US Army Corps
of Engineers ®
Galveston District

Appendix I

Ecological Modeling

for

Coastal Texas Protection and Restoration Feasibility Study

August 2021

Coastal Texas Protection and Ecosystem Restoration Feasibility Study

Ecological Modeling

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United States Army Corps of Engineers
Regional Planning and Environmental Center

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Acronyms and Abbreviations

°F	degrees Fahrenheit
AAHUs	Average Annual Habitat Units
BEG	Bureau of Economic Geology
C-CAP	Coastal Change Atlas Program
CE/ICA	Cost Effectiveness/Incremental Cost Analysis
Coastal Texas Study	Coastal Texas Protection and Restoration Study
CSRM	coastal storm risk management
DIFR-EIS	Draft Integrated Feasibility Report and Environmental Impact Statement
ER	ecosystem restoration
ESRI	Environmental Systems Research Institute
FIFR-EIS	Final Integrated Feasibility Report and Environmental Impact Statement
FWOP	Future-without Project
FWP	Future-with Project
GIS	Geographic Information System
GIWW	Gulf Intracoastal Waterway
GLO	Texas General Land Office
Gulf	Gulf of Mexico
HEAT	Habitat Evaluation and Assessment Tools
HEP	Habitat Evaluation Procedures
HSI	Habitat Suitability Index
HUs	habitat units
ICA	incremental cost analysis
LiDAR	Light Detection and Ranging
NAVD 88	North American Vertical Datum of 1988
NEPA	National Environmental Policy Act
NOAA	National Oceanographic and Atmospheric Administration
NRC	Natural Research Council
NWI	National Wetland Inventory
NWR	National Wildlife Refuge

ppt	parts per thousand
RSLC	relative sea level change
RSLR	relative sea level rise
SAV	submerged aquatic vegetation
SLR	sea level rise
TCEQ	Texas Commission on Environmental Quality
TPWD	Texas Parks and Wildlife Department
TY	target year
USACE	U.S. Army Corps of Engineers
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geologic Survey
V	habitat variable
WVA	Wetland Value Assessment

1.0 INTRODUCTION

This appendix provides documentation of the habitat evaluation and quantification process that was conducted to evaluate potential adverse and beneficial impacts to various habitat types if the recommended plan of the Coastal Texas Protection and Restoration Feasibility Study (Coastal Texas Study) is implemented. Quantification is needed in the project planning process to evaluate benefits or impacts of project features because traditional benefit/cost evaluation is not applicable when valuing habitat.

1.1 STUDY DESCRIPTION

The U.S. Army Corps of Engineers, Galveston District (USACE), in partnership with the Texas General Land Office, have undertaken the Coastal Texas Study, which is examining coastal storm risk management (CSRM) and ecosystem restoration (ER) opportunities within 18 counties of the Texas Gulf coast (

Figure 1). This Study seeks to develop a comprehensive plan along the Texas coast to mitigate coastal erosion, relative sea level rise (RSLR), coastal storm surge, habitat loss, and water quality degradation.

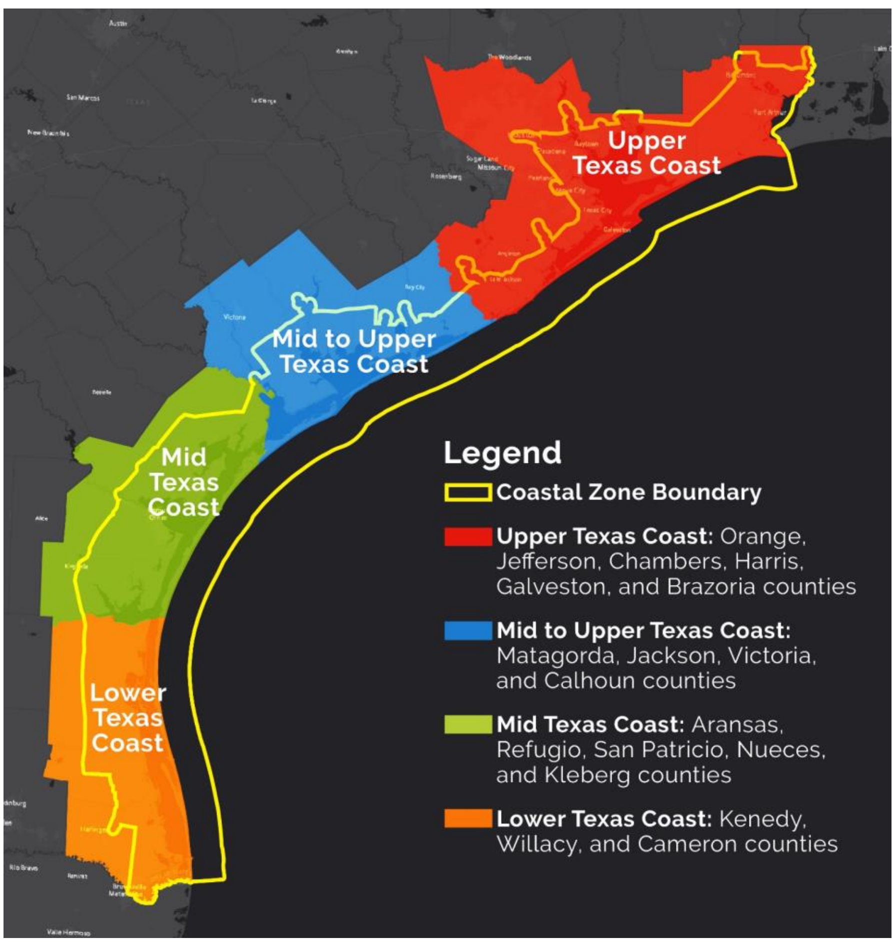

Figure 1. Coastal Texas Study Area

The Coastal Texas 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.

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 Environmental Impact Statement (EIS) as the basis for approving the entire project, the USACE 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 select 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, USACE will shift to a Tier Two assessment, which involves preparation of one or more additional NEPA documents [either an EIS or Environmental Assessment (EA)] that builds 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.

1.2 ALTERNATIVES CONSIDERED

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 of the proposed systems, 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 marshes, 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 concert with other measures considered, connect to existing systems, and be adaptable over time.

Three primary iterations occurred during the planning process, as follows:

- **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:** Refining the TSP, considering public, agency, and technical comments, in addition to further technical refinement, to identify the Recommended Plan.

1.2.1 Ecosystem Restoration

For ER, the study team assembled a wide variety of potential measures, drawn from the GLO's Coastal Resiliency Master Plan, past USACE studies, NEPA public scoping, and resource agency suggestions. During the conceptual phase of screening, the 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 (Figure 2). 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 restoration through the nourishment of 664 acres of eroding and degrading marshes 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: Follets Island Gulf Beach and Dune Restoration**
    - Restoration of 10.1 miles (1,113.8 acres) of beach and dune complex on Gulf shorelines of Follets Island in Brazoria County.

- **B-12: West Bay and Brazoria GIWW Shoreline Protection**
    - Shoreline protection and restoration through nourishment of 551 acres of eroding and degrading marshes and construction of about 40 miles breakwaters along unprotected segments of the GIWW in Brazoria County,
    - Construction of about 3.2 miles of rock breakwaters along western shorelines of West Bay and Cow Trap lakes, 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 restoration through the nourishment 236.5 acres of eroding and degrading marshes and construction of 12.4 miles of breakwaters along unprotected segments of the GIWW near Big Boggy National Wildlife Refuge (NWR) and eastward to the end of East Matagorda Bay,
    - Restoration of 96 acres (3.5 miles) of island 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 restoration through the nourishment of 529 acres of eroding and degrading marshes and construction of 5.0 miles of breakwaters along shorelines fronting portions of Indianola, the Powderhorn Lake estuary, and Texas Parks and Wildlife Department (TPWD) Powderhorn Ranch.

- **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 Brazos Santiago Pass and the Port Mansfield Channel 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 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 a n elevation of 7.5 feet (NAVD 88).

The remaining ER measures were combined into alternatives based upon specific planning objectives and strategies. These strategies generated six ER alternatives (Table 1), which include selected subsets of the measures in Alternatives 2 thorough 6, and all measures in Alternative 1 (Table 2).

Table 1. 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

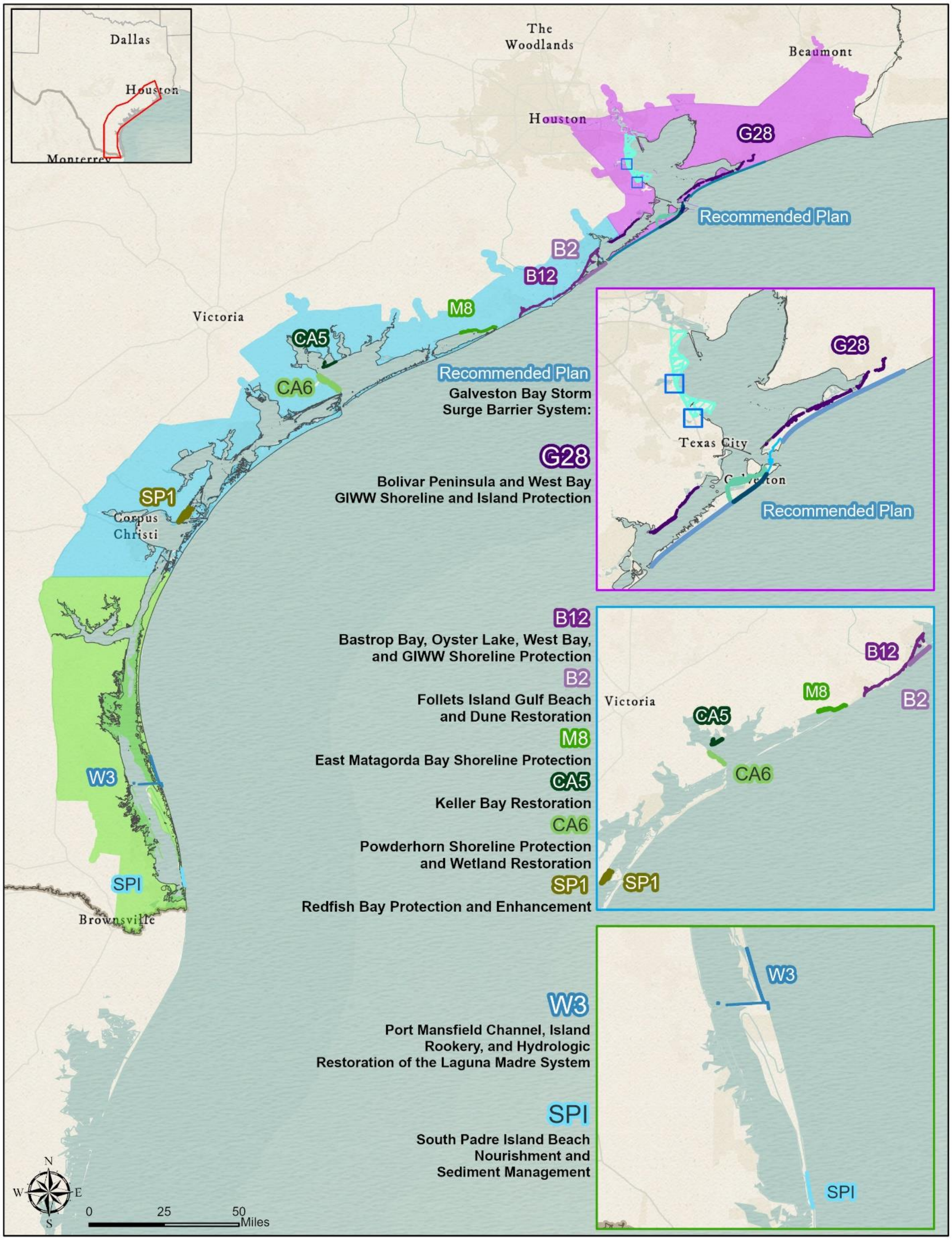

Figure 2. Recommended Plan with ER Measures that have been retained

Table 2. Measures in each ER Alternatives

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	●	●	●		●			

The final screening iteration to identify the National Ecosystem Restoration (NER) plan requires estimation of the ecological life, or benefits, between the future without- (FWOP) and future with-project (FWP) condition for each alternative in Average Annual Habitat Units (AAHUs). The modeling and results described in this appendix provide critical information needed to complete the cost-effective analysis that will ultimately help identify the cost effective and "Best Buy" plans from which a final recommended plan can be selected.

