibility of carrying out projects for flood damage reduction, hurricane and storm damage reduction, and ecosystem restoration (ER) in the coastal areas of Texas. Further, the scope of the study provides for the protection, conservation, and restoration of wetlands, barrier islands, shorelines, and related lands and features that protect critical resources, habitat, and infrastructure from the impacts of coastal storms, hurricanes, erosion, and subsidence.

The purpose of this Planning Aid Letter (PAL) is to provide the Service's comments and recommendations regarding the Coastal Texas Study and identify planning constraints that have influence on the ability of the Service to fulfill our reporting responsibilities under Section 2(b) of the Fish and Wildlife Coordination Act (FWCA, 48 Stat. 401, as amended; 16 U.S.C. 661 et seq.).

The PAL is prepared under the authority of the FWCA; however, it does not constitute the final report of the Secretary of the Interior as required by Section 2(b) of the Act. Additionally, comments in this letter are provided under, the National Environmental Policy Act (NEPA) of 1969 (83 Stat. 852; 42 U.S.C. 4321 et seq.), the Endangered Species Act (Act) of 1973 and the Migratory Bird Treaty Act (MBTA) of 1918. The Service has provided copies of this letter to the National Marine Fisheries Service and the Texas Parks and Wildlife Department (TPWD); if any comments are received on this letter they will be forwarded under a separate cover letter.

As a result of the Corps compartmentalization of the Coastal Texas Study, only the ecological restoration portion of the study is addressed under this PAL and we expect to address storm surge reduction measures and associated impacts in a separate PAL as the information becomes available. Due to geographic span of the study, the Corps delineated the coast into four regions to be applied to both the ER and storm surge protection portions of the Coastal Texas Study (**Figure 1**) and will be utilized throughout both PALs.

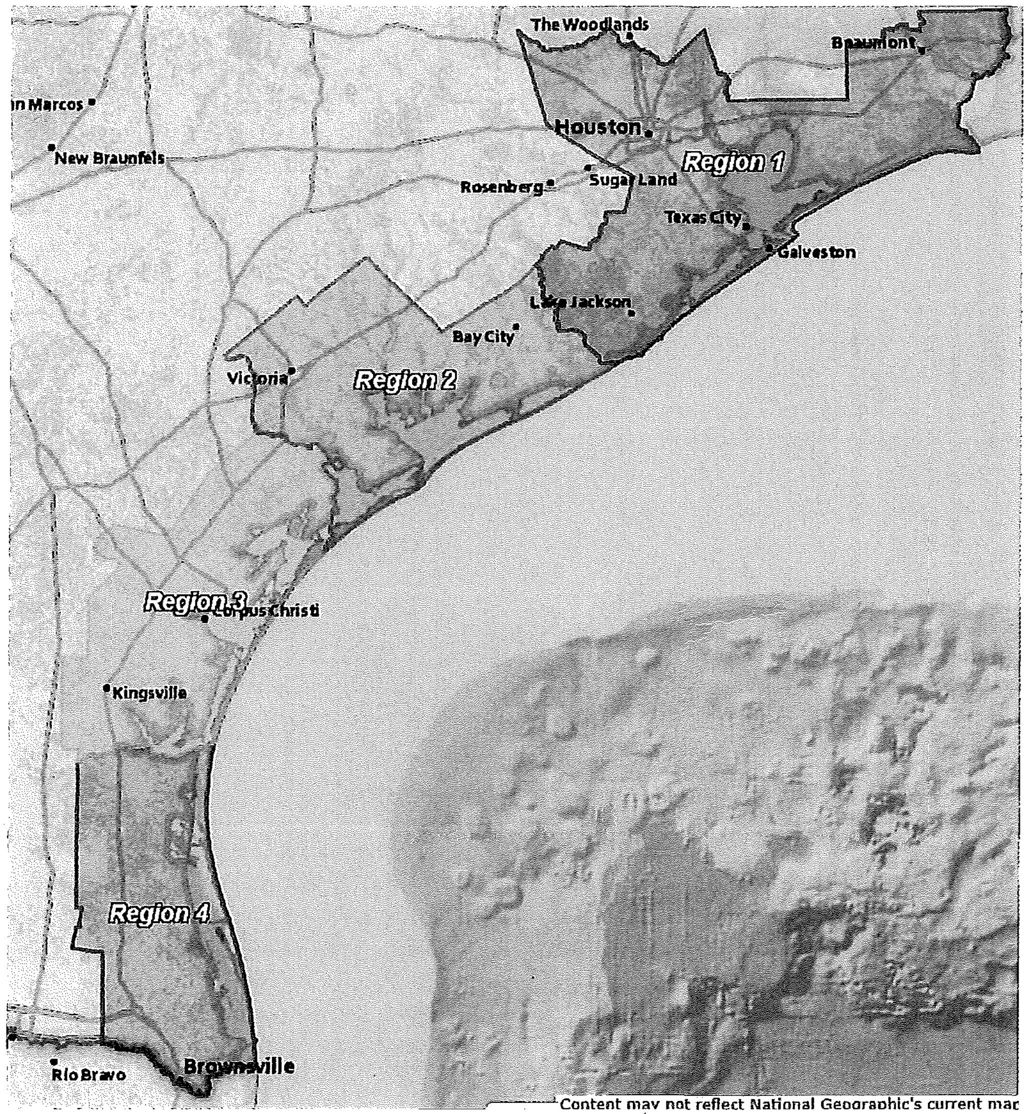

Figure 1 Coastal Texas Regions as delineated by the Corps
Source: Corps (2017)

Due to excessive delays by the Corps in processing a formal scope of work providing the Service the opportunity to formally comment under the FWCA, the Corps moved forward with a list of ecological restoration measures which mimic the Texas General Land Office's (TGLO) list of Coastal Resiliency Master Plan projects; a list compiled from ongoing Restore Council funding; and restoration measures from various other sources. Initial Service review of this project list revealed: previously completed projects; projects formerly vetted by the resource agencies and eliminated from further consideration;

inaccurate project descriptions; and projects not clearly defined as restoration. The Service recognizes that the TGLO is the Texas Coastal Study sponsor and there were time constraints imposed by the Corps Smart Planning Process. This may have resulted in the Corps not fully vetting these projects with the appropriate Service field offices and National Wildlife Refuges during the project scoping process.

The Service believes the Corps' identified restoration opportunities focused largely on protecting barrier islands and coastal and bay shorelines. While these are both important focal areas in light of concerns over sea level rise, the Service contends there is a critical need to restore and protect additional habitats not previously identified by the Corps' "project list" that should be included as part of the comprehensive ER plan. Adjacent areas such as coastal prairies, bottomland hardwood forests, and Tamaulipan thrornscrub are rarities along the Texas coast providing habitat for a vast diversity of fish and wildlife species and were not addressed by the Corps. We have provided a summary of: key focal habitats; environmental concerns; possible study opportunities; the trust species that lie within the Coastal Texas Study's purview; and in some cases, current and future Service coordinated projects. While the coastal storm reduction measures are not addressed here, we believe the Corps should use this PAL to guide and identify measures aimed at avoiding impacts to: fish and wildlife; critical habitat areas; and actions that impede natural flows in the bays, bayous, rivers, and estuaries along the Texas coast.

The Service is dedicated to ensuring the protection and management not only of our federal trust resources (migratory birds, interjurisdictional fisheries, federally threatened and endangered species and public lands), but also for at-risk species and those of concern to our partners. As such, the Service established the Gulf Coast Emphasis Area and adopted a model to effectively establish long-term strategic conservation priorities aimed at creating the greatest return on our conservation investments. The Gulf Coast Emphasis Area (**Figure 2**) includes some of the most productive marsh and estuaries in North America. It encompasses near-coastal bottomland

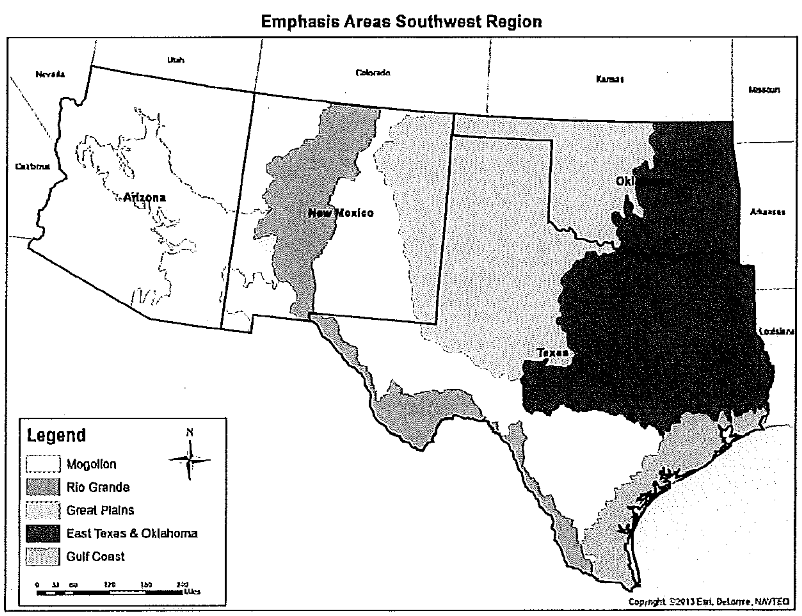

Figure 2 Service Emphasis Areas

hardwood forests and oak mottes, which are important to millions of migrating songbirds, shorebirds, wading birds and other wetland dependent species. The Service has a large conservation presence along the Texas Gulf Coast, roughly 450,000 acres that are either Service owned or managed for trust species and to protect many of the most important wildlife habitats in Texas. We believe the Coastal Texas Study's comprehensive ecological restoration plan provides a unique opportunity to identify, protect, and restore degraded natural resources along the Texas coast to benefit future generations.

Fish and Wildlife Resources

Finfish and shellfish

Close to 97 percent of all finfish and shellfish are dependent in some way on the coastal areas where fresh water from streams and rivers mix with salt water from the Gulf of Mexico creating food rich estuaries. Many species migrate into the estuaries to spawn, or use the estuaries for protection of young against predators with most fish and shellfish migrating back to the Gulf of Mexico as adults. Almost 85percent of recreationally important fish species use coastal wetlands and estuarine habitats during at least one life stage. Marshlands adjacent to the bay systems tend to provide significant quantities of organic material which forms the base of the food chain in the estuaries.