1.2.2 Coastal Storm Risk Management

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 Texas coast and the upper Texas Coast, after assessing need across the entire coast.

1.2.2.1 Lower Texas Coast

On the lower Texas coast, South Padre Island (SPI) is vulnerable to coastal storms and is included as a hydrologically separable CSRM feature. The region was included because of the City's dense concentration of structures and 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 12.5 ft (NAVD88) dune and

100-foot-wide berm from Reach 3 through 5 (Figure 2). The economic analysis confirms that beach nourishment is cost effective when considering construction costs and benefits, and recreation benefits, but may be infeasible due to the real estate costs to acquire easements for privately owned portions of the dune and beach.

1.2.2.2 Upper Texas Coast

On the upper Texas coast, the Galveston Bay system 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 features 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 gulfward land masses 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. The alternatives considered in the conceptual screening phase included:

- **Conceptual Alternative A – Coastal Barrier:** This alternative prevents storm surge from entering Galveston Bay with a levee system across Bolivar Peninsula and west Galveston Island and a closure at Bolivar Roads.

- **Conceptual Alternative B – Coastal Barrier:** This alternative is similar to Alternative A, but avoided the barrier islands and used existing landscape features such as the GIWW disposal dikes and the Texas City Dike as the tie-ins for the closure.

- **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 started on the east side of Galveston Bay near Smith Point, and continued across the bay, crossing the ship channel, and tying into the existing Texas City Levee System.

- **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.

- **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.

After comparing the relative performance of the alternatives and the potential cost or environmental impacts, Alternatives B and C were screened out since Alternative A provided comparable if not better performance in terms of reduced risk, with fewer negative impacts. Similarly, Alternative D1 was screened out since Alternative D2 provided better performance in terms of reduced risk, with fewer negative impacts.

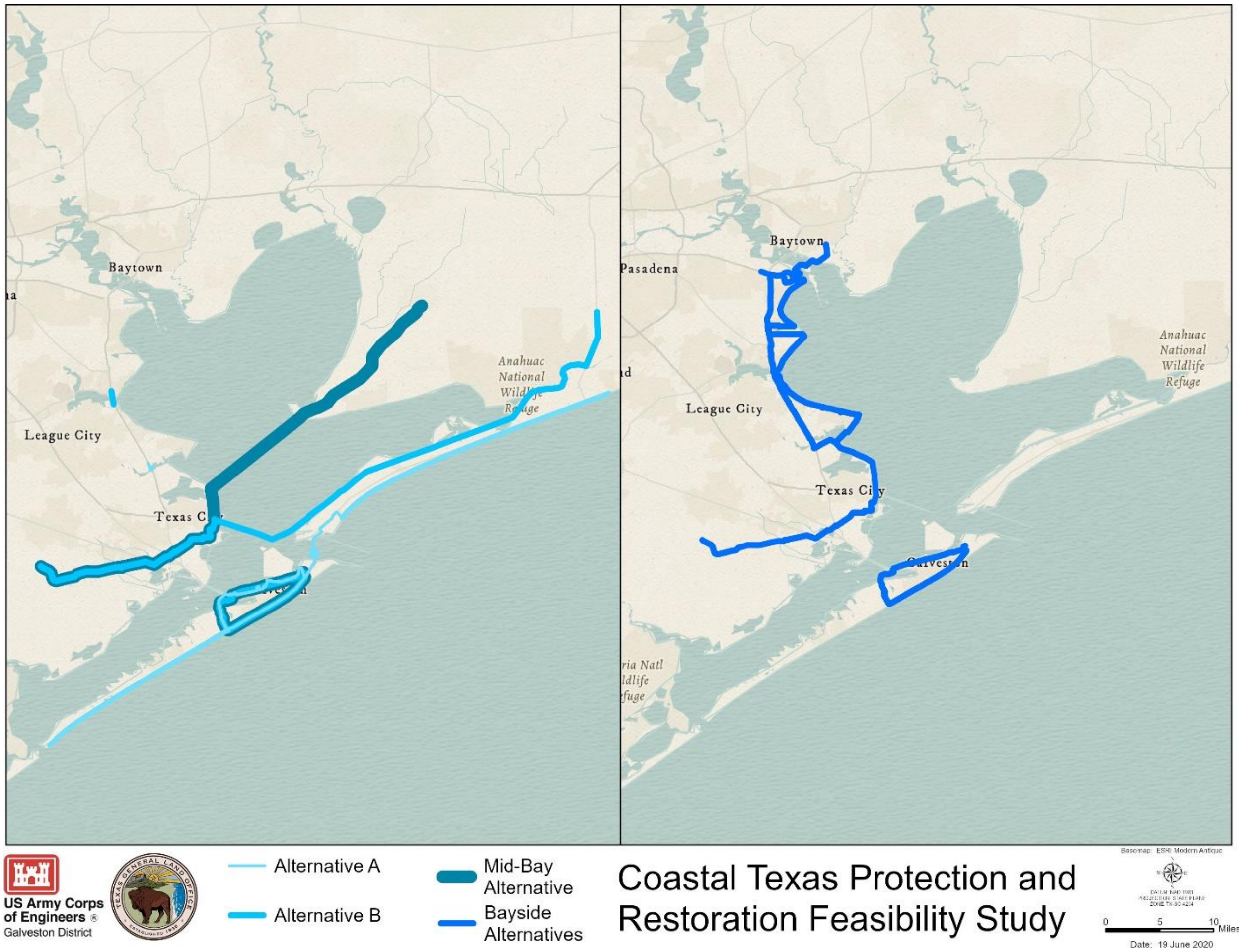

Figure 3. Comparison of Alternatives

The comparison of the gulfward Alternative A and interior Alternative D2 required standard benefit evaluation procedures for damage reduction (NED) 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. Both Alternative A and Alternative D2 included a ring barrier around the central portion of Galveston Island to protect against back-bay flooding.

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 takes a systems approach when reviewing the regions larger system context. The Gulfward alignment 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.

Figure 4 shows the spatial relationship between the Gulf and Bay lines of defense of Alternative A. Measures which make up Alternative A include:

- The Bolivar Roads Gate System, across the entrance to the Houston Ship Channel, between Bolivar Peninsula and Galveston Island (Figure 5);
- 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 (Figure 5);
- Improvements to the existing 10-mile Seawall on Galveston Island to complete the continuous line of defense against Gulf surge (Figure 5);
- 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;
- 2 surge gates on the west perimeter of Galveston Bay (at Clear Lake and Dickinson Bay) that reduce surge volumes that push into neighborhoods around the critical industrial facilities that line Galveston Bay; and
- Complementary non-structural measures, such as home elevations or floodproofing, to further reduce Bay-surge risks along the western perimeter of Galveston Bay.

Figure 4. Galveston Bay Storm Surge System

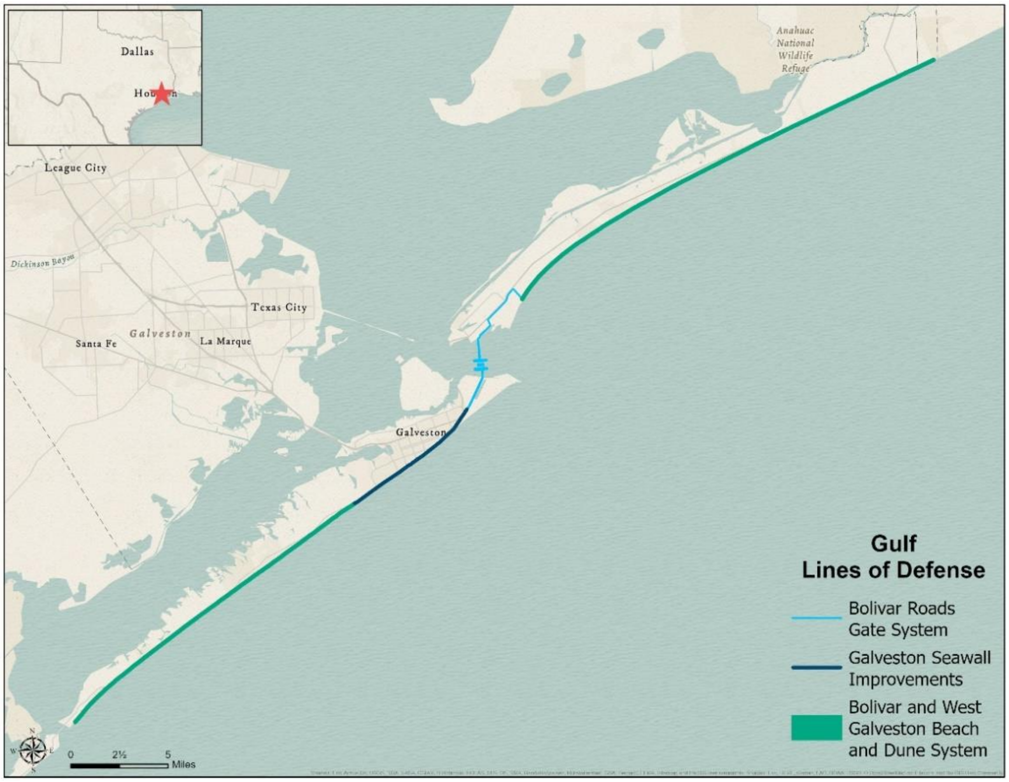

Figure 5. Gulf Lines of Defense of the Galveston Bay Storm Surge System

1.2.3 Mitigation Plan

Compensatory mitigation is required for unavoidable impacts to the environment that are caused by the recommended plan. No mitigation is 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.

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 shown in the previous section (i.e. net loss in AAHUs). Impacted habitat types are estuarine emergent wetland, palustrine emergent wetland, oyster reef and open bay bottom. 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 a mitigation site.

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. An interagency 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 using a suite of screening criteria to identify the final array. 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 6 and Table 3).

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.