Texas routinely accounts for almost a quarter of the red snapper *Lutjanus campechanus* harvested in the Gulf of Mexico, and one quarter of all domestic shrimp landed in the United States comes from Texas. In fact Texas Parks and Wildlife Department claims shrimp accounts for both 85 percent of landing and overall economic value of the Texas commercial fishing industry. In 2015, 52.6 million pounds of brown shrimp *Farfantepenaeus aztecus* and 16.6 million pounds of white shrimp *Litopenaeus setiferus* were landed with revenues of $96.8 million and $46.6 million respectively in Texas. Brown shrimp landing in Texas accounts for 49 percent of the total harvest in the Gulf of Mexico (Audubon Nature Institute, 2017).

Finfish are usually highly mobile therefore; any impacts to those species will be minimal and temporary. However, increases in suspended sediments and turbidity levels from dredging and disposal operations, could under certain conditions, result in adverse effects on marine animals and plants by reducing light penetration into the water column and by the actual physical disturbance. Likewise, shellfish can suffer from breathing problems associated with clogged and damaged feeding apparatus and young fish can have increased fatalities when sediments become trapped in their gills from heavily turbid waters (Wilbur & Clarke, 2001).

Oyster Reef

Where there is hard bottom in the bays, oysters typically grow as consolidated reefs providing important feeding and refuge habitat for well over 300 aquatic species. Oysters are filter-feeders, filtering up to six gallons of salt water per hour. They consume plankton helping to maintain good water quality in Texas bays and estuaries. Oysters support a valuable commercial fishery in Texas, with 22,760 acres of public reef and 2,321 acres of private reef available for harvesting. Texas A&M reports that Texas provides nearly 15 percent of the nation's total oyster harvest resulting in a $50 million impact on the state's economy (Texas A&M University). Ninety percent of the public reefs utilized by commercial and recreational fisherman are found in Galveston, Matagorda and San Antonio Bays with Galveston Bay landings usually the highest. Galveston Bay's oyster reefs were hit particularly hard during Hurricane Ike in 2008 leaving many of the reefs buried in layers of sediment and debris ultimately smothering live oysters. This devastating event destroyed almost 60 percent of the oyster reef habitat in Galveston Bay, and 80 percent of the East Bay's oyster population. The oyster fishery was slow to bounce back from the devastation of Hurricane Ike. Extreme conditions of drought, algae, red tide, and extreme influxes of fresh water beginning in 2010 led Galveston County to declare a disaster declaration for the ailing oyster industry. Extreme rainfall events during the spring of 2015 and 2016 led to a catastrophic oyster die off in Galveston Bay resulting in 1.67 million pounds of oysters landed (half of the previous year's total landing). Local oyster industry officials suggest restoration of damaged oyster reefs may take $20 to $30 million (Houston Chronicle, 2015). Oyster reef restoration occurs throughout the Texas bay systems and can take several forms. Smaller "oyster gardening" projects are perfect to engage homeowners in active restoration efforts. However, the creation of larger artificially constructed reef pads is necessary to continue oyster reef growth in all of the Texas bay systems.

Recommendations
The Service recognizes the significant contribution of oysters to the aquatic ecosystems, supports the creation of oyster reef habitat throughout Texas bay systems, and is willing to assist with restoration site identification in conjunction with the other federal, state, and local natural resource agencies. Any oyster restoration or creation should be conducted within publicly harvestable or restricted or closed areas and not subject to lease by TPWD or others. Success criteria for created and restored sites should be coordinated with TPWD and harvest limited to sustainable levels.

Migratory Birds

Piping Plover

Listed as threatened and endangered species under the Act in 1986, the piping plover is a small stocky shorebird approximately 7 inches in length with a wingspan of about 15 inches (Palmer, 1967, Service, 2009). Plumage and descriptive characteristics include a pale back, nape, and crown, white under parts, a stubby bill, and orange legs and during the breeding season, the legs and bill are bright orange, the bill has a black tip, and a single black breast band and forehead bar are present. In winter, its legs become pale orange, its bill turns black, and the darker bands and bars are lost (Wilcox, 1959, Service 2009).The historic range of the piping plover has traditionally been divided into breeding and wintering ranges. The breeding range encompasses the northern Great Plains and Prairies, the Great Lakes, and the North Atlantic ecoregions of the United States and Canada while the wintering range extends along coastal areas of the U.S. from North Carolina to Texas and portions of Mexico and the Caribbean (Service, 2009). The species current range remains similar to its historic range except that piping plovers have been extirpated from several Great Lakes breeding areas (Service 2003).

On their migration and wintering range, piping plovers forage and roost among a mosaic of beach and bay habitats and move locally (within a home range) among these habitats in response to a variety of factors including tidal stage, weather conditions, human disturbance, and prey abundance (Drake, 2001, Cohen et al., 2008, Noe and Chandler 2008). Foraging habitats include bayside flats and islands, the intertidal zone of ocean beaches, wrack microhabitats, washover passes (channel cuts created by storm driven water), and shorelines of ephemeral ponds, lagoons, and salt marshes. Roosting habitats include back-beach areas, dunes, wrack microhabitats, inlets, and river mouths as roosting habitats (Arvin, 2009, Service, 2009).

Approximately 35 percent of the known global population of piping plovers winters along the Texas Gulf Coast, where they spend 60 to 70 percent of the year (Haig & Elliott-Smith, 2004). Piping plovers are a common migrant and rare to uncommon winter resident on the upper Texas coast most likely due to habitat conditions (Lockwood, 2004). Plovers on the wintering grounds suggest that they show some site fidelity, returning to the same stretch of beach year after year. On the lower Texas coast, piping plovers are known to use areas about 3,000 acres in size, moving two miles or more between foraging sites as tidal movements shift the availability of productive tidal flats.

Red knot

The red knot *Calidris cantus rufa* is considered a threatened species under the Act and generally flies more than 9,300 miles from south to north every spring and fall without stopping, making this species one of the longest-distance migrants in the animal kingdom (Morrison, Ross, & Niles, 2004). Breeding takes place in the Canadian Arctic with arrival beginning in late May or early June varying with snowmelt conditions. Most adult and juvenile red knots leave the breeding grounds in late July however some remain as late as mid-August. Red knots occupy all wintering areas as early as September and as late as May in Texas. In addition, the birds are found in coastal bays, estuaries, and inlets returning to the same wintering ground yearly. Declines in the red knot population occurred in the 2000s primarily from reduced food availability from increased harvest of horseshoe crabs in Delaware Bay (the main stop over point for red knots). While red knot numbers may have stabilized some in the past few years, their numbers remain at low levels relative to earlier decades and warranted federal protection on January 12, 2015.

Whooping crane

The endangered whooping crane *Grus Americana,* with less than 600 birds in the wild, winters along the marshes of the central Texas coast and feeds on aquatic invertebrates such as insects, blue crabs, small vertebrate fish, amphibians, birds, mammals, and plants commonly found in freshwater to brackish marsh regimes and coastal prairies. A portion of the original wild flock (defined as always living in natural circumstances) winters at the Aransas National Wildlife Refuge September through April each year and then migrates north to breed at Wood Buffalo National Park in Canada. With occasional use of upper Texas coastal marsh habitat, a non-essential experimental population of 59 whooping cranes is yearlong residents of the marsh and rice fields of southwest Louisiana. Across the Texas coast, the primary threat to whooping cranes remains habitat loss; however, adequate food supplies are critical to whooping cranes. Lack of freshwater inflows can create saline conditions not favorable for key forage species and can threaten whooping crane overwinter and migration success. Migration flights to and from the breeding grounds are not direct or non-stop and stop overs are required for rest and refueling. Healthy wetlands (of all types) on the wintering grounds and along the migratory route continue to play an integral part into the whooping crane's survival and should be preserved. Due to the location of potential restoration project within coastal salt marsh, there is the potential for occurrences of the federally listed endangered whooping crane along the upper and mid Texas coast where they are known to utilize similar salt marshes outside of the historic wintering grounds.

Colonial Waterbirds

Colonial waterbirds are birds that gather in large groups called rookeries or colonies during the nesting season and they obtain all or most of their food from the water. While many species of colonial waterbirds appear to have incredibly large populations, they face many threats such as oil pollution associated with increased tanker traffic and spills, direct mortality from entanglement and drowning in commercial fishing gear, depletion of forage fish due to overexploitation by commercial fisheries, habitat limitations, and the presence of predators at nesting sites. Texas islands host nesting colonies for most North America seabirds as well as many of the last populations of endemic landbird species.

Comprehensive restoration of priority islands for breeding birds is needed as many islands are still overrun by invasive species. The Service identified 18 historic colonial waterbird colonies within the project area. These islands or sites are no longer suitable due to: the presence of invasive predator species; overgrown vegetation; lack of open ground nesting habitat; erosion or subsidence; and no longer have appropriate elevations to support nesting birds, or the lack of available forage sites in close proximity to nesting habitat. The Texas Colonial Waterbird Society (TCWBS) recognizes over 500 active and historic colony and sub colony sites within the study area. Since 1978, the TCWBS annually surveys 23 colonial waterbird species to identify population trends and make management recommendations to our partners along the coast. Recent trends (2000 through 2014) indicate a decline for many of the surveyed species which may be attributed to predator presence (including humans) and habitat erosion or conversion. The once endangered brown pelican *Pelecanus occidentalis,* considered a major conservation success story, was delisted in 2009 in large part to intensive rookery management and island creation in Texas promoting optimal breeding and foraging habitats.

The construction of bird islands using new work dredged matieral is well documented, but it was not until the 1970s that the importance of this dredged material to nesting waterbirds was realized (Golder, Allen, Cameron, & Wilder, 2008). Dredge spoil islands created out of local sand and clays provide immediate nesting opportunties for bare ground nesters such as terns and skimmers. Successional vegetation including mangroves, bacharris, and other shrub spieces provide suitable nesting habitat for three species of egrets, five species of herons, white ibis *Eudocimus albus*, and rosette spoonbills *Platalea ajaja*. This and subsequent projects could positively contribute to the colonial waterbird populations across the Gulf of Mexico.