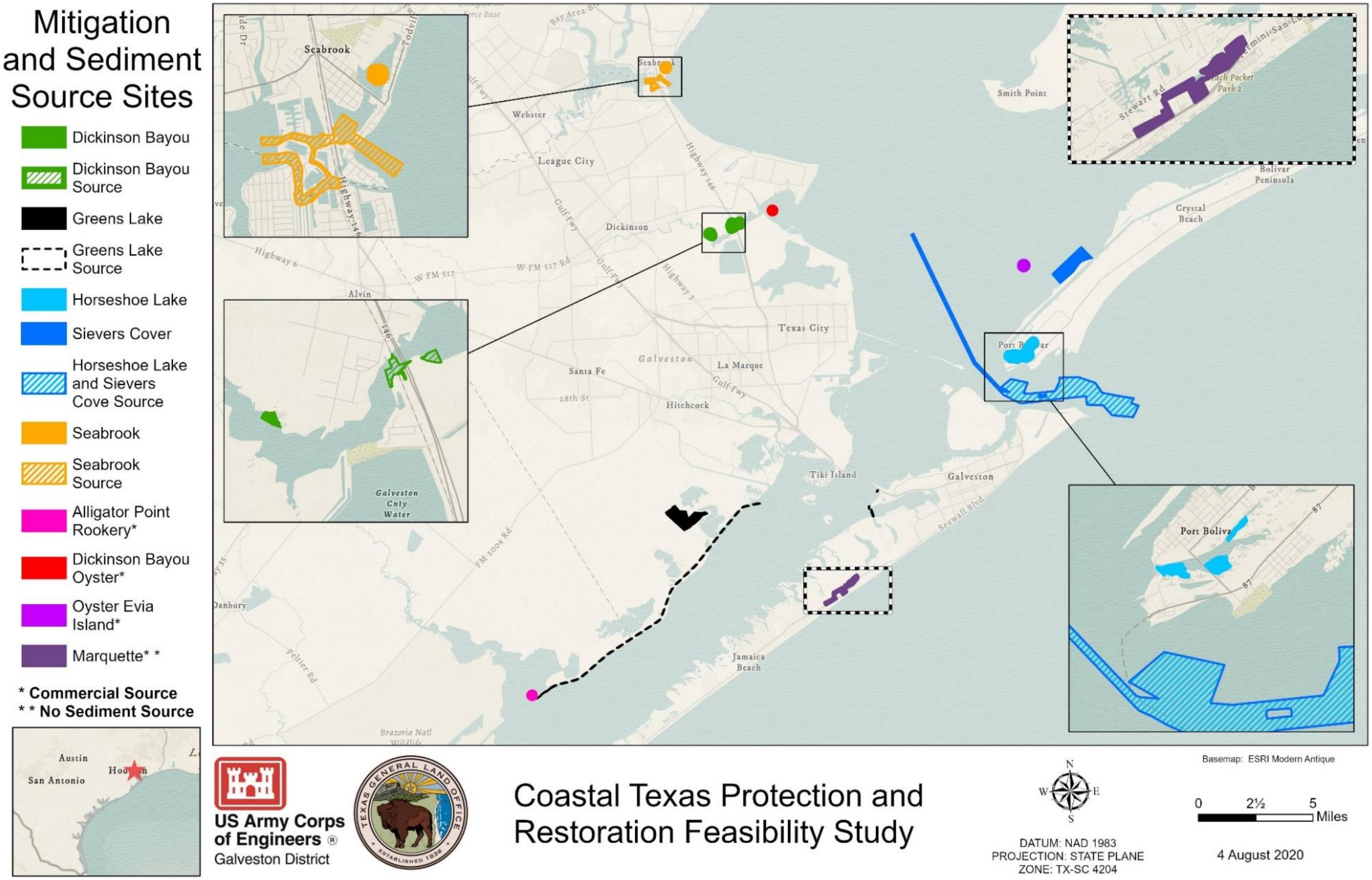

Figure 6. Potential Mitigation Sites

Table 3. Description of Mitigation Sites Being Considered

Mitigation Site	Description	Mitigating For	Acres
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)	667.0
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)	562.0
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)	1: 25.0 2: 27.0 3: 10.0 Total: 62.0
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)	4.0
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)	7.0
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 1-foot of the winter water table.	Galveston Island Ring Barrier (Direct Impacts)	161.8
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)	30.0
Dickinson Bayou	7 acres of oyster reef constructed in Dickinson Bay.	Dickinson Bayou Surge Gate (Direct Impact)	7.0
Alligator Point	10 acres of oyster reef constructed around the bird rookery at Alligator Island.	Open Bay Bottom from Ring Levee (Direct Impact)	10.0

1.3 ECOLOGICAL COMMUNITIES IN THE PROJECT AREAS

The Texas Gulf coast is highly complex and ecologically diverse, with obvious differences in geomorphology between the upper, mid, and lower coast. The project areas consist of marine, estuarine, and freshwater coastal environments including: tidal waters, barrier islands, estuaries, coastal wetlands, rivers and streams, and adjacent areas that make up the interrelated ecosystems along the coast of Texas.

1.3.1 Upper Texas Coast

Within the upper Texas coast (Sabine Lake to east Matagorda Bay), wetland systems are like southwestern Louisiana marshes, where the elevation gradients are gradual, freshwater inflows are relatively higher, and transitional salinity gradients with freshwater wetlands inland transitioning into brackish and intermediate marsh with the gradient ending in the tidal salt marshes within the bays (Moulton et al. 1997).

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 allows the region to support a wide variety of habitats, including tidal and freshwater coastal marshes; shallow bay waters, which support seagrass beds, tidal flats, and reef complexes; coastal prairie with small wetland depressions; and forested riparian corridors. Extensive oyster reef habitat occurs throughout the Galveston Bay complex. A barrier peninsula (Bolivar) and island (Galveston) separate Galveston Bay from the Gulf, while the remainder of the upper coast is bounded by barrier headlands such as the Freeport area.

G-28, B-12, M-8, and all components of the Upper Texas Coast CSRM Alternative A and mitigation plan would occur within the upper Texas coast regions and potentially impact tidal and freshwater coastal marshes, seagrass beds (submerged aquatic vegetation [SAV] habitats), oyster reefs, bird island rookeries, and beach and dune complexes.

1.3.2 Mid to Upper Texas Coast

Matagorda, Jackson, Victoria, and Calhoun counties occur in the mid to upper Texas coast and include several bay systems (Matagorda Bay, Lavaca Bay, Espiritu Santo Bay, and parts of San Antonio Bay). Primary watersheds feeding these bays include the Colorado, Lavaca, and Guadalupe rivers, which forms the boundary between the mid to upper coast; deltas of the Colorado and Guadalupe rivers also occur in the region. Matagorda Bay is the largest of the bay systems in the mid to upper coast and includes numerous minor estuaries.

Notable features of the mid to upper coast include Half Moon Reef (a historic oyster reef that was successfully restored and continues to undergo additional restoration actions), Mad Island Preserve and Mad Island Wildlife Management Area (WMA), Matagorda Island State Park, and several National Wildlife Refuges (NWR) (TNC, 2016a). 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 tidal and freshwater coastal marshes; shallow bay waters that support seagrass beds, tidal flats, and reef complexes; coastal prairie with small wetland depressions; and forested riparian corridors. Extensive seagrasses and mangroves occur in Espiritu Santo Bay, near Pass Cavallo, and seagrass is also relatively prevalent immediately behind

Matagorda Island and Matagorda Peninsula. Important large navigation channels in this region include the Matagorda Ship Channel and the Victoria Barge Canal.

CA-5 and CA-6 are the two ER measures that occur in this region. Both potentially impact tidally-influenced marshes, seagrass beds, and oyster reefs.

1.3.3 Mid Texas Coast

The mid Texas coast is also characterized by large bays and estuaries, with river inflows. However, unlike in the upper and mid to upper Texas coast regions, less freshwater inflow is experienced and the freshwater to salt marsh gradients is typically reduced relative to the upper coast areas. Additionally, coastal prairies become more dominant, with less forested wetlands than the two upper regions (Moulton et al., 1997).

The mid coast occurs within Aransas, Refugio, San Patricio, Nueces, and Kleberg counties, and includes several bay systems (Corpus Christi Bay, Copano Bay, Aransas Bay, Nueces Bay, portions of San Antonio 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 boundary between the mid to lower coast). This area includes the barriers of North Padre Island, San Jośe Island, Mustang Island, and portions of Matagorda Island. Padre Island National Seashore is owned and managed by the National Parks Service (NPS) and is the longest stretch of undeveloped barrier island in the world (NPS, 2016b). 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 hard reefs occur within Baffin Bay; these unique hard reefs were formed from either remnant beach rock, or fossilized serpulid worm reefs.

SP-1 is the only ER measure found in the mid Texas coast region. The measure has the potential to impact seagrass beds, oyster reefs and bird island rookeries.

1.3.4 Lower Texas Coast

The lower Texas coast is characterized by the Upper and Lower Laguna Madre, which is one of the few hypersaline lagoons in the world. High overall temperatures and evaporation rates, combined with low rainfall and freshwater input, drive the high salinity (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, averaging approximately 3.3 feet deep, and, including the South Bay and the Bahia Grande complex, contains approximately 180,000 acres of shallow flats (Tunnel and Judd, 2002). The main outlet into the Gulf for the southern reach of the Lower Laguna Madre is Brazos Santiago Pass, through which passes the deep-draft Brazos Island Harbor navigation channel.

Abundant tidal flats in this region provide important habitat for a variety of coastal wildlife from migratory waterfowl, shorebirds, wading birds, and other estuarine-dependent species like shrimp and various finfish (White et al., 1986). These 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 several locations worldwide, including the Persian Sea, Red Sea, and eastern Mediterranean Sea (Morton and Holmes, 2009).

W-3 is within the lower Texas coast region and could potentially impact SAV habitat, rookery islands, and beach and dune complex.

2.0 ECOLOGICAL MODELING

The USACE and its stakeholders used a suite of habitat models to evaluate the ecological impacts of proposed CSRM, ER, and mitigation measures. The models evaluate potential changes to the complex ecosystem processes and patterns operating at the local, regional, and landscape levels across the Texas coast. To summarize the overall process, the following steps were completed in the assessment of the study's proposed ER, CSRM, and mitigation designs:

- Building a multidisciplinary evaluation team.
- Defining the proposed ER and CSRM measures.
- Setting goals and objectives and defining a project life and target years.
- Selecting ecological models to evaluate ecological impacts.
- Calculating baseline conditions and forecasting Future-without Project (FWOP) and Future-with Project (FWP) conditions.
- Reporting the results of the analyses.

2.1 HABITAT EVALUATION PROCEDURES (HEP)

Before any impacts can be identified, a baseline assessment using the Habitat Evaluation Procedure (HEP) was required. HEP involves 1) defining the study area, 2) delineating habitats (i.e. cover types) within the study area, 3) selecting HEP models and/or evaluation species; and 4) characterizing the study area based on the results of the HEP.

HEP was developed by the US Fish and Wildlife Service (USFWS) in order to quantify the impacts of habitat changes resulting from land or water development projects (USFWS 1980). HEP is based on suitability models that provide a quantitative description of the habitat requirements for a species or group of species. HEP models use measurements of appropriate variables to rate the habitat on a scale from 0.0 (unsuitable) to 1.0 (optimal).

Habitat quality is estimated through the use of species models developed specifically for each habitat type(s). Each model consists of a 1) list of variables that are considered important in characterizing fish and wildlife habitat, 2) a Suitability Index graph for each variable, which defines the assumed relationship between habitat quality and different variable values, and 3) a mathematical formula that combines the Suitability Index for each variable into a single value for habitat quality. The single value is referred to as the Habitat Suitability Index (HSI).

The Suitability Index graph is a graphic representation of how fish and wildlife habitat quality or "suitability" of a given habitat type is predicted to change as values of the given variable change. It also allows the model user to numerically describe, though the Suitability Index, the habitat quality of an area for any variable value. The Suitability Index ranges from 0.1 to 1.0, with 1.0 representing optimal condition for the variable in question.

After a Suitability Index has been developed, a mathematical formula that combines all Suitability Indices into a single HSI value is constructed. Because the Suitability Indices range from 0.1 to 1.0 the HSI also ranges from 0.1 to 1.0 and is a numerical representation of the overall or "composite" habitat quality of the particular habitat being evaluated. The HSI formula defines the aggregation of Suitability Indices in a manner that is unique to each species depending on how the formula is constructed.

2.1.1 Species Model Selection

An Interagency Team made up of state and federal natural resource agencies selected the HEP models to be used for this study. The team reviewed all USACE-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 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 which was certified for one-time use in April 2021. The ECO-PCX and the resource agencies support use of these models.

Detailed methodologies regarding cover types, cover type mapping, and assumptions made for the applications of the HSI models are presented in Section 3.0. 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 wetland and marsh. The HSI model variables were determined to be sensitive and responsive to marsh and wetland habitat restoration, and the model assumptions are consistent with USACE policy for habitat restoration.

- **American Alligator** (Newsom et al., 1987) – American alligator was selected to capture impacts to non-tidal palustrine wetland and marsh 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 wetland and marsh 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 USACE 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 USACE 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 through the ECO-PCX certification process for one-time use.

2.2 DATA COLLECTION

A judgment-based method, supported by the scientific and professional expertise of the interagency team, was used to forecast the changes in the natural ecosystems and evaluate the effectiveness of the proposed alternative scenarios, rate project performance, and determine many other important aspects of the FWOP and FWP conditions.

A series of workshops were held with the interagency team to characterize baseline conditions and forecast future conditions of cover type and variable data for the HEP analysis. A large percentage of the variables were determined using Geographic Information System (GIS), including calculating cover type acreages and measuring distances from locations along the coast. However, not all future projections were substantiated in this way, and some projections were based on best professional judgment and collective knowledge from the interagency team.

A variety of resources were utilized in the desktop analysis to obtain baseline data, including TPWD water quality data for salinities and water temperatures; land cover datasets for marshes, oyster reefs, and seagrass; Light Detection and Ranging (LiDAR) elevation data; and NOAA sea level rise (SLR) scenarios. Per USACE guidance, field sampling was not conducted for the Coastal Texas Study on the justification that all data necessary for the HEP analyses would be acquired through readily available data or applications in GIS.

2.2.1 Cover Type Mapping

The HEP model allows a numeric comparison of baseline conditions to each future condition and provides a combined quantitative and qualitative estimate of project-related benefits or impacts on ecosystem resources. To quantify the applicable habitat conditions within each project site, the HEP process requires that the cover types within each project footprint (i.e., ER or CSRM measure) be quantified in terms of acres (quantity) and variables (quality) per each corresponding HSI model. The process of quantifying acres, referred to as "cover typing," allows the user to define the differences between vegetative cover types and clearly delineate these distinctions on a map.

The NOAA C-CAP 2010 and Marsh Migration land cover datasets were used to evaluate and identify cover types for each existing, FWOP, and FWP condition for areas within the project footprint and areas indirectly affected beyond the footprint (NOAA, 2017b; pers. com. N. Herold [NOAA], 2017). Other land cover datasets (such as USFWS National Wetland Inventory [NWI], U.S. Geologic Survey [USGS] land cover, and TPWD land cover) were considered for evaluation (TPWD, 2017; USFWS, 2017; USGS, 2017). However, it was determined that the NOAA land cover datasets would be 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 evaluations (NOAA 2017a, 2017c).

The USACE guidance (USACE 2013, USACE 2014) specifies the procedures for incorporating climate change and RSLR into planning studies and environmental/engineering design projects. The proposed projects must consider measures that are formulated and evaluated for a wide range of possible future rates of relative sea level change (RSLC). The guidance requires that alternatives be evaluated using either “low,” “intermediate,” or “high” rates of future RSLC, as defined below:

- **Low** – Low rates of local sea level change are determined by identifying the historical rate of local mean sea level change, which are best determined by local tide records.
- **Intermediate** – Intermediate rates of local sea level change are estimated using the modified Natural Research Council (NRC) Curve I, which is corrected for the local rate of vertical land movement.
- **High** – High rates of local sea level change are estimated using the modified NRC Curve III, which is corrected for the local rate of vertical land movement.

As discussed earlier, the Texas coast was divided into four planning regions that each serve as a spatial framework for the research, assessment, and management of both ecosystem components and CSRM components. For the purposes of cover typing, the four regions allowed incorporation of historical rates of RSLC using the USACE intermediate SLR curve. The four regions and CSRM and ER measures that occur within that region are described below:

The USACE computed future rates of RSLC were predicted for the years 2017 to 2085 for each of the four regions (USACE, 2017). Table 4 shows the relationship between the USACE intermediate SLR curve and the NOAA land cover dataset used to determine future conditions for each target year across each region (NOAA 2017b; USACE, 2017; pers. com. N. Herold [NOAA], 2017).

Table 4. Relationship between USACE Intermediate SLR Curve and NOAA Landcover Datasets

Calendar Year	TY	Region 1 – Intermediate		Regions 2 and 3 – Intermediate		Region 4 – Intermediate	
		USACE-RSLC (feet)	Corresponding NOAA Output (feet)	USACE-RSLC (feet)	Corresponding NOAA Output (feet)	USACE-RSLC (feet)	Corresponding NOAA Output (feet)
2017	0	0.00	C-CAP 2010	0.00	C-CAP 2010	0.00	C-CAP 2010
2025		0.56	0.50	0.50	0.50	0.32	0.25
2034		0.89	1.00	0.80	1.00	0.57	0.75
2035	1	1.07	1.00	0.89	1.00	0.68	0.75
2045		1.36	1.25	1.15	1.25	0.88	1.00
2055		1.67	1.75	1.42	1.50	1.11	1.00
2065	31	2.00	2.00	1.71	1.75	1.35	1.25
2075		2.35	2.50	2.02	2.00	1.60	1.50
2085	51	2.72	3.00	2.34	2.50	1.88	1.75

Source: NOAA (2017b); USACE (2017); pers. com. N. Herold (NOAA), 2017.

Additional data for the cover type evaluations were provided by the GLO for the TPWD oyster locations data, which were used to capture the effects to oyster reefs with the proposed CSRM and ER measures. The Texas Commission on Environmental Quality (TCEQ) Office of Water provided the Galveston Bay Estuary's Status and Trends Atlas for seagrass locations along the Texas coast (Texas A&M University, 2017).

Footprints containing all areas directly and indirectly benefitting from or adversely affected by proposed ER and CSRM measures were developed in GIS and applied to the NOAA C-CAP and NOAA Marsh Migration land cover datasets to identify all applicable cover types, including estuarine and palustrine wetland, open water, and developed/upland areas. Each HSI model was associated with a cover type to evaluate the project-related benefits on ecosystem resources within the project footprints of the CSRM and ER measures (Table 5).

Table 5. HSI Model Applied to Each Measure

Model	Cover Type	Measure Location Where Model Applied
Brown Shrimp	Estuarine Wetland and Marsh	ER Measures: G-28, B-12, M-8, CA-5, CA-6 CSRM Measures: Bolivar Roads Gates, Galveston Ring Barrier, Dickinson Surge Gate, Clear Lake Surge Gate Mitigation Measures: Sievers Cove, Greens Lake, Horseshoe 1-3, Seabrook, Dickinson Bayou
American Alligator	Palustrine Wetlands	CSRM Measures: Bolivar Roads Gates, Galveston Ring Barrier Mitigation Measures: Marquette
Spotted Seatrout	SAV	ER Measures: CA-5, SP-1, W-3
Brown Pelican	Bird Rookery Islands	ER Measures: G-28, M-8, SP-1, W-3
American Oyster	Oyster Reefs	ER Measures: G-28, B-12, M-8, CA-5, SP-1, W-3 CSRM Measures: Dickinson Surge Gate, Clear Lake Surge Gate Mitigation Measures: Evia Island, Dickinson Bayou, Alligator Point
Kemp's ridley sea turtle	Beach/Dune	ER Measures: B-2, W-3

2.2.2 Hydrodynamic Modeling

A 3D Adaptive Hydraulics (AdH) model was developed and validated by the Engineer Research and Development Center, Coastal and Hydraulics Laboratory (ERDC-CHL) to inform how implementation of the storm surge protection measures would affect the hydrodynamics, salinity and sediment transport in the study area. The first AdH model for the Galveston Bay Storm Surge Barrier System was completed using the 2018 design (McAlpin et al. 2019) and updated 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 continue to change the tidal prism (difference in water volume between high and low tide) and amplitude (change in the water level from low tide to high tide and vice versa), water velocities, and salinities in the Galveston Bay System, albeit lower than the 2018 design. The AdH model results were used to define the HSI modeling FWOP and FWP conditions for direct and indirect impacts to marsh (brown shrimp HSI model), palustrine wetland (American alligator HSI model) and oysters (American oyster HSI model) and included the following results:

- Potential tidal prism changes range from 3-7% across all of the stations in Galveston Bay.
- The tidal amplitude comparisons between FWP and FWOP project range between +3% and -6%, with the greatest change occurring at Bolivar Roads and all bay side locations showing a decrease in tidal amplitude. This is equivalent to a 0.01-0.02 meter (0.4-0.8 inch) change (Lackey and McAlpin 2020).
- Velocity magnitudes for the FWP condition do not vary greatly from the FWOP condition at different locations in the bays. The velocity magnitudes 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.
- The change in mean salinity between FWP and FWOP 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. The salinities are almost identical near the HSC entrance but begin to diverge further into the system at Mid Bay Marsh and Morgan's Point.

2.3 COORDINATION

The Coastal Texas Study interagency team worked together to establish baseline and future conditions of the project sites, evaluate and select HSI models, and conduct forecasting and model evaluations for the study. The interagency team includes representatives from Federal, State, and local natural resource agencies, the non-Federal sponsor, and technical experts from the consulting firm assisting with modeling analysis. Monthly meetings were held to discuss the models and impacts/benefits of each of the measures. Consensus was reached on model use, variable assumptions, and variable forecasting before proceeding with running the models and calculating the change from the action. After the models were run, the results were presented to the team and consensus was reached on the soundness of the results. Where necessary modifications to variable assumptions or inputs were recommended by the team to better describe the anticipated changes based on previous experience and best professional judgement.

2.4 HISTORY OF ECOLOGICAL MODELING

In 2019, a draft Integrated Feasibility Report and EIS (DIFR-EIS) was published for public review, which included an appendix describing the modeling efforts completed for the study to that point. The modeling at that time employed the use of Habitat Evaluation and Assessment Tools (HEAT) software to calculate the benefits of ER measures. Following publication of the DIFR-EIS, the USACE decided to forgo the use of the HEAT software and instead developed certified HEP/HSI spreadsheet models for each of the species-specific models. The HEAT software had limitations in how the results were presented which made it difficult to assess impacts and benefits or to see where and why certain values were being generated. All data in the HEAT software was migrated to the spreadsheets without revision.

The 2019 DIFR-EIS also assessed impacts to beach and dune communities using a Wetland Valuation Assessment (WVA) Barrier Island Community Model, a community-based HEP model. In the monthly interagency meetings that followed the 2018 Draft Report members of the team expressed dissatisfaction with the performance of the WVA model in predicting ecological benefits for beach and dune system in Texas. To improve the quality of the ecological modeling, the team developed the Kemp's Ridley sea turtle nesting model to calculate benefits and impacts from proposed beach and dune ER and CSRM measures. The model is being submitted to the USACE Ecosystem Planning Center Community of Practice for certification.

3.0 HABITAT MODEL ASSUMPTIONS AND VARIABLES

This section describes the methodology used to determine existing, FWOP, and FWP conditions for each HSI model and each project area. The habitat variables (V) of each model are briefly described here. The existing and FWOP condition modeling assumptions apply to ER, CSRM, and mitigation locations. The FWP assumptions for ER are also applied to the mitigation sites as these areas would be restored and result in long-term benefits, while the CSRM features have varying assumptions because of the long-term loss anticipated. Based on the assumptions described below, it is likely that the benefits for ER and mitigation sites have been underestimated, while the CSRM sites have been overestimated to err on the side of the resource and assume worst-case scenarios (i.e. ER benefits may not be fully realized to what the interagency team and USACE actually think will occur; CSRM features may not have as extreme of loss but don't actually know so assume the worst to ensure sufficient mitigation of net losses).

3.1 PERIOD OF ANALYSIS/TARGET YEARS

Federal projects are evaluated over a period of time that is referred to as the "project life," which is defined as the period of time between the time that the project becomes operational and the end of the operational lifespan as dictated by the construction effort or the lead agency (Burks-Copes and Webb, 2010). Given the goals and objectives of the Coastal Texas Study (see Section 1.0 of the DIFR-EIS), the USACE designated a "project life" of 50 years and developed a series of target years within the 50-year setting to guide the projections of both FWOP and FWP actions. Four target years (TY) were defined:

- **TY 0 (2017):** Refers to the baseline conditions for both the CSRM and ER evaluations;
- **TY 1 (2035):** For CSRM measures, selected to capture 1 year of impacts under the proposed with-project conditions; for ER measures, selected to capture 1 year of vegetative growth under the proposed with-project conditions; refers to the end of the construction and the beginning of the operation period;
- **TY 31 (2065):** For CSRM measures, selected to capture 30 years of impacts under the with-project conditions; for ER measures, selected to capture 30 years of vegetative growth under the with-project conditions and refers to the period of out-year marsh nourishments; and
- **TY 51 (2085):** For CSRM measures, selected to capture 50 years of impacts under the with-project conditions; for ER measures, selected to capture 50 years of vegetative growth under the with-project conditions; refers to the end of the period of operation.

3.2 BROWN SHRIMP MODELING

Marsh vegetation and open water acreages were based on a classification conducted using the appropriate NOAA Marsh Migration land cover dataset for each SLR scenario (see Table 1) and areas affected by tidal amplitude. Brown shrimp was modeled using the estuarine wetland and marsh cover type. Changes in water temperature, salinities, and substrate composition were also considered over the period of analysis.