Waterfowl

Most waterfowl depend upon wetlands for some or all stages of their lifecycles. The mottled duck *Angus fulvigula,* a medium sized dabbling and non-migratory duck, is the only duck species adapted to breed in the southern wet coastal prairies and marshes of the Texas gulf coast. Not federally listed under the Act, but a focal species for the Service and many others, mottled ducks spend their entire life on the coastal prairie and adjacent marshes relying on the availability of coastal marsh for its existence (Merendino et. al, 2005). Once abundant along the Texas coast, the mottled duck is primarily found along preserved and development free areas with highest densities often observed in fresh and intermediate coastal marshes of the Texas Chenier Plain and moderate densities found in the coastal marshes of the Texas Mid-Coast. Most common habitats include fresh to brackish coastal marsh ponds, emergent freshwater wetlands, and flooded rice fields of the prairie. In south Texas, mottled ducks are frequently found in resacas of the Rio Grande Valley and freshwater ponds associated with coastal grasslands. Mottled duck populations have declined over the years mostly attributing to the loss of suitable nesting and brood-rearing habitat (Krainyk & Ballard, 2015) which include grasslands and palustrine and estuarine wetlands.

Although the amount of Gulf coastal prairie is small, it provides wintering habitat for large concentrations of waterfowl: 95 percent of gadwall, 90 percent of mottled duck, 80 percent of green-winged teal, 80 percent of redheads, 60 percent of lesser scaup, 25 percent of pintails, and mid-continent lesser snow and white-fronted geese (Ducks Unlimited). Additionally, coastal prairie provides migration habitat for most of the blue-winged teal that winter in Central and South America. With such large waterfowl populations migrating through or wintering in coastal Texas, federal and state partners have set aside land specifically aimed to conserve wetlands and coastal prairies for the benefit of waterfowl.

Other Migrating Birds

The Service published the *Birds of Conservation Concern 2008* (BCC) in December 2008 as a result of the 1988 amendment to the FWCA that mandates the Service to identify species, subspecies, and populations of all migratory nongame birds that, without additional conservation actions, are likely to become candidates for listing under the Act. The BCC is divided into Bird Conservation Regions (BCR). Within the Coastal Texas Study area lies BCRs 36, Tamaulipan Bushlands and 37 Gulf Coastal Prairie U.S. portion only (**Figure 3**) with a full species lists included as an appendix. We expect many of the species identified in BCR 37 will be present within the Texas Coastal Study footprint.

Marsh, bird islands, and placement areas created by large scale Corps projects all are suitable habitat for resident and migratory birds to forage, nest, and may play a critical life cycle role as other coastal habitats erode and become less suitable. The recent State of North America's Birds 2016 (North American Bird Conservation Initiative, 2016) identifies seabirds as declining. This guild continues to be severely threatened by invasive predators on nesting islands, accidental bycatch by commercial fishing vessels, as well as overfishing of forage fish stocks, pollution, and climate change. By adopting broad best management practices such as the continued building of bird islands, managing invasive species and vegetation on existing islands and placement areas, the Corps will help to ensure the growth of colonial waterbird populations and shorebirds along the Texas mid coast and at the broader Gulf of Mexico level for years to come.

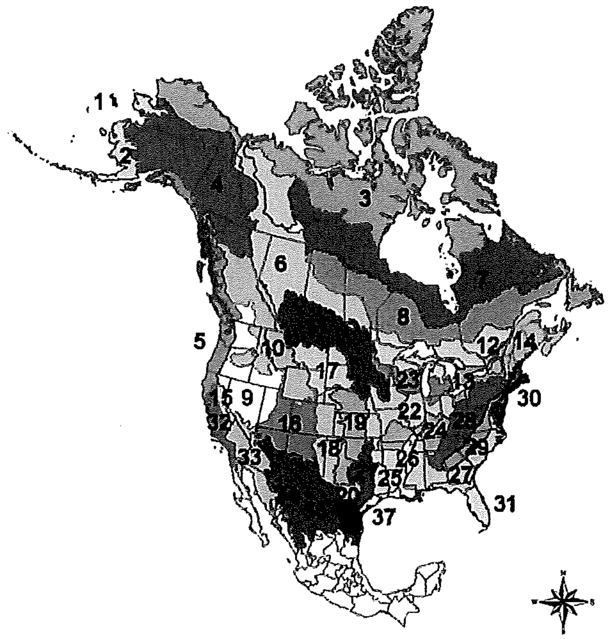

Figure 3 Birds of Conservation Concern Region Map

Most Texas birds are not year-round residents and are considered to be seasonal residents or migrants. The Texas mid coast is critically important habitat for migrating birds due to their use of uplands, wetlands, beaches and marshes as feeding, resting and nesting sites. The Matagorda Bay area is located within the path of the Central flyway. In existence today, there are 338 Neotropic North American species, 333 have been documented in Texas (Haggerty & Meuth, 2015). The coastal and bay shorelines provide stop over and fall-out habitat for many neotropical birds migrating across the Gulf of Mexico to their summer grounds in the northern United States and Canada. These weary and energy-drained birds seek wooded areas to feed and recharge before taking flight again. Various species of hawks and raptors are found in the project area throughout the year, however most are migrants and are found primarily during the winter months. Eagles, owls, and hawks are resident and are common on the landscape.

As of December 2013, the Service documents 1,026 avian species protected under the Migratory Bird Treaty Act of 1918 The Act makes it illegal for anyone to take, possess, import, export, transport, sell, purchase, barter, or offer for sale, purchase, or barter, any migratory bird, or the parts, nest, or eggs of such a bird except under the terms of a valid permit issued pursuant to Federal regulations. While the purpose of the PAL is to identify key focal habitats within the study area and pinpoint means to minimize impacts to trust resources if alternatives are presented, we recommend the Corps evaluate each ER and coastal storm surge reduction study measures for negative impacts to resident and migratory bird species, specifically those that are listed on the BCC and the North American Bird Conservation Initiative. We recommend the use of the Service's Nationwide Standard Conservation Measures as guidance to reducing impacts to birds and their habitats. The guidelines can be accessed at https://www.fws.gov/birds/management/project-assessment-tools-and-guidance/conservation-measures/nationwide-standard-conservation-measures.php.

Sea turtles

The Service and NOAA share joint jurisdiction over five species of sea turtles found in U.S. waters and nesting on U.S. beaches: leatherback, hawksbill, loggerhead, green and Kemp's ridley. NOAA retains jurisdiction when sea turtles are in a marine environment and the Service picks up jurisdiction when sea turtle emerge to nest. The leatherback, hawksbill and green sea turtles rarely nest in the southeastern U.S., but offshore waters are important feeding, resting, and migratory corridors. Texas sea turtle nesting season occurs from March 15 to October 1 with the Kemp's ridley, green, and loggerhead sea turtles known to nest along the Texas coast. Kemp's ridley sea turtles nest bi-annually with most nesting occurring along the Tamaulipan coast of Mexico. However, during the 2017 nesting season, Kemp's ridley sea turtles laid a record setting 352 nests along the Texas coast (Shaver, 2017). These turtles return to their natal beaches to nest and can lay more than one clutch in a season. Should the Corps determine that beach nourishment or shoreline protection are viable options under this study, the Service recommends the Corps evaluate these actions for specific impacts to nesting sea turtles under Section 7 of the Act. Similarly, impacts to sea turtles in the marine environment should be evaluated and coordination with NOAA's Protected Resource Division Permitting Office at 877-376-4877.

Threatened and Endangered Species Consultation

The Service recommends the Corps conduct a review for threatened and endangered species two years prior to construction. In order to obtain information regarding fish and wildlife resources concerning a specific project or project area, we recommend that the Corps first utilize the Service developed Information, Planning, and Conservation (IPaC) System. The IPaC system provides information about natural resources the Service has responsibility for and assists project proponents in planning their activities within the context of natural resource conservation. Additionally the system can assist people through the various regulatory consultation, permitting and approval processes administered by the Service, achieving more effective and efficient results for both the project proponents and natural resources. The IPaC system can be found at: http://ecos.fws.gov/ipac/.

Critical Habitat

Critical habitat is the specific areas occupied by the species at the time it was listed that contain the physical or biological features essential to the conservation of endangered and threatened species. Critical habitat may also include areas not occupied by the species at the time of listing but are essential to its conservation. The Act requires Federal agencies to use their authorities to conserve endangered and threatened species and to consult with the USFWS about actions that they carry out, fund, or authorize to ensure that they will not destroy or adversely modify critical habitat. The prohibition against destruction and adverse modification of critical habitat protects such areas in the interest of conservation.

We have reviewed our files and determined that critical habitat for the federally endangered piping plover and whooping crane lie within the study area boundaries and are outlined in yellow in **Figures 4, 5, 6 and 7**. Further analysis for specific habitat units impacted by this study should be conducted and we also recommend coordination pursuant to the "Act" with the Service's Texas Coastal Ecological Services Office prior to the commencement of any restoration activities.

Critical habitat was designated for all wintering piping plovers on July 10, 2001 (66 FR 36038). This designation aimed to provide sufficient wintering habitat to support the piping plover at the population level and geographic distribution necessary for recovery of the species. This designation included

142conservation units along the coasts of North Carolina, South Carolina, Georgia, Florida, Alabama, Mississippi, Louisiana, and Texas. A total of approximately 165,211 acres or 1,798 miles were designated. There were 37 critical habitat units (approximately 62,454 acres, 797 miles) designated in Texas (**Figures 4, 5, and 7**). These areas were believed to contain the essential physical and biological elements for the conservation of wintering piping plovers, and the physical features necessary for maintaining the natural processes that provide appropriate foraging, roosting, and sheltering habitat components.

Critical habitat for the endangered whooping crane was finalized in 1978 and occurs on the Aransas National Wildlife Refuge as depicted in **Figure 6** and includes salt marshes and tidal flats on the mainland and barrier islands, dominated by salt grass *Distichils spicata*, saltwort *Kali turgida*, smooth cordgrass *Spartina alterniflora* , glassworts *Salicornia* spp. and sea ox-eye daisy *Borrichia frutescens*. The cranes occasionally fly to upland sites when attracted by fresh water or foods such as acorns, snails, crayfish and insects, and then return to the marsh to roost. Uplands are particularly attractive to the cranes when partially flooded by rainfall, burned to reduce plant cover or when food is less available in the salt flats and marshes.

At this time there is no critical habitat designation for the red knot; however, the Corps should analyze effects of the project for all threatened and endangered species pursuant to Section 7 of the Act prior to the commencement of any construction. The Service's Critical Habitat Mapper provides information regarding threatened and endangered species critical habitat designation that may be of use during project design and evaluation and is found at https://ecos.fws.gov/ecp/report/table/critical-habitat.html?

Essential Fish Habitat

Estuarine wetlands and associated shallow waters within the project area have been identified as Essential Fish Habitat (EFH) for post larval, juvenile and sub-adult stages of brown shrimp *Crangon crangon*, white shrimp *Litopenaeus setiferus*, and red drum *Sciaenops ocellatus.*. EFH requirements vary depending upon the species and life stage with categories within the project area including estuarine emergent wetlands, estuarine water column, submerged aquatic vegetation, and estuarine water bottoms. Detailed information on federally managed fisheries and their EFH is provided in the 2005 generic amendment of the Fishery Management Plans for the Gulf of Mexico, prepared by the Gulf of Mexico.

Fishery Management Council (GMFMC) and can be found at http://gulfcouncil.org/fishery-management/. That generic amendment was prepared in accordance with the Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA), (P.L. 104-297).

We recommend the Corps initiate consultation with National Marine Fisheries Services, Southeast Regional Office, Habitat Conservation in Galveston, Texas at 409-766-3699 to determine specific impacts to EFH as a result of the proposed ecological restoration measures of the Texas Coastal Study.

Bird Island Creation

Since 1973, the Service along with other federal, state, local non-governmental agencies and private citizens monitored several hundred coastal colonial waterbird sites along the Texas coast. While some islands are natural, most are man-made and are the result of nearby dredging activities. The creation of man-made islands usually occurs in waters adjacent to a shipping channel, cut, or pass and thereby may be subject to increased rates of erosion. In general, spoil islands provide suitable bare ground nesting habitat and subsequent vegetation succession can create shrub and tree habitat for other colonial nesters.

Figure 4 Upper Texas Coast Critical Habitat (piping plover)

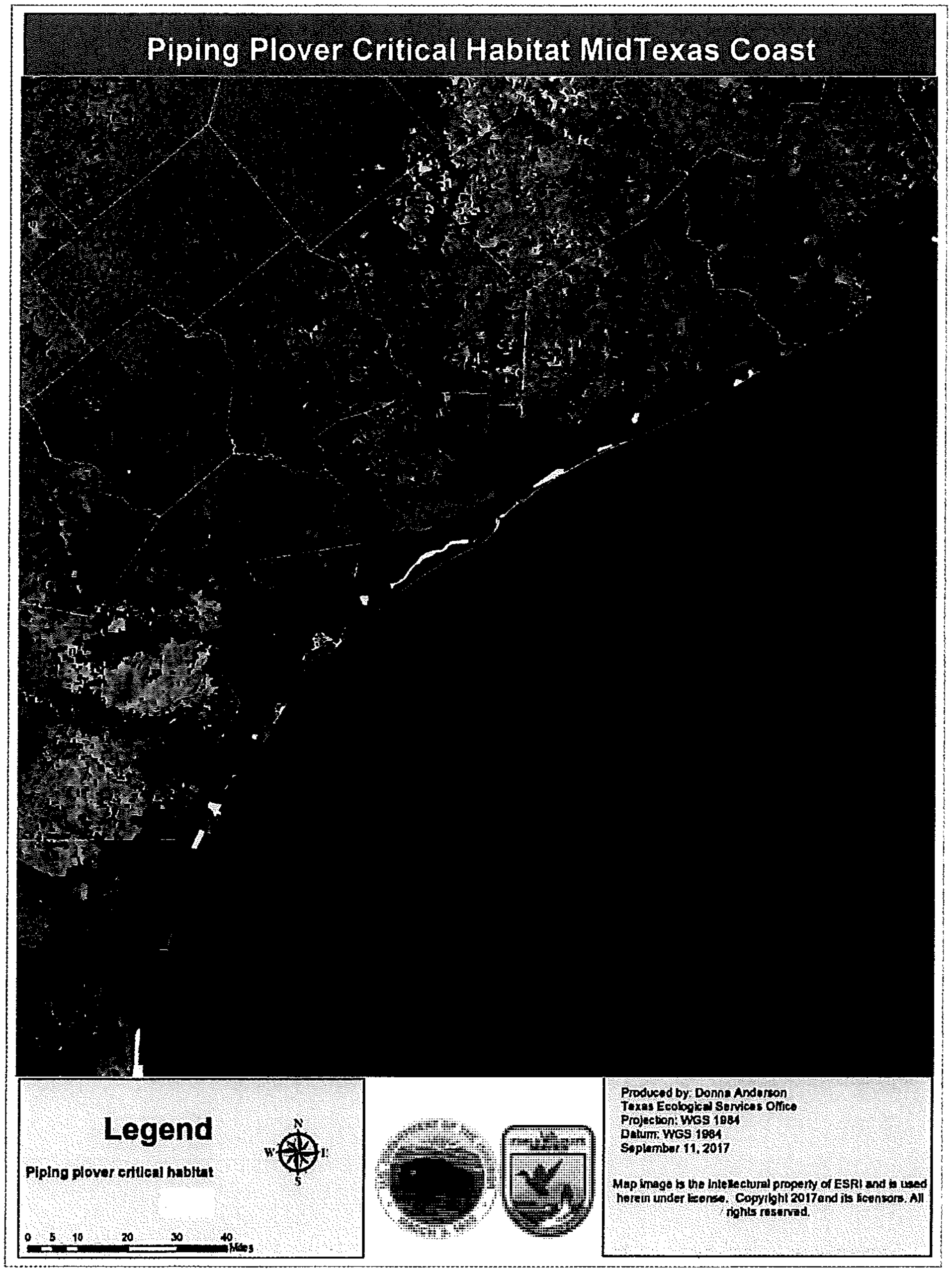

Figure 5 Mid Coast Critical Habitat (piping plover)

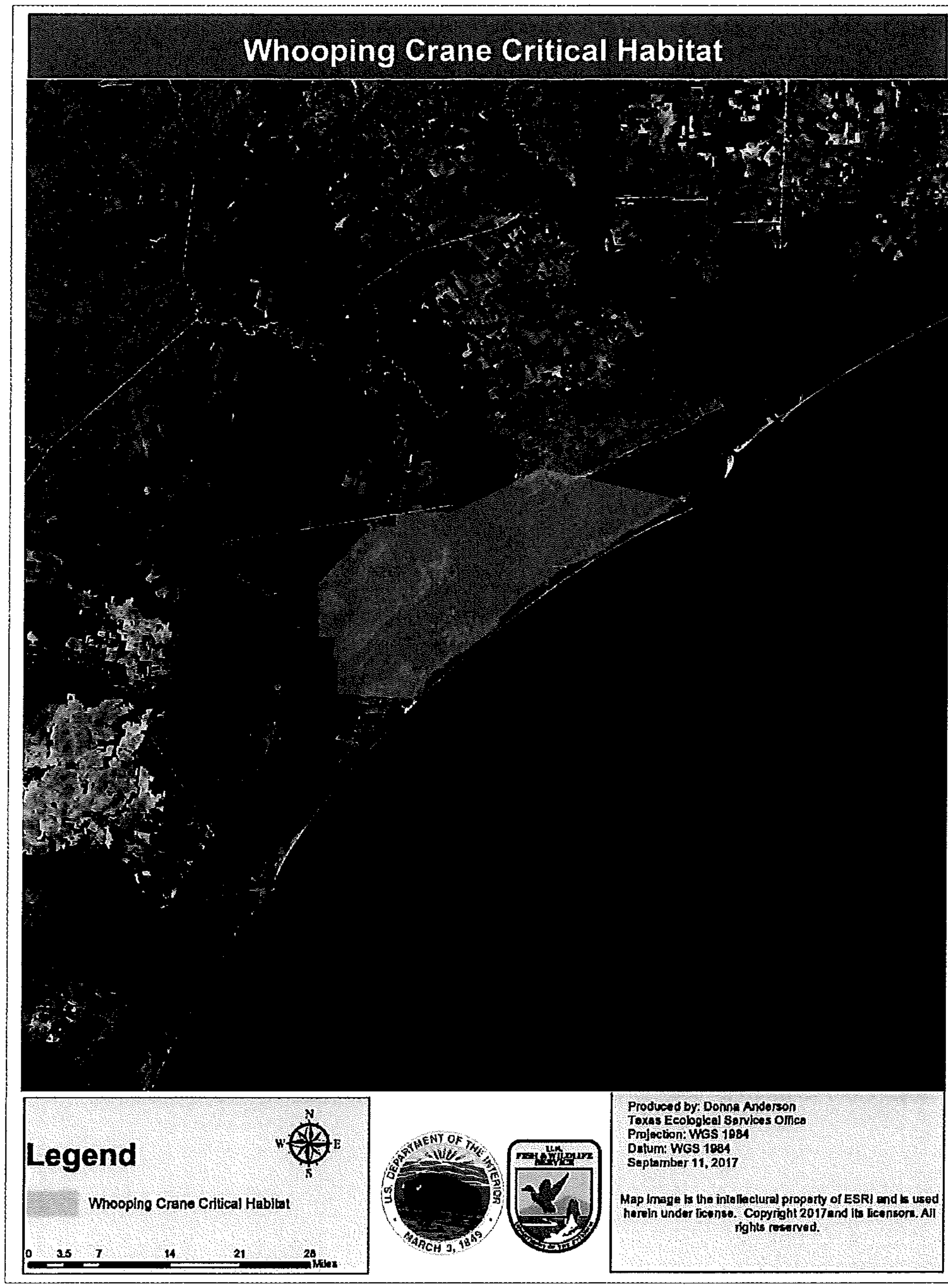

Figure 6 Mid Coast Critical Habitat cont'd (whooping crane)