Using the AdH modeling, where tidal amplitude increased or overlapped marshes, those area were assumed to have altered hydrology that was more like open water than estuarine marsh. Therefore, areas (acres) where surface elevation rose because of tidal amplitude were removed from the total area of estuarine marsh and assumed to convert to open water.

3.2.1 V_1 – Percentage of Estuary Covered by Vegetation

Persistent emergent vegetation within an estuary offers both a concentrated source of food and a refuge from predators for brown shrimp, which depend heavily on these environments. In the brown shrimp model, a bay, estuary, or hydrologic unit that is 100 percent covered by marshes or submerged grasses is assumed to have an optimal HSI of 1.0. Habitat suitability decreases in a linear fashion if cover is below this value (Turner and Brody, 1983). For the purposes of this study, "estuary," which was not defined in the model document in terms of geographic scope, was defined as the total ER measure footprint and variables were evaluated at that scale.

Existing Conditions. Existing (baseline) total marsh and open water acreages of each affected wetland area were based on acreages measured in ArcGIS and classified using the NOAA C-CAP 2010 land cover dataset. The percentage of estuary covered by vegetation was computed from the ratio of marsh to open water acreages within the estuary to determine the existing condition for this variable.

FWOP Conditions. Acreages were reclassified for each target year using the NOAA Marsh Migration land cover dataset to determine FWOP conditions. The ratio of marsh to open water changed at each target year with an increasing amount of open water and a decreasing amount of marsh. Where applicable, an erosion rate of 4 feet/year was applied to unprotected segments of the GIWW and assumes that this area converts to open water due to ship wake induced erosion.

FWP ER/Mitigation Conditions. The ratio of marsh to open water acreages within the estuary was computed to determine the FWP conditions for each target year. The initial construction footprints for marsh were digitized in GIS and represent areas of degrading or eroding marsh inland or immediately adjacent to the GIWW. It is assumed that construction will end in 2035 and that all wetlands within the initial construction footprint are restored.

FWP ER (Passive Benefits) Condition. It is expected that once the breakwaters are constructed, marsh loss from ship wake induced erosion is eliminated. As well, the design mitigates future SLR conditions. It is also expected that strips of wetland will develop landward of the breakwater because as each ship passes it stirs up sediment which can then accumulate behind the breakwater and settle out effectively increasing the area of marsh; however, the rate at which this will happen is speculative. To not overestimate the benefits, it is assumed that erosion is stopped and the ratio of marsh to open water is maintained consistent with the existing condition in all TYs following construction of the breakwaters rather than attempting to quantify marsh increases.

FWP CSRM Conditions: The ratio of marsh to open water acreages within the estuary was computed to determine the FWP condition for each target year. It was assumed that by TY 1 (2035), the CSRM alternative has been constructed and all estuarine emergent wetland has been lost through the end of the project life (2085).

3.2.2 V_2 – Substrate Composition

Brown shrimp prefer soft bottom substrates. This variable contributes to the food and cover component in the model and is important in determining shrimp distribution throughout the estuarine system. Soft bottoms with decaying vegetation were assigned the highest SI, while areas with substrates composed of muddy sands, coarse sands, or shell and/or gravel were assigned lower values (Turner and Brody, 1983).

Existing Conditions. Existing substrate composition was determined using collective knowledge from the interagency team. Class 1 (soft bottom) and Class 2 (muddy or fine sands) were the two classifications used in the analyses to represent substrate composition across the Texas coast.

FWOP Conditions. This variable was held constant through the 50-year period of the project life for FWOP conditions because it was concluded that future changes due to no project action would not lead to significantly different substrate compositions across the Texas coast.

FWP ER/Mitigation Conditions. This variable was held constant through the 50-year period of the project life for FWP conditions because it was concluded that future changes due to project action would not lead to significantly different substrate compositions across the Texas coast.

FWP CSRM Conditions (Direct and Indirect Impacts). This variable was held constant through the 50-year period of the project life for FWP conditions because there is not an option in the model that would describe the infrastructure substrates that would be constructed with the CSRM alternative.

3.2.3 V_3 – Mean Water Salinity during Spring

Salinities in bays and estuarine systems are important to brown shrimp during the spring season. Salinities within the range of 10 to 20 parts per thousand (ppt) are optimal for brown shrimp (Turner and Brody, 1983). Salinities were determined using TPWD water quality data from 2007 to 2016 (pers.com M. Fisher [TPWD, 2017]).

Existing ER/Mitigation Conditions. Existing conditions were determined by averaging spring salinities from 2007 to 2016 within each of the ER measure footprints. Spring months included March, April, and May.

FWOP ER/Mitigation Conditions. Data to forecast and evaluate changes in salinity with no project action were not readily available; as a result, the interagency team determined that a 10 percent increase to baseline salinities should be applied TY31 and a 20 percent increase to baseline salinities should be applied to TY51 for the FWOP conditions to capture the potential change in salinities over the period of analysis.

FWP ER/Mitigation Conditions. As described above, a 10 and 20 percent increase was applied to baseline salinities for the FWP conditions for TY 31 and TY51, respectively, to capture the potential change in salinities over the period of analysis.

FWP CSRM (Direct and Indirect) Conditions. The AdH modeling did not provide discreet multiple year, monthly salinity data similar to the data used to define the existing condition. In the absence of FWP data, the conclusion drawn from the AdH modeling was that the FWP conditions would result in less than 2 ppt increase. The interagency team assumed this level of change would be captured within the adjustments to the FWOP condition for RSLC. As described above, 10 and 20 percent increase was applied to baseline salinities for the FWP conditions for TY 31 and TY51, respectively, to capture the potential change in salinities over the period of analysis.

3.2.4 V_4 – Mean Water Temperature during Spring

Temperature represents a localized habitat variable in the water quality component for the brown shrimp model. Optimal temperature for brown shrimp is between 68 and 86 degrees Fahrenheit [°F] (Turner and Brody, 1983). Data for this variable were determined using TPWD water quality data from 2007 to 2016 (pers. com. M. Fisher [TPWD], 2017).

Existing Conditions. Existing conditions were determined by averaging spring water temperatures from 2007 to 2016 within each of the ER measure footprints. Spring months included March, April, and May.

FWOP Conditions. Although climate change indicates water temperatures will rise in the future, it is not believed that the temperature rise will raise mean spring temperatures above 86°F, at which point the SI value would be negatively impacted (pers. com. GLO and USACE, 2017). For these reasons, temperature was assumed to be held constant for the FWOP conditions through the project life.

FWP ER/Mitigation/CSRM (Direct and Indirect) Conditions. As described above, it is not believed that the water temperature rise due to climate change will raise mean spring temperatures above 86°F, at which point the SI value would be negatively impacted (pers. com. GLO and USACE, 2017). For these reasons, temperature was assumed to be held constant for the FWP conditions through the project life.

3.3 AMERICAN ALLIGATOR

Impacts to palustrine emergent wetland were evaluated using the American alligator model for the post-TSP CSRM analysis. The model was developed to determine the suitability of coastal wetlands as habitat for American alligators. Wetland vegetation and open water acreages were based on a classification conducted using the appropriate NOAA Marsh Migration land cover dataset for each SLR scenario. Changes in percentage of open water, ponding and hydroperiods, and interspersion were considered over the period of analysis. The data were then input into the modified HEP/HSI model spreadsheets to generate HSI, HU, and AAHU outputs.

3.3.1 V_1 – Percentage of wetland that is open water

Alligators are known to breed in relatively deep, open water. Suitability of an area as breeding habitat is influenced by the amount and type of open water versus vegetated wetland. Open water is defined in the model as an area that maintains less than 10 percent canopy cover of emergent vegetation. Optimal breeding and nesting habitat for alligators is assumed to be an area that maintains 20 to 40 percent open water and 60 to 80 percent vegetated wetland; this percentage range is assumed to have an optimal HSI of 1.0. Habitat suitability decreases in a linear fashion if the percentage of open water is either less than 20 percent or greater than 40 percent (Newsom et al., 1987). For the purposes of this study, "wetland area", which was not defined in the model document in terms of geographic scope, was defined as the total CSRM/mitigation measure footprint and variables were evaluated at that scale.

Existing Conditions. Existing (baseline) total palustrine wetland and open water acreages of each wetland area were based on acreages measured in ArcGIS and classified using the NOAA C-CAP 2010 land cover dataset. The percentage of wetland area covered by vegetation was computed from the ratio of palustrine wetland to open water acreages within the project footprint to determine the existing condition for this variable.

FWOP Conditions. Acreages were reclassified for each target year using the NOAA Marsh Migration land cover dataset to determine FWOP conditions. The ratio of palustrine wetland to open water remained generally consistent at each target year with a steady amount of open water versus wetland, and therefore, the variable HSI remained the same through the end of the project life. It was assumed that once the Marsh Migration land cover data showed conversion of palustrine to estuarine marsh as a result of RSLC, the value was set to 0 indicating no wetland areas remained.

FWP Mitigation Conditions. It was assumed that it would take approximately 10 years after construction for the template design conditions to be achieved; therefore, the template designs for the mitigation site was used to determine the percent of open water and vegetated wetlands and applied to TY11. Under RSLC, it was assumed that the restored site would follow the FWOP condition by maintaining a generally consistent ratio of palustrine wetland to open water site; therefore, the TY11 value was held constant for TY31 and TY51.

FWP CSRM Conditions. The ratio of marsh to open water acreages within the estuary was computed to determine the FWP conditions for each target year. It was assumed that by TY 1 (2035), the CSRM alternative has been constructed and all palustrine emergent wetland has been lost through the end of the project life (2085).

3.3.2 V_2 – Percentage of open water that is bayous or canals

Deepwater areas in bayous, canals, ponds, and lakes are known to be essential habitat components for adult alligators during breeding seasons and for immature/juvenile alligators throughout the year. However, shallow water areas must also be present to support prey species as a food resource. Habitat suitability is optimal when 10 to 20 percent of the open water is bayous, canals, or deeper than 1.2 meters in ponds or lakes. Suitability decreases as this value increases above 20 percent and habitat becomes unsuitable when bayous, canals, and deep water represent 100 percent of open water within the wetland area (Newsom et al., 1987).

Existing Conditions. Best professional judgement was used to determine the assumptions associated with this variable for baseline conditions. It was assumed that 5 percent of open water can be classified as bayous, canals, or deeper than 1.2 meters in ponds or lakes.

FWOP Conditions. This variable was held constant through the 50-year period of the project life for FWOP conditions. It was concluded that future changes that would affect open water that can be classified as bayous, canals, or deeper than 1.2 meters in ponds and lakes would not change the ratio of deepwater areas significantly with RSLC. It was assumed that once the marsh migration viewer showed conversion of palustrine to estuarine marsh as a result of RSLC, the overall acreage was adjusted to remove the converted habitat, indicating a complete loss of fresh, deepwater habitat in that area.

FWP Mitigation Conditions. It was assumed that it would take approximately 10 years after construction for the template design conditions to be achieved; therefore, the template designs for the mitigation site was used to determine the percent of open water areas that can be classified as bayous, canals, or deeper than 1.2 meters in ponds and lakes and applied to TY11. Under RSLC, the TY11 value was held constant through TY51 as it is assumed the site would follow the FWOP condition.

FWP CSRM Conditions. It was assumed that by TY 1 (2035), the CSRM alternative has been constructed and all open water within the project footprint has been lost through the end of the project life (2085).

3.3.3 V_3 – Interspersion

Nesting alligator habitat is known to be directly related to the degree of interspersion of water bodies within vegetated wetland areas. Optimal habitat maintains a high interspersion of water and vegetation (10-15 ponds per 15 acres) and is assumed to have an HSI of 1.0. The variable has a categorical response with decreasing degrees of suitability between high, medium, and low interspersion (Newsom et al., 1987).

Existing Conditions. Best professional judgement was used to determine the assumptions associated with this variable for baseline conditions. It was assumed that low interspersion occurs throughout the CSRM measure footprint (2 or fewer ponds per 15 acres, or highly eroded and fragmented marsh).