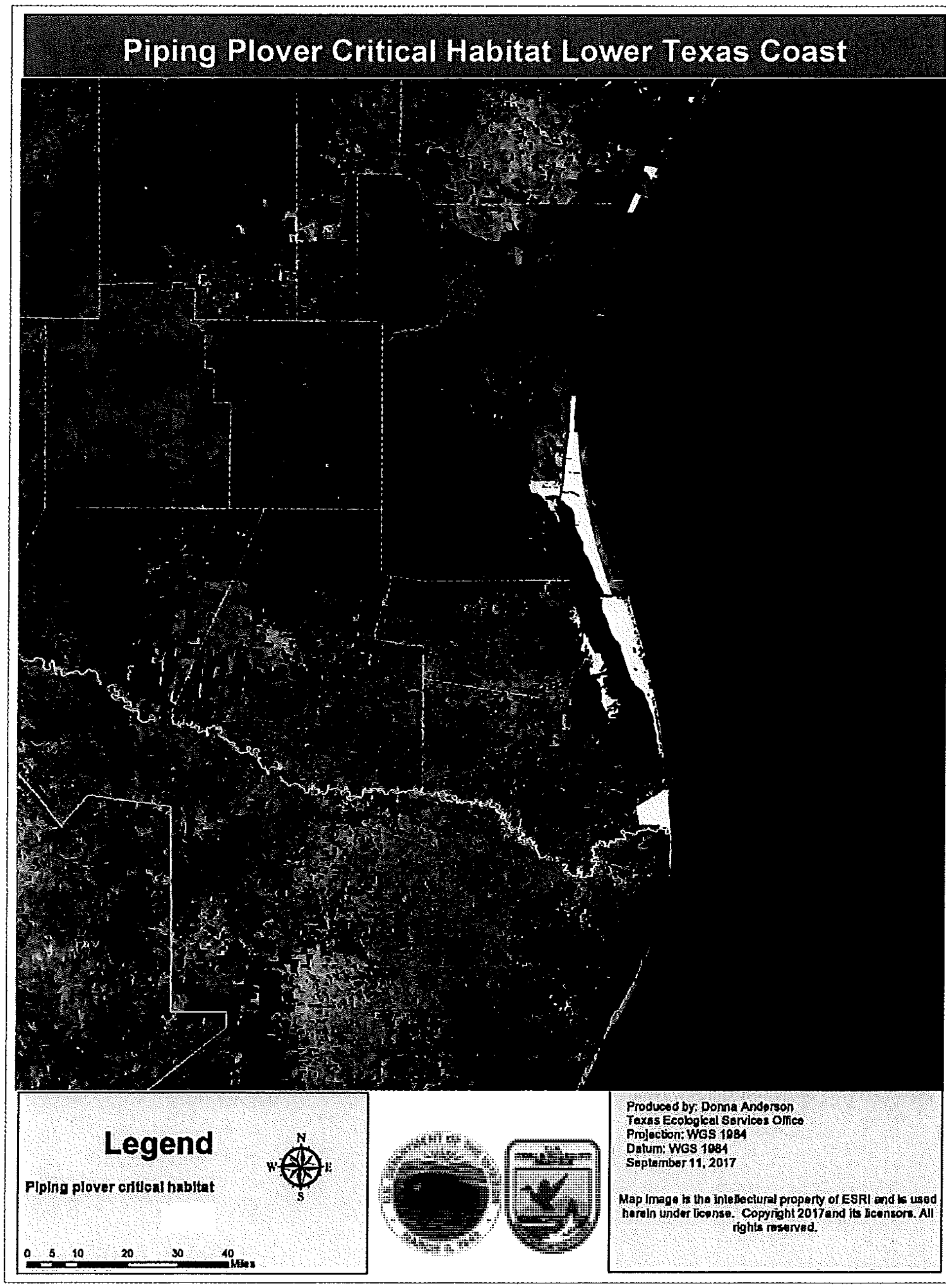

Figure 7 Lower Coast Critical Habitat (piping plover)

The importance of coastal rookeries to bay ecosystems is well documented in terms of fisheries, recreational opportunities, and photography. Audubon Texas (2016) conducted studies to quantify erosion along Texas rookery islands and project future land loss. Fourteen islands were rated as the highest priority in need of protection and eight of those islands are predicted to experience a complete land loss within 50 years. Audubon Texas (2017) authored a comprehensive Texas Coastal Rookery Conservation Plan (Plan) that identified all current and historical colonial waterbird islands as well as birds commonly found breeding at each site. Additionally it identified management needs and challenges for each island. Many coastal rookery islands face erosion issues as a result of increased storm frequency and intensity, sea level rise, and wave fetch caused by increased size and number of commercial and recreational vessel traffic.

Some Texas bay systems appear to be more resilient in terms of bird nesting which may be associated with frequency of dredge events and placement options. Sabine Lake had four active rookery sites however; predator presence, subsidence, and erosion have eliminated all nesting sites as of 2013. Maintenance dredge material from the Sabine Neches Water Way is either placed in upland confinement or pumped offshore and new work material necessary for island creation is seldom available.

The Galveston Bay rookeries experience high rates of erosion and predator presence at most nesting sites. Many sites are Corps dredge spoil islands that are not maintained or managed and are located adjacent to the mainland or near to the Houston Ship Channel. While dredging frequency and material are plentiful, placement of additional dredge material at Galveston Bay rookeries remains a challenging due to limited pumping distances and costs. Jigsaw, Rollover Pass, Struvey Lucy, Marker 52, Vingt-et-un, and Smith Point islands all experience some level of erosion, most likely from increased wind fetch and wave energy, and would benefit from added dredge material and rock protection measures.

Like the Sabine Bay system, Matagorda Bay and the smaller feeder bay systems have few islands suitable for colonial nesters. Chester Island (Matagorda Bay) and Lavaca Bay Spoil (63-77) (Lavaca Bay) line the Matagorda Ship Channel, are both eroding dredge spoil islands, and provide the only nesting habitat for most of the Matagorda Bay systems. The Mouth of Chocolate Bayou, Lavaca Bay Spoils (51-63), Point Comfort-AlCOA, Mouth of Lavaca River, and Matagorda Bay Spoils (39-51), Coon Island sites lack sufficient elevation to support nesting birds and most likely contribute to the declines in nesting bird populations along this portion of the coast during the late 1990s and early 2000s. Increasing nesting opportunities by creating islands strategically placed in Matagorda Bay system may be an alternative to armoring the existing two islands. Designing islands with a suite of habitats to provide nesting and foraging opportunities will attract the greatest diversity of colonial nesters.

The Laguna Madre is a critically important area for natural resources supporting a rich diversity of birds throughout the year. Historically, the Laguna Madre supported 42 colonial waterbird islands; mainly constructed during the original dredging of the Gulf Intercoastal Water Way (GIWW). However, many of these constructed sites (like other Texas bay systems) now lack suitable elevations to support colonial nesters. The Texas Colonial Waterbird Society (2017) reported a declining trend for colonial waterbird populations where habitat availability and predator presence may be limiting factors. While some of these islands receive periodic dredge maintenance material, others have not. Many islands have and continue to erode warranting additional protection measures.

Recommendations

The Service recommends the Corps evaluate bird rookery island design, construction, and restoration opportunities along the entire Texas coast in conjunction with the other federal, state, local resource agencies, and local partners, due to the decline in available nesting habitat in all the major bay systems.

We believe this evaluation will demonstrate the need for both the restoration of the historic islands and the construction of new nesting island or suite of islands. Island design should strongly consider proximity to mainland, sea level rise, erosive forces if placed in high wave energy environments, and should contain habitat suitable for a variety of guilds. In addition, as a study opportunity, the Service recommends research funding be dedicated to identifying colonial waterbird foraging habitats, optimum island capacity, migratory patterns of focal colonial waterbird species, optimal elevation for colony islands, and analysis of preferred island locations and marginal habitat sites. We believe these studies will yield valuable data and would be used to guide site selection, island design, and construction methods. The Study's Comprehensive Plan should also capture migratory bird research needs such as understanding beach recolonization of benthic communities, understanding avian movement in and within adjacent habitats, and optimal foraging distances from nesting areas.
Close coordination with natural resource agencies, academia, and NGOs with expertise in nesting colonial waterbirds and island design is highly recommended to further develop research needs.

Beach Nourishment and Dune Restoration
Beach nourishment is a process that occurs regularly along the Texas Coast and utilizes sand from various sources, either onshore or offshore, to replace sand from beaches suffering erosion. Beach nourishment is often proposed as an alternate to other hard structure alternatives such as seawalls and usually requires an ongoing commitment of public funding. Texas shorelines typically advance or retreat depending on the actions of waves, currents, tides, and availability of sediment in the littoral system. The availability of sediment is hampered largely by natural and anthropogenic means such as increased frequency of hurricane level events, recurring dredging activities, and the presences of jetties, dykes, and groins. Most sediment is either permanently removed from the system or transported far enough offshore that smaller waves are unable to carry the material back to the beach resulting in sand starved beaches. Changes in shoreline location are of enormous importance to Texas residents, industry, local governments, and can result in millions of lost tourist revenue, damages to homes, commercial and industrial businesses, infrastructure (roads, bridges, power lines etc.), and pipelines. These natural and anthropogenic changes generally negatively impact shoreline ecosystems, wildlife, and human recreation activities.

Increased intensity and frequency of natural coastal processes (hurricane and storm events) can reduce the efficiency of dune ecosystems along the Texas coast resulting in severe shoreline and dune degradation. In some coastal areas, overtopping during storm events compromise dune structures, alter ingress and egress flows of historically fresh marsh areas, and can result in the conversion to open water habitat displacing fish and wildlife. The reduction and loss of shoreline habitat can be directly correlated with the status of seven federally threatened and endangered species. With the creation of dunes and forebeach, we expect suitable habitat will be provided for threatened and endangered species such as the piping plover, red knot, nesting Kemp's Ridley, loggerhead, and green sea turtles, hawksbill sea turtles, and the leatherback sea turtle. Historic use of Texas beaches for these species is well documented; however, current habitat conditions may not be favorable (limited sand and dune availability) along some portions of the coast resulting in avoidance or diminished use.

Much of the Texas coast remains severely eroded by hurricane events, sea level rise, regular high tides, and reduced sediment supplies resulting in the loss of dunes and coastal shorelines. Beach nourishment projects provide protection of forebeach, back dune wetlands, and create additional nesting, resting, and foraging opportunities for listed and non-listed migratory shorebirds, sea turtles, and fish species of commercial and recreational importance.

Recommendations
Generally, the Service supports the overall concept of beach renourishment, dune creation, and debris removal along the entire Texas coast. However, the Service recommends the Corps assess and identify the causes for site specific shoreline erosion and provide long term solutions for shoreline stabilization. The Service recommends the Corps work in coordination with local, state and federal resource agencies to identify beach habitat in immediate need of restoration and develop a schedule for recurring renourishment (based on engineering, monitoring, and adaptive management) events in lieu of one-time placement opportunities. We suggest the Corps adopt long term perpetual funding mechanisms for beach nourishment aimed at ensuring future ecosystem benefits to trust resources. The selection of suitable sediment sources is critical and must be dependent upon consistent grain size, color, and mineralogy, is the same quality as the existing beach sediments, and does not contain toxic materials. Beach and dunes should shall be designed and constructed to complement existing conditions or if necessary, constructed to meet historic elevations where the system was once resilient. All beach nourishment projects should include monitoring efforts specific to benthic organisms aimed at assessing impacts or benefits to threatened and endangered species that utilize beach habitat. The Corps should coordinate with state and federal natural resource agencies for site specific beach nourishment recommendations prior to conducting nourishment activities.