FWOP Conditions. Best professional judgement was used to determine the assumptions associated with this variable for baseline conditions. It was assumed that low interspersion occurs throughout the CSRM and mitigation measure footprint (2 or fewer ponds per 15 acres, or highly eroded and fragmented marsh).

FWP Mitigation Conditions. It was assumed that the design template would incorporate 15 ponds per acre and it was assumed that it would take approximately 10 years after construction for the template design conditions to be achieved. The template designs for the mitigation site was used to determine the interspersion and applied to TY11. Under RSLC, the TY11 value was held constant through TY51 because it is not anticipated that the rate of ponds per acre would increase beyond 20 ponds per acre under RSLC after reviewing the Marsh Migration dataset.

FWP CSRM Conditions. Best professional judgement was used to determine the assumptions associated with this variable for baseline conditions. It was assumed that low interspersion occurs throughout the CSRM measure footprint (2 or fewer ponds per 15 acres, or highly eroded and fragmented marsh).

3.3.4 V_4 – Percentage of ponded area with water ≥ 15 cm deep

Ponds or lakes that dry out during the spring and summer tend to restrict the travel and mobility of alligators and increase the vulnerability of the young/juvenile alligators to predation. It is assumed that at least 15 centimeters of water must be present throughout the nesting period for alligators to use a pond. Habitat suitability increases as the percentage of ponds retaining this water depth increases (Newsom et al., 1987).

Existing Conditions. Best professional judgement was used to determine the assumptions associated with this variable for baseline conditions. It was assumed that 10 percent of ponds retain equal to or more than 15 centimeters of water during the spring and summer.

FWOP Conditions. Best professional judgement was used to determine the assumptions associated with this variable for baseline conditions. It was assumed that 10 percent of ponds retain equal to or more than 15 centimeters of water during the spring and summer. This variable was held constant for the FWOP conditions throughout the life of the project because it was assumed that the ponds would not likely become dry during the spring or summer.

FWP Mitigation Conditions. The percent of ponded areas were estimated from the design template. It was assumed that pond areas could be designed to target depths that would allow at least 60 percent of the ponds to retain more than 15 centimeters of water during the spring and summer. It was also assumed that it would take approximately 10 years after construction for the template design conditions to be achieved; therefore, it was assumed that 60 percent of the ponds maintained water depths greater than 15 centimeters during the spring and summer beginning in TY11. This was held constant through TY51 because it was assumed that under RSLC the depth of the water in the ponds would at a minimum be maintained, but more likely the depth would increase.

FWP CSRM Conditions. Best professional judgement was used to determine the assumptions associated with this variable for baseline conditions. It was assumed that 10 percent of ponds retain equal to or more than 15 centimeters of water during the spring and summer. This variable was held constant for the FWP conditions throughout the life of the project because it was assumed that the ponds would not likely become dry during the spring or summer.

3.4 SPOTTED SEATROUT MODELING

The spotted seatrout model considers habitat suitability for the egg, larval, and juvenile life stages. These three life stages are considered the most sensitive to environmental variations and are the most responsive to restoration of SAV. The model assumes two primary factors, or life history requisites, for determining habitat quality of a project site: water quality (including temperature and salinity) and food/cover (Kostecki, 1984).

3.4.1 V_1 – Lowest Monthly Average Winter-Spring Water Salinity

Lowest monthly average winter-spring salinity represents the minimum value of the 4 monthly mean salinities determined for each year of data between the months of December and March (Kostecki, 1984). This variable was determined using TPWD water quality data from 2007 to 2016 (pers. com. M. Fisher [TPWD], 2017).

Existing Conditions. Existing conditions were determined by calculating the average monthly salinity for the months of December, January, February, and March, and taking the minimum of those values.

FWOP Conditions. Data to forecast and evaluate changes in salinity with no project action were not readily available; as a result, the interagency team determined that a 10 percent increase to baseline salinities should be applied to TY31 and a 20 percent increase applied to baseline salinities in TY51 for the FWOP conditions to capture the potential change in salinities over the period of analysis.

FWP ER Conditions. As described above, a 10 and 20 percent increase was applied to baseline salinities for the FWP conditions in TY31 and TY51, respectively, to capture the potential change in salinities over the period of analysis.

3.4.2 V_2 – Highest Monthly Average Summer Water Salinity

Highest monthly average summer salinity represents the maximum value of the 3 monthly mean salinities determined for each year of data between the months of June and September (Kostecki, 1984). This variable was determined using TPWD water quality data from 2007 to 2016 (pers. com. M. Fisher [TPWD], 2017).

Existing Conditions. Existing conditions were determined by calculating the average monthly salinity for the months of June, July, and August, and taking the maximum of those values.

FWOP Conditions. Data to forecast and evaluate changes in salinity with no project action were not readily available; as a result, the interagency team determined that a 10 percent increase to baseline salinities should be applied to TY31 and a 20 percent increase applied to baseline salinities in TY51 for the FWOP conditions to capture the potential change in salinities over the period of analysis.

FWP ER Conditions. As described above, a 10 and 20 percent increase was applied to baseline salinities the FWP conditions in TY31 and TY51, respectively, to capture the potential change in salinities over the period of analysis.

3.4.3 V_3 – Lowest Monthly Average Winter Water Temperature

Lowest monthly average winter water temperature represents the minimum value of the 4 monthly mean temperatures determined for each year of data between the months of December and March (Kostecki, 1984). This variable was determined using TPWD water quality data from 2007 to 2016 (pers. com. M. Fisher [TPWD], 2017).

Existing Conditions. Existing conditions were determined by calculating the average monthly water temperature for the months of December, January, February, and March, and taking the minimum of those values.

FWOP Conditions. This variable was held constant through the 50-year project life.

FWP ER Conditions. This variable was held constant through the 50-year project life.

3.4.4 V_4 – Highest Monthly Average Summer Water Temperature

Highest monthly average summer water temperature represents the maximum value of the 3 monthly mean salinities determined for each year of data between the months of June and September (Kostecki, 1984). This variable was determined using TPWD water quality data from 2007 to 2016 (pers. com. M. Fisher [TPWD], 2017).

Existing Conditions. Existing conditions were determined by calculating the average monthly water temperature for the months of June, July and August, and taking a maximum of those values.

FWOP Conditions. This variable was held constant through the 50-year project life.

FWP Conditions. This variable was held constant through the 50-year project life.

3.4.5 V_5 – Percentage of Study Area that is Optimal Cover

The preferred habitat of juvenile spotted seatrout is the shallow, vegetated area of estuarine environments, and most ideally near the edges of grass flats, which provide shelter, protection, and an abundance of food resources. Cover, including submerged and/or emergent vegetation, submerged islands, oyster beds, or shell reef, over more than 50 percent of the total area indicates an optimal HSI of 1.0. Cover below this mark decreases in a linear fashion, where no cover indicates suboptimal HSI of 0 (Kostecki, 1984).

Existing Conditions. For baseline conditions, this variable was determined by evaluating historical maps and aerial photographs using Google Earth aerial imagery (2016) and gaining consensus from the interagency team.

FWOP Conditions. For FWOP conditions, it was assumed that existing seagrass beds within a project area were depleted due to increased energies and increased water depth as a result of SLR breaching existing “barriers” protecting seagrass beds.

FWP Conditions. For FWP conditions, it was assumed that existing seagrass beds within a project area remain due to protective actions (i.e., the installation of breakwaters, creation of oyster reef, or restoration of marshes) that do not allow breaching of existing "barriers" by SLR, thereby allowing optimal conditions to exist at the end of construction (2035) and remain through the period of analysis.

3.5 BROWN PELICAN MODELING

Eastern brown pelican colonies occur on coastal islands small enough to be free from human habitation and recreation, and far enough from the mainland to be inaccessible to potential predators (Hingtgen et al., 1985). Along the Texas coast, brown pelicans use both natural and man-made islands, specifically dredged material placement areas along the GIWW.

3.5.1 V_1 – Island Surface Area

The total island surface area is assumed to be an indication of its accessibility to opportunistic predators. Islands larger than 20 acres may be able to support resident populations of predators and are assumed to have a suboptimal SI of 0.4. Likewise, islands smaller than 5 acres do not have the capacity to accommodate brown pelican colonies, which average about 100 nests or more per every 2.5 acres (Hingtgen et al., 1985).

Optimal habitat suitability depends on several components, including accommodating colony size at a density of 100 nests per every 2.5 acres, and having enough area for loafing and drying (about 2.5 acres per colony). In order to achieve the highest habitat suitability, islands must be 4.9 to 19.8 acres in size (Hingtgen et al., 1985).

Existing Conditions: Total island surface area at existing conditions was determined by measuring island size using Google Earth aerial imagery (2016). Class 1 (islands less than 4.9 acres in size) and Class 3 (island greater than 19.8 acres in size) were the two classifications used in the analyses to represent island size of the four project areas across the Texas coast. Both classifications represent a suboptimal HSI of 0.4.

FWOP Conditions: Acreages were reclassified for each target year by applying an assumed erosion rate of 4 feet per year as a result of ship wake induced erosion, the primary cause of island area loss. The area of the island was then adjusted for SLR by calculating the area of the reclassified island that would remain above the changed water elevation for the target year. It was assumed that by 2065 all island acres are lost to SLR with no action.

FWP ER Conditions: The USACE provided typical cross sections and dimensions for each island creation and restoration action. It is assumed that construction would end in 2035, and that all acreages within the island restoration footprints are restored. It is expected that once the breakwaters are constructed, island area loss from ship wake induced erosion is eliminated and strips of wetland will develop landward of the breakwater because as each ship passes it stirs up sediment which can then accumulate behind the breakwater and settle out effectively increasing the area of the island. Some loss due to RSLR was assumed at each target year using the same method as applied for the FWOP condition;

however, as the sediment accumulates behind the breakwaters, land loss would not occur at the same rate as the FWOP as a result of SLR.

3.5.2 V_2 – Distance from the Mainland

Optimal distance from the mainland is assumed to be about 0.25 mile or more for nesting brown pelicans (Hingtgen et al., 1985).

Existing Conditions. This variable was determined by measuring the distance from the centroid of the island to the mainland using Google Earth aerial imagery (2016). Habitat suitability for each project area in terms of distance from the mainland ranged from suboptimal at 0.09 mile to optimal at 1.55 miles.

FWOP Conditions. This variable was held constant for each target year until zero island acres remained as a result of RSLR. The area of the island was assumed to be completely lost in year 2065 (see V_1 FWOP Condition assumptions).

FWP ER Conditions. This variable was held constant through the 50-year period of the project life for FWP conditions. Distance was initially measured from the centroid of the island; however, since the island area does not change significantly, it was concluded that the restoration of the islands would not lead to significantly different distances from the mainland (see V_1 FWP ER Conditions assumptions) .

3.5.3 V_3 – Distance from Human Activity

The principle source of eastern brown pelican nesting failure is direct and indirect human interference with nesting colonies. Islands that have permanent human inhabitants or are visited by humans for recreational or commercial purposes during breeding season are assumed to have suboptimal habitat suitability (Hingtgen et al., 1985). Optimum distance of nesting colonies from centers of human activity is assumed to be 0.25 mile or more.

For the purposes of this study, the closest urban development on the mainland was considered "human activity." Although the model document lists commercial activity as a human activity center, the GIWW or nearby seawall channels were not considered as threats to nesting brown pelican colonies for this evaluation. The appropriateness of whether or not commercial navigation along the GIWW should be considered a "human activity" was discussed at length with the interagency team. It was decided that because vessel traffic is an intermittent activity that does not typically produce a significant amount of noise, introduce predators, or contribute to potential nest failure, etc. As well, it is documented (both anecdotally and in bird nesting surveys) that Pelicans currently nest on the existing islands along the GIWW and therefore do not appear to be influenced by the commercial activity.

Existing Conditions. This variable was determined by measuring the distance from the centroid of the island to the closest urban development using Google Earth aerial imagery (2016). Habitat suitability for each project area in terms of distance from human activity was considered optimal, with distances ranging from a minimum of 0.6 mile to a maximum of 8.1 miles.

FWOP Conditions. This variable was held constant for each target year in the FWOP conditions because predictions regarding future urban development in proximity to the project areas were not considered.