Gulf Coastal Prairies
Native grasslands and prairies, with their ecologically complex plant and animal communities, were important components of the landscape of early Texas. The Texas coast was once home to 6.5 million acres of extensive coastal prairies interspersed with a maze of marshes that serve as wildlife nursery and refuge for many wildlife species. Some estimate less than 1 percent of the coastal prairie ecosystem remains in relatively pristine condition and many migratory and grassland bird species utilize coastal prairie habitat for portions of their life cycle. Plants once thought common within coastal prairie habitat have disappeared due to conversion to agriculture, urban sprawl, residential and commercial development, as well as numerous transportation systems. Gulf coastal prairie is a relatively flat and treeless region with rich productive soils suitable for rice production and cattle grazing increases water infiltration and water yield, increases water supply by reducing erosion and reservoir sedimentation, and increases water quality due to the lack of fertilizer, pesticide, and herbicide use. Prairie provide rare native habitat for birds, butterflies, insects, reptile, and other small wildlife and usually are composed of plants seldom found in other habitats. Many tall grass prairie bird populations such as the federally listed Atwater's prairie chicken *Tympanuchus cupido attwateri*, whooping crane, aplomado falcon *Falco femoralis*, and state listed white-tailed hawk *Geranoaetus albicaudatus* were once common on the prairie landscape but are now in decline due to current land practices such as conversion to agriculture, commercial and residential development, and oil and gas exploration. The resulting landscape is fragmented, degraded, and fraught with invasive species.

Historically, once one of the most abundant resident birds of Texas and Louisiana tall grass prairie ecosystems, the critically endangered Atwater's prairie chicken remain on the coastal prairie with only two wild populations (a total of 52 males were counted as part of the annual census). Presently, less than 200,000 fragmented acres of coastal prairie persist, leaving the birds scattered among two Texas counties. The Service's Attwater's Prairie Chicken National Wildlife Refuge is managed specifically for Attwater's prairie chicken; however, recovery activities stretch far beyond the refuge's boundaries. Pressure from coastal development, habitat fragmentation, climate change, predators, and the prolific spread of fire ants negatively affects this imperiled bird. Captive zoo and federal facility rearing programs located across the state show some promise and the Service continues to diligently work with partners to recover this species and acquire coastal prairie habitat.

The endangered aplomado falcon is a medium sized raptor 15 to 18 inches in length, a wingspan of 32 to 36 inches, and is a permanent resident in Texas. Unfortunately, aplomado falcon's numbers were reduced to zero in the United States during the 1930s with small numbers scattered throughout Mexico. Sound recovery efforts along with habitat management strategies allowed the aplomado falcon to become a permanent resident on south Texas coastal prairies, savannahs, marshes and tidal flats, and open grasslands with scattered trees. Release of captive reared birds into the wild and the installation of nest boxes have increased nesting success in South Texas resulting in a stable to increasing population at the present.

Recommendations
The Corps does not readily recognize this habitat type as one to be included within the purview of this study. The Service disagrees and recommends full consideration for the preservation, restoration, and acquisition of remaining coastal prairie habitats benefiting nationally recognized and recreationally important wildlife species. Prairies, in general, provide excellent stopover resting and feeding habitat for migratory birds. Supporting coastal prairie and grasslands through large scale preservation and restoration will sustain threatened grassland birds and wildlife species while improving watershed quality. The Service can work with the Corps to identify parcels for permanent conservation status aimed at reducing landscape fragmentation and enhancing current restoration efforts.

Bottomland Hardwood Forests
Harwood bottomland forests are some of the most widely distributed, biologically diverse, and productive of tree-dominated communities throughout southern regions of North America (Rosiere, Nelson, & Cowley, 2013). Bottomland hardwood forests, spanning over one million acres, are one of the most biologically productive ecosystems along the Texas Gulf Coast from Mexico to Louisiana. These riverine forested habitats play a significant role in the migration of millions of birds across Texas while maintaining river water quality, controlling sediments, and filtering pollutants (Kellison & Young, 1997). Further, these forests increase the quantity and quality of groundwater recharge, retard flood flows, and minimize erosion by providing dense root systems to bind soil material. More than 85 percent of the historical bottomland hardwood forests in Texas were lost (Texas Conservation Alliance) to development.

Bottomland hardwood forests occur within the floodplains of rivers and streams that cross the middle and upper coastal plains in Texas. The Sabine, Neches, Trinity, and Brazos Rivers have broad floodplains that support extensive forested wetlands. Most upper coast bottomland hardwood forests are dominated by willow oak *Quercus phellos*, water oak *Quercus nigra*, overcup oak *Quercus lyrata*, cherry bark oak *Quercus pagoda*, laurel oak *Quercus laurifolia*, green ash *Fraxinus pennsylvanica*, red maple *Acer rubrum*, black willow *Salix nigra*, and water tupelo *Nyssa aquatica*. The mid-coast forests typically exhibit pecan *Carya illinoinensis* , water hickory *Carya aquatica*, American elm *Ulmus americana* , cedar elm *Ulmus crassifolia*, water oak, live oak *Quercus virginiana*, green ash, hackberry *Celtis laevigata* , sycamore *Plantanus occidentalis* and a robust list of understory vegetation are similar along the entire coast. Old-growth examples of this habitat type are very rare. Large tracts of bottomland hardwood forest remain but most are either second or third growth stands.

The Columbia Bottomlands historically covered over 699,300 acres long the Brazos, Colorado, and San Bernard Rivers, but has since been reduced to 25 percent of its former extent (177,900 acres), remains highly fragmented, are threatened by residential and commercial development, agricultural conversion, timber removal, and infestation by invasive plants. The ecological importance, productivity, and diversity of these forests are well documented. Bottomland forests provide temporary or permanent residence as well as critical stopover and staging habitat for Neacrtic-Neoptropical migratory landbirds, and are consistently used year to year though migration patterns can shift. The diversity of the Columbia

Bottomlands is well documented and known to support upwards of 239 million birds representing 237 species. These birds migrate through, overwinter or are found to breed in the Columbia Bottomland forests. Because of the critical significance of bottomland hardwood forests to avian ecology, the Service authored the Columbia Bottomlands Conservation Plan (U.S. Fish and Wildlife Service, 1997) with two objectives: 1) to illustrate strategies that combine federal habitat protection efforts with conservation efforts of local communities and 2) to describe vegetation characteristics of a mature Columbia Bottomlands forest remnant as a formative step in guiding the evaluation, acquisition, and management of other protected tracks. The accelerating loss of habitat, particularly large stands with mature composition and structure, heightened the need to move forward with the plan's outlined protection measures.

Similarly to Columbia bottomland forests, east Texas bottomland hardwoods (from Galveston to Sabine) are much the same in terms of threats, diversity, and structure. They support distinct assemblages of plants and animals associated with particular landforms, hydric soils, and hydrologic regimes and are generally higher, intermittently-flooded strips of land immediately adjacent to the riverine ridge and to meander lakes (oxbows) are often forested by mature bottomland hardwood forest. The largest tracts are at the extreme upper end of the study area, just south of the Neches River saltwater barrier and along the Sabine River north of I-10, within Sabine Wildlife Management Area. Agriculture and silviculture are the major continuing threats on these forested wetlands leading to deforestation and altered hydrology. Restoration efforts are ongoing across Texas and Louisiana in an attempt to reconnect fragmented forest blocks and restore wetland forest functions.

Recommendations
Due to the rarity and ecological significance of the coastal bottomland forests and forested wetlands in general, the Service deemed this habitat a "focus area" for preservation, restoration, and research. We recommends the acquisition of lands adjacent to previously purchased and protected lands that increase the conservation footprint for bottomland hardwoods along the Texas coast. Once the properties have been acquired and placed in perpetual conservation easements, we recommend the Corps develop long-term funding mechanisms to ensure ecosystem benefits for fish and wildlife into the future. Finally, we recommend the Corps develop comprehensive restoration and management plans for the property identifying opportunities for invasive species removal, burning, woody and shrub species propagation, comprehensive species list, and identification of additional tracts of land to compliment acquisition efforts by the Service and other partners for the benefit of resident and migratory birds and wildlife. The Service looks forward to working with the Corps and other partners to identify suitable coastal prairie tracts for restoration and purchase.

Gulf Intracoastal Water Way Shoreline Protection and Sediment Transport
Texas navigable waterways once designed to support only local vessel traffic are now exploited for national and international commerce utilizing increasingly larger vessels. Increases in vessel size and frequency create greater tidal surges resulting in shoreline creep, widening canals, saltwater intrusion into freshwater marsh, and erosion of public and private lands bordering the waterways. The Texas portion of the Gulf Intercoastal Water Way (GIWW) is over 50 years old and 423 miles long, is an essential component of the state's and nation's transportation network, and continues to operate with the goal to provide safe, efficient and effective means for the movement of people and goods throughout the state. The Texas portion of the GIWW supports five of the top 33 leading ports in 2016 with combined domestic and foreign tonnage of 524.5 million. In 2016, Texas ranked second in the nation in total waterborne tonnage transported with 496.67 million tons of the total maritime freight volume on both deep and shallow draft waterways (USACE, 2016). However the total tonnage for the entire GIWW was 111.7 million tons in 2016, down 6.1 percent from 188.9 million tons in 2015. While these shipping volumes are impressive and necessary to sustain a growing national economy, many within the

environmental community have concerns over the degradation of the GIWW shoreline and adjacent lands and that current waterway conditions warrant additional shoreline protection. Authorized at 125 feet wide and 12 feet deep, some stretches of the GIWW are now over 600 feet wide.

Despite the economic gains to many local communities, the GIWW, serves as a conduit for transporting sediments, is a barrier to freshwater inflows from north to south, and continues to degrade the hydrological regimes of adjacent wetlands by eroding existing shorelines. Historic hydrologic sheet flows across the landscape are compromised often resulting in trapping or ponding of freshwater north and increased salinities in wetlands south of the GIWW. The Service continues to advocate for shoreline protection along the entire GIWW protecting state, private, and federal lands.

The Beneficial Use (BU) of dredged material, whether used as thin layer placement on wetlands, marsh creation, seagrass bed enhancement, or bird island creation, is critically important to coastal aquatic ecosystems. Most sediment located within the GIWW is composed of fine silts and does not lend itself well to stacking. However, this material is suitable for thin layer placement on adjacent private, state, and federal lands where wetland conversion, degradation, and subsidence are common. Stiffer clays stack better and are consistent with levee and island building. The Corps typically beneficially uses between 15-20 percent of the dredged material for the entire state and the Service strongly recommends the Corps adopt a stronger BU policy where at least 50 percent of dredged material is beneficially used. The Service can provide technical support for BU marsh and island creation throughout the coastal bay systems.