FWP ER Conditions. This variable was held constant for each target year in the FWP conditions because predictions regarding future urban development in proximity to the project areas were not considered.

3.5.4 V_4 – Nesting Coverage/Island Elevation

Brown pelicans that nest along the Texas coast usually do so on the ground or in small shrubs. Island elevation and the density of shrubs available for potential nesting habitat are two important components in the success of these colonies. Nesting vegetation that covers at least 50 percent or more of an island is assumed to be optimal for this model (Hingtgen et al., 1985).

Existing Conditions. Nesting coverage and island elevation for existing conditions were evaluated using Google Earth aerial imagery (2016). In general, islands evaluated under this study had abrupt slopes due to erosional processes, and the total island acreage was assumed to be nesting habitat (defined as areas higher than 2 feet in elevation). Therefore, habitat suitability was considered optimal.

FWOP Conditions. The nesting coverage variable was considered optimal if there were remaining island acres that had not been converted to open water. Once the island was completely overcome by SLR, the nesting coverage variable fell to zero.

FWP ER Conditions. Nesting coverage and island elevation for FWP conditions was calculated using GIS and evaluated using several sources of data, including Google Earth aerial imagery, the typical island cross sections, and the USACE intermediate SLR curve. The model document defines nesting coverage as all existing portions of island that are 2 feet or higher in elevation (North American Vertical Datum of 1988 [NAVD88]). The USACE intermediate SLR curve was used to determine the water elevation at the end of construction (calendar year 2035). Then, using the engineering assumptions developed for each island feature, the remaining island area was calculated.

3.6 AMERICAN OYSTER MODELING

Oyster reef acreages were based on a classification conducted using the TPWD oyster locations data to evaluate benefits/impacts to oyster from the proposed measures. Changes in oyster reef habitat associated with each NOAA SLR scenario were determined by consensus from the interagency team. Changes in salinities and substrate composition were also considered for the period of analysis and are described below.

3.6.1 V_1 – Percent Cultch

Percent cultch represents the percent of bottom covered with hard substrate. It is assumed that hard substrate (cultch), such as existing oyster reef, or other hard surfaces (limestone, concrete, granite, etc.) are optimal for oyster larvae to settle on and utilize as habitat (Swannack et al., 2014).

Existing Conditions. Existing conditions were determined by calculating the amount of oyster reef for each ER measure footprint, using the TPWD oyster locations data. It was assumed that if no oyster reef existed within the project footprint, then the percent cultch was suboptimal (SI = 0.0). Alternatively, any amount of oyster reef existing within the project footprint was assumed to provide optimal bottom substrate (SI = 1.0).

FWOP Conditions. Data to forecast and evaluate future changes in oyster reef habitat were not readily available. As a result, it was assumed that all oyster reef habitat, and therefore cultch, was eliminated with no project action due to SLR, increased bay energies, and changes in freshwater inflows and salinities.

FWP ER/Mitigation Conditions. Oyster habitat restoration or creation actions were assumed to be completed in 2035. Therefore, it was assumed that the creation or restoration actions would result in optimal SI of 1.0 through the end of the project life.

FWP CSRM (Direct Impact) Conditions. It is assumed that CSRM actions would result in the permanent loss of hard bottom substrate in 2035 and hard bottom substrate would not be replaced at the site of impact.

FWP CSRM (Indirect Impact) Conditions. It is assumed that hard bottom substrates would not be modified because of changes to hydrology, sedimentation, or salinity from implementation of any of the CSRM measures. Therefore, the FWOP condition was applied for all TYs.

3.6.2 V_2 – Mean Water Salinity during May–September

Mean water salinity during the spawning season for oysters represents the mean monthly salinity from May to September and reflects the optimal salinities required for spawning and larval stages (Swannack et al., 2014).

Existing Conditions. Existing conditions were calculated by averaging monthly values of salinity from May 1 through September 30 within the project footprint using TPWD water quality data from 2007 to 2016 (pers. com. M. Fisher [TPWD], 2017).

FWOP Conditions. Data to forecast and evaluate changes in salinity with no project action were not readily available; as a result, the interagency team determined that a 10 percent increase to baseline salinities should be applied to TY31 and a 20 percent increase applied to baseline salinities should be applied to TY51 for the FWOP conditions to capture the potential change in salinities over the period of analysis.

FWP ER/Mitigation Conditions. As described above, a 10 and 20 percent increase was applied to baseline salinities for the FWP conditions for TY31 and TY51, respectively, to capture the potential change in salinities over the period of analysis.

FWP CSRM (Direct and Indirect Impacts) Conditions. AdH modeling showed less than 2 ppt increase under the FWP condition and were assumed to be captured within the adjustments for RSLC. As described above, 10 and 20 percent increase was applied to baseline salinities for the FWP conditions for TY 31 and TY51, respectively, to capture the potential change in salinities over the period of analysis.

3.6.3 V_3 – Minimum Annual Water Salinity

Minimum annual salinity represents the minimum value of the 12 monthly mean salinities determined for each year of data. This variable reflects freshwater impacts (e.g., high rainfall years or freshwater diversions) on oysters and is an indication of the frequency of freshwater floods that are fatal to oysters (Swannack et al., 2014).

Existing Conditions. Existing or baseline conditions were calculated by averaging the mean monthly values of salinities for each year of data to determine the minimum annual salinity from 2007 to 2016 using TPWD water quality data (pers. com. M. Fisher [TPWD], 2017).

FWOP Conditions. Data to forecast and evaluate changes in salinity with no project action were not readily available; as a result, the interagency team determined that a 10 percent increase to baseline salinities should be applied to TY31 and a 20 percent increase applied to baseline salinities in TY51 for the FWOP conditions to capture the potential change in salinities over the period of analysis.

FWP ER/Mitigation Conditions. As described above, a 10 and 20 percent increase was applied to baseline salinities for the FWP conditions for TY31 and TY51, respectively, to capture the potential change in salinities over the period of analysis.

FWP CSRM (Direct and Indirect) Conditions. AdH modeling showed less than 2 ppt increase under the FWP condition and were assumed to be captured within the adjustments for RSLC. As described above, 10 and 20 percent increases were applied to baseline salinities for the FWP conditions for TY31 and TY51, respectively, to capture the potential change in salinities over the period of analysis.

3.6.4 V_4 – Annual Mean Salinity

Annual mean salinity represents the range of suitable salinities that adult oysters can tolerate and are viable. Salinities within the range of 10 to 15 ppt are assumed to be optimal for oysters (Swannack et al., 2014).

Existing Conditions. Existing, or baseline, conditions were calculated by averaging monthly mean salinity values to determine the annual mean salinity from 2007 to 2016 using TPWD water quality data (pers. com. M. Fisher [TPWD], 2017).

FWOP Conditions. Data to forecast and evaluate changes in salinity with no project action were not readily available; as a result, the interagency team determined that a 10 percent increase to baseline salinities should be applied to TY31 and a 20 percent increase applied to baseline salinities in TY51 for the FWOP conditions to capture the potential change in salinities over the period of analysis.

FWP ER/Mitigation Conditions. As described above, 10 and 20 percent increases were applied to baseline salinities for the FWP conditions for TY31 and TY51, respectively, to capture the potential change in salinities over the period of analysis.

FWP CSRM Conditions. FWP CSRM (Direct and Indirect) Conditions. AdH modeling showed less than 2 ppt increase under the FWP condition and were assumed to be captured within the adjustments for RSLC. As described above, 10 and 20 percent increase was applied to baseline salinities for the FWP conditions for TY 31 and TY51, respectively, to capture the potential change in salinities over the period of analysis.

3.7 KEMP'S RIDLEY SEA TURTLE

The Kemp's ridley sea turtle is considered a sentinel species for Texas' marine ecosystems, meaning, their abundance, distribution, and health are reflective of environmental conditions (NPS 2017). Additionally, researchers recently found statistical evidence to support the conclusion that specific variabilities in beach and dune geomorphologies influence Kemp's ridley nest site selection on Padre Island, TX, United States (Culver *et al*. 2020). This research provided key information that allowed the Study Team to develop the habitat suitability index for Kemp's ridley nesting.

The model was developed through a collaborative process that was headed by USACE and included input from the GLO, the USFWS, the National Park Service, and the Texas Parks and Wildlife Department. This habitat suitability model includes the geomorphic variables that were identified by Culver *et al.* (2020) as having the highest predictive power influencing nest site location. These influential geomorphic parameters include: the maximum dune slope, the average beach slope, and the elevation at the line of vegetation (a frequent nest location), which is closely associated with the toe of the dunes (change in steepness that indicates a transition between beach and dune habitats).

The interagency team also used a conceptual model developed by Dunkin *et al.* 2015, which identified categories and parameters that influence loggerhead sea turtle (*Caretta caretta*) nesting, to identify other non-geomorphic variables that would influence nesting habitat suitability. While the biology and nesting behaviors differ between loggerheads and Kemp's ridleys, Dunkin *et al.*'s (2015) conceptual model helped the team identify two additional variables which were carried forward into the model. The two additional non-geomorphic variables are artificial light (dune shade) and beach use.

R (R Core Team 2017) was used to investigate the distributions of the geomorphic variables in the dataset used by Culver *et al.* (2020) to assign index scores for the variable ranges. Density plots were used to identify breaks in ranges which then correspond to assigned index scores.

There are several assumptions that were made to run this model. Most of the assumptions apply to both FWOP and FWP scenarios including:

- All beach and dune areas are considered nesting habitat.
- Shoreline change trends identified in the Bureau of Economic Geology's Shoreline Change Atlas were applied to all the reaches.
- The Bolivar Peninsula and West Galveston Beach and Dune measure includes re-nourishment, so shoreline losses and effects from RSLC were not detracted for the FWP scenario
- Where the predicted shoreline erosion caused a complete loss of beach surface area for a reach before the end of the 50-project analysis, the predicted erosion was not

continued into the dune habitat (basically, the analysis did not predict loss of dune habitat).

- Mean Sea Level (MSL) and Mean Higher High Water (MHHW), which are known to vary along the Texas Coast, play important roles in habitat suitability and in determining the extent of the "wet beach" for a region. Culver *et al.* (2020) used NOAA station 8775870, the tide gauge at Bob Hall Pier in Corpus Christi which reports the local MSL as 0.48-foot NAVD 88 and Mean Higher High Water (MHHW) as 1.18-foot NAVD 88. The datums from NOAA station 8771510, the Galveston Pleasure Pier was used to compare Region 4 with Region 1. The Galveston Pleasure Pier Station reports MSL as 0.5-foot NAVD88 and MHHW as 1.4-foot NAVD88. After comparing the values from the two stations, no adjustments were made because MSLs were very close and even though Galveston had a MHHW that was 0.22-foot NAVD88 higher than Corpus Christi, the Dune Toe Elevation Variable was still suboptimal in that range.

- The beach use variable assumes that proximity to a beach access point and whether or not diving is allowed correlates to the amount of human recreational activity that would occur in a particular reach.

3.7.1 V_1 – Average Beach Slope

The research shows that Average Beach Slope is an important parameter influencing nest site selection Culver *et al.* (2020). Kemp's Ridley nests were far less dense on beaches with a steep average slope or those that were relatively flat. Using quantiles and the standard deviations from the distribution used by Culver *et al.* (2020), five scoring ranges were derived, and the relative nesting densities for those ranges were used to determine the scores for these ranges. The optimal range for the Average Beach Slope was determined to be within 4.2º and 2º.

Existing Conditions. Using GIS software and LiDAR datasets, the project areas were broken up into 100-meter-wide segments (reaches). The Average Beach Slopes, reported in degrees, were calculated for all reaches using the angle of repose for clay because existing sediments are found in a very thin lens of ancient finer sands overlaying clay.

FWOP Conditions. It is acknowledged that coastal processes (e.g. tides, wind, longshore forcing, and waves) are highly variable and would affect beach length and ultimately beach slope in the future; however, due to the uncertainty in the timing and extent of change, it was assumed the angle of repose of clay and water (proxy for slope) would not change in the future. Because the existing sediments are overlying a clay layer, coastal processes are not expected to change and therefore, the FWOP slope was the same as the existing condition for all TYs.