Recommendations
Shoreline stabilization and protection of lands adjacent to the GIWW continues to be of great concern for the Service. We recommend the Corps work with resource agencies, non-governmental organizations, and private landowners to develop a GIWW wide shoreline stabilization plan with dedicated funding to protect adjacent wetlands. The Service recommends the development of a comprehensive state wide sediment management plan to address sediment transport throughout the state's coastal rivers and bay systems. We expect this plan will address the GIWW as this waterway remains a major conduit for fluvial sediment transport during normal flows and severe flooding events. Preferred options for the placement of dredged material, emergency dredge disposal, beneficial use opportunities, understanding the fate of sediment-bound pollutants in our waterways, analysis of how channels change during flood events, hazard and debris removal, climate change/sea level rise, and the effect on sediment accumulation and transport also should be discussion topics in the plan. We also recommend the Corps analyzes landscape flows for a variety of flood events, identify restrictive barriers, and identify ways to provide safe alternatives for river flooding. The Service recommends the Corps develop a "tool box" with a variety of hard and non-structural technologies aimed at protecting the entire Texas GIWW shoreline. The Service can assist the Corps with identification of suitable protection measures and BU opportunities along the GIWW as some adjacent areas remain environmentally sensitive.

Wetland Preservation
All marsh habitats along the Texas coast serve as breeding, feeding, and nesting, habitat for a diverse range of fish and wildlife species. Many nationally important commercial and recreational fish and wildlife species spend portions of their life cycle within marsh habitats. As a result of agricultural practices, oil and gas exploration, and commercial development, marsh habitat has been drained or filled resulting in low quality and fragmented habitats. Recent efforts to protect, create, and restore marsh along the Texas coast have been successful; however, additional protection and preservation measures are needed. Wetland types found in coastal watersheds include saltwater marshes, bottomland hardwood swamps, freshwater wetlands, mangrove swamps, shrubby depressions, and prairie potholes. Much of the

Texas coast is dominated by intermediate, brackish, or saline wetlands while fresh water wetlands are either impounded and are usually found further inland. Coastal emergent wetlands provide important transitional habitat between the gulf waters and lands protecting against storm surge, act to slow wave velocity, combat sea level rise, and have a tremendous ecological and economic value.

Both freshwater swamp and freshwater marsh, often occurring in intermeshing context within large wetland tracts, occur in abundance within the northern upper Texas coast. Primary swamp type is cypress-tupelo swamp, which is characterized by common baldcypress *Taxodium distichum* and tupelo gum *Nyssa aquatica* overstory, and numerous aquatic understory species such as bulltongue *Sagittaria lancifolia*, swamp lily *Crinum americanum*, pickerel weed *Pontederia cordata*, smartweed *Polygonum sp.*, and blue iris *Iris sp.* Large tracts of cypress-tupelo swamp occur in permanently and semi-permanently flooded areas along the Neches River north of Interstate (I-) 10 and along the Sabine River north of I-10.

Swamp scrub and freshwater marsh are often intermixed within cypress-tupelo tracts, either in natural meander scars or in areas completely logged in the past which have not reforested. Primary plant species here are buttonbush *Cephalanthus occidentalis*, rattlebean *Sesbania drummondii*, box elder *Acer negundo*, swamp privet *Foresteria acuminata*, cattail *Typha latifolia*, and Virginia tea *Itea virginica.* Preserving and restoration of freshwater marsh/scrub shrub habitat, although cypress-tupelo swamp should be the long term goal along the upper Texas coast due to its high productivity and recreational value to wetland users, primarily waterfowl hunters, fishermen, and birdwatchers should be a principal concern for this study.

Intermediate marsh covers much of the study area and is characterized as marsh type is located between brackish and fresh marsh with salinity averages about 3.3 ppt. Intermediate marsh has an irregular tidal regime, is oligohaline, and is dominated by narrow-leaved, persistent species such as marshhay cordgrass (*Spartina patens*). Plant diversity and soil organic matter content is higher than in brackish or saline marshes. This marsh is characterized by a diversity of species, many of which are also found in freshwater and brackish marshes. Characteristic species include roseau cane *Phragmites australis*, bulltongue *Sagittaria lancifolia*, coastal water hyssop *Bacopa monnieri*, spikesedge *Eleocharis* spp., Olney's bulrush *Schoenoplectus americanus*, California bulrush *Schoenoplectus californicus*, American bulrush *Schoenoplectus pungens*, saltmarsh bulrush *Bulboschoenus robustus*, deer pea *Vigna luteola*, seashore paspalum *Paspalum vaginatum*, switch grass *Panicum virgatum*, bearded sprangletop *Leptochloa fascicularis*, camphor-weed *Pluchea camphorata*, Walter's millet *Echinochloa walteri*, fragrant flatsedge *Cyperus odoratus*, alligator weed *Alternanthera philoxeroides*, southern naiad *Najas guadalupe*nsis, big cordgrass *Spartina cynosuroides*, and gulf cordgrass *S. spartina*e. Two other major autotrophic groups in intermediate marsh are epiphytic and benthic algae. Intermediate marsh occupies the least acreage of any of the four marsh types. This marsh type is very productive of many species of wildlife and is important to larval and postlarval marine organisms such as shrimp sp., crabs *Callinectes* sp., Gulf menhaden *Brevoortia patronus*, etc. Hydrological changes to this marsh community may shift to either fresh or brackish marsh if salinities rise or fall due to weather events such as droughts, excessive rainfall, or influxes of sea water.

Brackish marsh occurs in areas located between the high-salinity saline marshes near the Gulf of Mexico and the intermediate areas further removed from the Gulf. Brackish marsh is generally considered "slightly salty"; with salinity levels varying over a wide range from location to location. In coastal Texas, the typical brackish marsh vegetation pattern occurs in areas within approximately the 4 to 15 ppt normal salinity range. Common, usually dominant, vegetation in these areas is saltmarsh bulrush *Bulboschoenus robustus*, seashore saltgrass *Distichlis spicata*, marshhay cordgrass *Spartina patens*, dwarf spikerush

Eleocharis parvula, waterhemp *Amaranthus australis*, and marsh pea *Vigna luteola*. Brackish marsh areas have cyclically high waterfowl populations, especially in years following high-salinity events when freshwater levels return to normal and periodic "blooms" of prime food plants such as widgeongrass *Ruppia maritima* and *Paspalum* sp. occur. Furbearers such as muskrat *Ondatra zibethicus*, formerly an important commercially-harvested animal in portions of the study area, also occur in cyclically high numbers. Brackish marshes have suffered some of the highest rates of marsh loss due to subsidence and loss of organic materials as formerly fresh areas are subjected to salinity intrusion, resulting in plant loss.

Salt marsh is formed when salt-tolerant plants take root on mud flats around edges of bays, usually slowing the flow of water during high tides, allow sediment to settle out, an raises elevation for plant life to continue. Plants in the salt marsh are usually dominated by smooth cordgrass *Spartina alterniflora*, seashore saltgrass, blackrush *Juncus romerianus*, saltmarsh aster *Aster tenuifolius*, and glasswort *Salicornia* sp. Gulf coastal salt marshes are often almost exclusively smooth cordgrass-dominated and comprise important marine nursery habitat, probably due to its ready access to estuaries, though wildlife populations are less diverse than in nearby intermediate and freshwater marshes. However Gulf coast coastal marsh habitat southward from the Coastal Bend area comprises mainly black mangrove *Avicennia germinans* interspersed with smooth cordgrass.

Texas NWRs many established to conserving wetland habitats specifically for the benefit of migratory waterfowl contain coastal marshes that provide wintering habitat for hundreds of thousands of geese and ducks and provide critical landfall sites in the spring for neotropical migratory birds. Wetland hydrologic connectivity remains a challenge across the coastal landscape as much of the region was transformed as a result of agricultural practices, navigation, development, and industry. Reestablishing hydrologic connectivity among wetlands remains a focus for the Service.

Recommendations

The Service supports the creation, preservation, and restoration of wetlands along the Texas coast to include coastal and inland marsh habitats. Much of the coastal landscape is altered in large part due to commercial, industrial, and residential development. Restoring hydrological flows by removing barriers specific to tidal exchange, impoundments, and levees will improve aquatic function, promote fish and wildlife dispersal, and aid in providing improved sediment and water quality on the larger landscape. Large tracts of coastal and inland marsh benefit the endangered whooping crane and other aquatic and terrestrial wildlife species; while providing improved water quality and protection from storm surge events. The Service, in conjunction with the other federal, state, and local natural resource agencies, can assist with priority wetland tract identification that benefits migratory fish and wildlife.

Seagrass Beds

One of the most biologically productive, recreationally and economically valuable habitats, seagrass beds provide feeding and nursery habitat for waterfowl, fish, shrimp, crabs and other economically important estuarine species (U.S. Fish and Wildlife Service) as well as sea turtles, manatees, and countless invertebrates that are produced within, or migrate to seagrasses. Seagrass helps to dampen the effects of strong currents, prevent erosion, enhance water clarity, provide protection to fish and invertebrates, and prevent scouring of bay bottom areas. Sea grasses are usually found in calm, shallow gulf waters where higher salinities, light, and nutrients are plentiful. Excessive freshwater inflows into a bay system can decrease salinities to near brackish conditions, and depending on the duration of the fresh conditions, some seagrass species are not physiologically capable of tolerating these extreme conditions and may die and areas recolonized with less favored species.

The majority of Texas seagrass meadows occur along the middle and lower Texas coast where waters are warm, clear, and have higher salinities. Almost 80 percent of the remaining seagrass habitat in Texas is located in the Laguna Madre System and however abundant, this resource remains threatened. The Laguna Madre is the only hyper-saline coastal lagoon in North America, one of only five in the world. These seagrass beds are the winter home to 80 percent (as many as 700,000 individuals) of the continental population of redhead ducks and are now confined to wintering areas on the Gulf of Mexico due to declining abundance of seagrasses along the Atlantic Coast. Ducks Unlimited, (2017) estimates the decline of shoalgrass, the preferred forage of redheads, is more than 40 percent in the Laguna Madre since 1965 and can be linked to decreasing salinities and navigation projects. 1950's aerial photographs indicate seagrasses once present in the Galveston Bay system, ranged from 2,500 to 5,000 acres, and were completely eliminated by 1989. Restoration efforts by transplanting and seed broadcasting in portions of West Galveston Bay have been successful and seagrasses are slowly spreading on the upper Texas coast. Biotic and abiotic threats to seagrasses such as storms, excessive grazing by herbivores, disease, and anthropogenic threats due to point and non-point sources of pollution, decreasing water clarity, excessive nutrient runoff, sedimentation, sea level rise, and prop scarring negatively affect these diverse communities coast wide.

Conservation and protection of sea grass is the best and first approach for this vital resource, however restoration efforts to benefit seagrasses have had some success along the Texas coast. The Service along with other federal, state, and local partners work cooperatively to restore seagrass meadows along the coast utilizing a combination of hand planting and specially designed boats which rapidly injects nutrients, plant growth hormones and sprigs of seagrass in the bottom substrate, and by hand-planting seagrasses. Although restoration efforts are underway, continued damage from prop scaring, anchors, and ill-timed dredge material deposition threaten coastal seagrass beds all along the coast.

Recommendations

The Service recommends the Corps work in coordination with the federal, state, and local resource agencies to develop an interagency team focused on small and large scale seagrass monitoring and restoration along the entire Texas coast as well as dedicating funding for seagrass research. The Service recognizes the Corps' need to dispose of dredge maintenance material and remains committed to working with the Corps to monitor and address seagrass issues related to on-going maintenance dredging work. We expect any future Corps dredging actions including but not limited to, beneficial use of dredge material and open water placement will fully consider effects to seagrasses and will include coordination with the aforementioned interagency team. Finally, the Service continues to recommend a combined approach of outreach, education, and improved signage within channels and marinas aimed to avoid and reduce impacts to seagrass beds. As part of the outreach effort, the Service recommends the Corps develop and permanently fund a website dedicated to the status, monitoring, and research of seagrasses along the Texas coast.

Tamaulipan Thornscrub Habitat

Tamaulipan thornscrub has a unique richness of flora and fauna not found in other ecosystems and is attributed to improved hunting experiences in South Texas (Erwing & Best, 2004). The presence of rare communities combined with the area's rich diversity of bird and butterfly species make South Texas one of the state's most popular nature tourism destinations. Private wildlife sanctuaries (such as those purchased and managed by The Nature Conservancy and others) provide protection for wildlife and help create much needed migratory corridors aimed at connecting tamaulipan thornscrub habitats. Land clearing for ranching, agriculture and urbanization resulted in the loss of more than 95 percent of the wildlife habitat in the Lower Rio Grande Valley of Texas. While ranching and agriculture traditionally have been the dominant industries in the Lower Rio Grande Valley area, landowners increasingly turn to alternative land uses; and as a result, landowners are more interested in developing wildlife based habitats and activities. The diverse habitat of the lower Rio Grande Valley combined with the Valley's location within the Central Flyway, more than 500 bird species have been recorded in the area. A diverse avifuana presence on the LRGNWR makes it a key birding destination where over 354 bird species can be seen. The dense scrub habitat

The Service established the Lower Rio Grande Valley National Wildlife Refuge (LRGNWR) to specifically acquire, manage, and restore tamaulipan thornscrub habitat creating a wildlife corridor stretching from Falcon Dam on the Rio Grande to the Gulf of Mexico (approximately 140 miles) (Erwing & Best, 2004). This wildlife corridor aims to benefit wildlife species including the ocelot *Leopardu pardalis,* jaguarundi *Puma yagouaroundi*, Texas tortoise *Gopherus berlandieri*, northern aplomado falcon *Falco femoralis septentrionalis*, Brownsville common yellowthroat *Geothlypis trichas insperata*, Lomita Carolina wren *Thryothorus ludovicianus* , southern yellow bat *Lasiurus ega* , speckled racer *Drymobius margaritiferus* , black-spotted newt *Notophthalmus meridionalis*, Mexican white-lipped frog *Leptodactylus fragilis* , and the Rio Grande lesser siren *Siren intermedia.*

Current population estimates for the ocelots in South Texas is fewer than 60 individuals with a total of 100 remaining in the United States where the gene pool exchange remains limited. Habitat loss, fragmentation, and vehicular collisions are common and contribute to overall population decreases. The Service continues to work with private landowners and other federal, state, and local agencies to acquire, secure easements, and provide technical assistance to restore tamaulipan thornscrub habitat in this area.

While the endangered jaguarundi have historically occurred in southeast Arizona, South Texas, Mexico and Central and South America as far south as northern Argentina, biologists today believe the cat still occurs throughout most of the range except in Arizona; however, the population status is unknown and presumably smaller than the ocelot because confirmed sightings are rare. In South Texas, jaguarundi are known to occur (last verified siting in mid-1990s) in only Cameron and Willacy counties where they prefer dense mixed brush with dry washes, arroyos, resacas, and the floodplains of the Rio Grande. Unfortunately, loss of habitat to agriculture production remains the main threat to the jaguarundi. The Service supports the acquisition of property aimed at preserving thornscrub habitat which furthers the Service's Recovery Plan's (U.S. Fish and Wildlife Service, 2013) effort to create a wildlife corridor for terrestrial species negatively impacted by thornscrub clearing.

Recommendations

Tamaulipan thornscrub is not a recognized habitat within the Texas Coastal Study. The Service considers this a rare habitat unlike any other region of the United States due to the combination of climate, vegetation, and associated wildlife. We remain committed to the preservation of thornscrub habitat and recommend the Corps coordinate with other federal, state, and local natural resource agencies to identify suitable tracts of land for acquisition or placement into conservation status. This action will promote the status of key wildlife species; improve wildlife corridors and the overall health of tamaulipan thornscrub ecosystems in south Texas.

Research and Monitoring Needs

To ensure a bright future for fish and wildlife in the face of widespread threats such as drought, climate change and large-scale habitat fragmentation, we can no longer base our actions solely on past experiences and success. Conserving these large landscapes which are subject to multiple changing pressures and uncertainties will require application of the best available science at every step. Because management of natural systems is not always predictable, having specific and measurable biological objectives that summarize the existing scientific knowledge and present testable hypotheses is essential for effective restoration planning.

The Service relies on informed decision making where gathering and improving knowledge is a reiterative process and necessary in understanding the stressors on coastal habitats and living marine resources of Texas and the larger ecosystems of the Gulf of Mexico. Stressors such as continued energy exploration, the procession of climate change, coastal developments, alterations in hydrology, industrial activities, fishing pressures, and many others continue to impact the system and can hinder its ability adapt and function at healthy levels.

Losses of these coastal habitats and living marine resources directly translate into diminished future resources available for coastal residents. The Service supports the research priorities identified under the Texas One Gulf draft Strategic Research and Action Plan (2017) which aim to maintain or increase biodiversity, defining "baseline" conditions, idenitfy stressors and pressures impacting the Gulf of Mexico, and understand connections between estuarine and coastal environments and the offshore and deeper Gulf of Mexico environments.

Recomendations
We encourage the Corps to consider recommending the study and analysis of specific coastal issues in the Study's Comprehensive Plan to compliment restoration project identification. The Service in combination with the other state and federal natural resource agencies can work with the Corps to identify gaps in research specific to coastal habitats. This approach will assure the greatest chance for future restoration success. Additionally, monitoring of natural resources after project construction is also recommended where project success will be defined by specific criteria prior to construction. The Service appreciates the opportunity to review and comment on the success criteria developed for each restoration site.

Service Priorities
Through this PAL, the Service outlined key habitats and research opportunities within the four regions of the Coastal Texas Study's boundaries. Specifically, the Service provided concerns and recommendations to conserve and protect these highlighted habitats: wetlands, oysters, bird islands, beach and dune habitat, coastal prairies, seagrasses, and tamaulipan thornscrub. Below is a list of high action coastal Texas priorities based on the Service's visions:

- Restore and conserve agricultural and working ranchlands that complement and support the connectivity of land, invasive species control and water conservation efforts in the Rio Grande area.
- Enhance the existing network of conservation lands linking the Rio Grande River Valley and the South Texas coastal ecosystem to ensure that fish and wildlife resources are sustainable.
- Reconnect hydrology and watershed diversions, such as the Bahia Grande, and restore wetlands and aquatic habitat for fish and other aquatic and wetland dependent species.
- Create a conservation network of lands through conservation easements or acquisition of grassland savanna and prairies, woodlands, and riparian areas in the Texas coastal bend region.
- Manage non-native species, reintroduce native plants, restore natural drainage features and use frequent prescribed fire to restore grassland savannas and prairies on former farmland and working ranchlands to enhance habitat for native plant pollinators.

- Support water-sharing efforts to provide freshwater input to coastal ecosystems that account for the needs of people and natural resources, including commercially significant fisheries and culturally important species like the whooping crane in the Coastal Bend area.
- Conservation, restoration, and continued management of native grassland prairie habitats are necessary to meet the life requisites of federally listed species and species of concern and continue to be a focus for the Service.
- Protect critical bottomland habitat adjacent to the Trinity, San Bernard, and Brazos Rivers that represent significant stopover destinations and staging areas for millions of songbirds and landbirds during their migration across the Gulf.
- Protect and restore coastal prairie in its historic upland and wetland complex on former rice cultivation fields to support pollinators, grasslands and wetland dependent species like the mottled duck and the bobwhite quail, as well as wintering waterfowl, water birds, and shorebirds.
- Restore hydrologic processes including watersheds and diversions (e.g., Salt Bayou project) to restore and enhance wetlands and aquatic habitats to enhance fisheries and habitat for wetland dependent species.
- Restore landscapes and interrupted sedimentary processes by incorporating beneficial use of dredged material, direct, dredging and erosion protection with willing public and private land managers.
- The Chenier Plain is best served by conserving coastal prairie landscapes by recovering historic pothole and mound complexes and re-introducing native prairie species on former agricultural (rice) lands to support pollinators, grassland and wetland dependent species like the mottled duck and bobwhite quail, and wintering waterfowl, waterbirds, and shorebirds.
- Success criteria, monitoring, and adaptive management should be incorporated in to all projects to ensure project success.

We appreciate the opportunity to identify and highlight key coastal habitats and the fish and wildlife that occur there. We look forward to working with the Corps and our partners in the future to identify to develop a list of specific research and restoration opportunities. Please contact staff biologist, Donna Anderson or myself at 281-286-8282 with any questions.

Sincerely,

Charles Ardizzone
Field Supervisor

cc: Rebecca Hensley, TPWD Dickinson
Rusty Swafford, NMFS Galveston
Dawn Gardiner, USFWS Corpus Christi
Barbara Keeler, EPA Dallas

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