FWP ER/CSRM Conditions. Under the FWP condition, coastal processes would be changed as compared to those under the FWOP conditions primarily through sediment composition changes and modification to the beach profile which affects how and where waves attenuate and run up. The Average Beach Slope was calculated utilizing the design templates for the beach and dune measures using the angle of repose for sand rather than clay since the new sediment is a coarser grained (riverine) sand that would allow for reworking of sediments. The Average Beach Slope was calculated for each reach at TY1 and applied to all TYs. Because of the significant amount of sediment being placed and based on the erosion rate for the area, it is projected that the slope would be maintained (wouldn't reach the clay layer) within the 50-year period of analysis.

3.7.2 V_2 – Maximum Dune Slope

Like the results for the Average Beach Slope variable, Kemp's ridley nests were far less dense on beaches with steep or shallow values for Maximum Dune Slope. This makes sense because escarpments (very steep) have been correlated to false crawl behavior in nesting sea turtles. Additionally, some evidence suggests that many nesting Kemp's ridley's prefer to nest near the toe of the dune and if the maximum dune slope is too flat the toe of the dune may not be as discernable.

Existing Conditions: Using GIS software and LiDAR datasets, the project areas were broken up into 100-meter-wide segments (reaches). The Maximum Dune Slopes, reported in degrees, were calculated for all segments.

FWOP Conditions. Dune geometry under the FWOP is predominately shaped by toe erosion (daily tides and storm surge events), overwash during storm surge, lack of sediment availability and wind, each of which affects dune stability and dune shape. Because the beach is sediment starved and currently very narrow, it is anticipated that the beach would erode to the point of encroaching on the dune in some places; however, the extent and timing of erosional changes to the slope of the dune is highly speculative. Therefore, it is assumed the maximum slope would not change in the future because the angle of repose of clay and water is assumed to remain constant (i.e. the existing condition value was applied). By maintaining a constant value rather than projecting dune slope changes, the FWOP condition quality is assumed to be higher than it will likely be in the future (overestimated) and errs on the side of caution to not overestimate benefits of the FWP condition.

FWP ER/CSRM Conditions. With beach nourishment, a wider beach and change in grain size/composition (riverine vs ancient) allows the tides to attenuate farther out than under the FWOP condition, thereby significantly reducing the potential for erosion to affect the dune during normal tides and storm surge events. Additionally, the increase in sediment will promote reworking of the sediments which is expected to contribute to dune formation or at a minimum maintenance of the template profile. Similar to the FWP for V_1, the Maximum Dune Slope was calculated utilizing the design templates for the beach and dune measures and took into account the angle of repose for sand and water. Attempting to calculate how and when the project would affect dune formation and slope changes in the future was too speculative, so the Maximum Dune Slope was calculated for each reach for TY1 (assumed to optimal) and applied to all TYs (assumed to remain constant because it would not be subjected to wave runup). This approach would undervalue the benefit of the project by not accounting for dune height increases and slope adjustments to the optimal range that have been observed in other areas where beach nourishment have been previously implemented.

3.7.3 V_3 – Dune Toe Elevation

Culver *et al.* (2020) found that nest elevation and distance from the nest site to the shoreline were two of the most predictive variables. It was challenging to find a way to score those variables because they were measured by individual nest and at first it was uncertain as to whether or not these variables were tied to a specific geomorphic characteristic. Culver *et al.* (2020) reported that the nest locations were frequently found along the potential line of vegetation which usually occurs at a geomorphic feature known as the "toe of the dune." Due to some of these assumptions, a large section of the elevation range was considered optimal (75% of the distribution). The optimal range for the toe of the dune was between 2.4- and 5-foot NAVD88.

Existing Conditions. Using GIS software and LiDAR datasets, the Dune Toe Elevation were calculated for all the segments and were reported in feet above 0 NAVD88.

FWOP Conditions. RSLC rates were applied to the Dune Toe Elevation variable by subtracting the 2018 elevations from the predicted RSLC elevation for the region and the TY. As RSLC is applied, the scores for this variable diminish.

FWP ER Conditions. The design template Dune Toe Elevation was applied to TY1. For future TYs, RSLC rates were applied to the TY1 elevation to project the future elevations using the same method as the FWOP condition.

FWP CSRM Conditions. The design template Dune Toe Elevation was applied to all TYs because renourishment cycles were assumed to occur at an interval that would keep up with RSLC.

3.7.4 V_4 – Artificial Light (Dune Shade)

Kemp's ridley sea turtles primarily nest during daylight hours in synchronized emergences, known as "arribadas." While the presence of artificial light on the beach wouldn't affect nesting behavior, it still could disorient hatchlings reducing their chances of reaching the gulf waters.

The presence of artificial light and the shading benefits provided by dunes (both FWOP and FWP) were determined using the 2018 Upper Coastal LiDAR dataset, to extract building locations and existing dune profiles. A simulated light source was set on each building at 10' below the maximum height to approximate the elevation of a porchlight. A viewshed analysis was run with each point set as an 'observer' against the 2018 DEM, and again against the modified DEM for FWOP and FWP conditions in place. The raster output of the viewshed showed where each point on the ground was visible from at least one light source. For each scenario, the raster was converted to a polygon, clipped to each beach sector, and the area of the viewshed polygon was compared against the area of the beach sector, giving the percentage of the beach that would be shaded from artificial light coming from the structures.

If a beach doesn't have houses or lamp posts within 0.25 miles of the reach a score of 1 is assumed for this variable.

Existing Conditions: The same light source locations and elevations were used for both the with and without project analyses. For this variable, the existing condition dune elevations included the additional shading provided by existing vegetation. This was accomplished by including the vegetation in the dune elevation analysis.

FWOP Conditions: It was assumed that no additional structures/light sources would be constructed in or near the analysis area in the future and the top of dune crest elevation and vegetation density/height would remain unchanged; therefore, the existing condition variable was applied to all TYs. It is acknowledged that, development could occur in the future resulting in an increase in artificial light sources and that dune crest elevations are trending toward dune elevation loss due to measured sediment deficits for all reaches of beach, both of which would contribute to degraded long-term habitat quality. However, forecasting these changes for specific beach reaches over the 50-year period of analysis would be too speculative for inclusion. By maintaining the existing condition, the assumption only risks overvaluing the FWOP condition by not accounting for anticipated degradation.

FWP ER/CSRM Conditions. It was assumed that no additional structures/light sources would be constructed in or near the analysis area in the future. To account for the impact of dunes on shading, the project template was simulated in front of the existing dunes and assumed that vegetation on the dunes would be 2 feet above the crest of the dune, which is the average height of most plant species found on dunes in Texas. The template dune design is assumed to be maintained (see V_2 and V_3 assumptions) so the value of TY1 was applied to all TYs

3.7.5 V_5 – Beach Use Activity

This variable considers the adverse impacts that human beach activities can have on nesting Kemp's ridleys sea turtles and hatchlings. The adverse impacts to nesting sea turtles from automobiles driving on beaches have been well documented. Vehicles have been known to strike turtles, damage nests, increase sand compaction, and the head lights contribute to light pollution. Additionally, beaches that offer pedestrian access (non-vehicular) have been shown to have higher levels of discarded plastics than beaches with restricted access. Also, the mere presence of people could discourage nesting.

This variable scored Beach Use Activity by assessing the proximity of the reaches to beach access points and by considering whether or not driving is allowed on the beach. Reaches greater than 1.0 mile from an access point were scored a 1.0, while reaches less than 1.0 mile from an access point that only allowed pedestrian access (no driving) were scored a 0.5 and reaches that allowed driving were scored a 0.1.

Existing Conditions. Google Earth's measure tool was used to measure the distance from known beach access locations to each reach.

FWOP Conditions. It was assumed that the number and location of beach access points would remain the same in the future.

FWP ER/CSRM Conditions. It was assumed that the number and location of beach access points would remain unchanged from the existing condition. Access locations may need to be modified in order to construct the dunes; however, to comply with the Texas Open

Beaches Act, access must be maintained similar to the existing condition, so it is assumed the method of access would not be changed and location movements would be insignificant for purposes of this analysis.

3.8 OPEN BAY BOTTOM MODELING

Constructing and operating the Galveston Bay Storm Surge System would primarily impact open bay bottom habitat through loss of subtidal bay bottom habitat. This presented two challenges: how to determine the mitigation need and how to mitigate for open bay bottoms.

<u>Challenge 1:</u> Quantification of impacts to open bay bottom habitat are difficult because the subtidal bay bottom areas are part of a large and dynamic system for which no community-based models are available. The interagency team found that species-specific models only targeted specific habitats, not the whole system and seasonal shifts in fauna and siltation further complicated selecting a species-specific model. Utilizing multiple species-specific models was considered; however, it became apparent that as more models with different assumptions and variables/inputs are used to capture unique habitat requirements, the statistical complexity of the overall HEP analysis increased making the results more uncertain. The team narrowed the potential species-specific models down to the Southern Flounder HSI model (Enge & Mulholland 1985) as the preferred model. However, it became apparent after further investigation into the model that the higher salinities observed near Bolivar Roads would have resulted in a suboptimal score for the existing condition, which was not indicative of the health of the benthic communities located in those sediments and would therefore undervalue the existing habitat suitability. In the absence, of suitable models, the interagency team considered developing a model that would be better suited to quantifying open bay bottom impacts; however, this raised concerns over how to mitigate for open bay bottom.

<u>Resolution 1:</u> Since the quality of the open bay bottom habitats are challenging to quantify, it was determined to forego a species-specific model or development of a community-based model and assume habitat quality. The following assumptions were applied to the habitat quality assessment:

Existing Conditions. The quality of the open bay bottom is assumed to have an HSI score of 1.0 (optimal conditions). The resource agencies and study team agree that all open bay bottom areas in Galveston Bay are consistent in quality, with no known low-quality areas, therefore, the open bay bottom in Galveston Bay is considered optimal for the study area. By applying the surrogate score, the risk of underestimating the existing habitat quality, as shown for the flounder model or a suite of species-specific models, is avoided because all areas are assumed to be optimal.

FWOP Conditions. The quality of the open bay bottom is unchanged in the future, despite RSLC. Subtidal open bay bottom is one of the few habitats where the quality is not expected to measurably change because of RSLC and projecting those changes would be highly speculative; therefore, the values were not adjusted for those expected changes.

FWP CSRM Conditions. Any location that was permanently converted to non-subtidal habitat (e.g. permanent structures and gate islands) was assumed to be a complete and permanent loss (HSI = 0.0 or no habitat present). This assumes the HUs for the open bay bottom impacts are equal to the acreage of the structure. It is also assumed that dredging disturbances are temporary in nature and recolonization of the substrates by interstitial species is highly likely, resulting in temporary (several months to a maximum of 2 years) degradation, but no permanent loss of subtidal habitat.

By assigning a score of 0.0 to all converted areas, the impact is fully accounted for but may be overestimated, resulting in over-mitigating for the impacts. This is because the surface of the permanent structures, particularly the scour pads, will provide hard substrate for sessile organisms to colonize. However, the colonization rate/extent and actual comparative value to open bay bottom and other subtidal habitats would be highly speculative and were therefore not attempted to be quantified. The team felt this approach was erring on the side of the resource.

Challenge 2: The resource agencies and study team had significant concerns over how to mitigate for open bay bottom. Typically, the first mitigation technique considered to offset the loss is to identify low quality existing habitat and restore the habitat to increase the quality and gain lift. However, no low-quality open bay bottom habitat exists within a reasonable distance to the impact area to offset the loss (i.e. the quality of open bay bottom is consistent where present and can't be modified to create lift). The second most common mitigation technique would be to create habitat somewhere within a reasonable distance to the impact area. To create additional open bay bottom, other habitat types, such as oyster reefs, sea grass meadows, or salt marshes, would have to be converted to open bay bottom. This would result in losses to habitat types that are each substantially more productive, relatively scarce and considered significant habitats that would result in a net-loss of those habitat types that would then require mitigation. Terrestrial habitat could also be converted to open bay bottom, but there is concern that where terrestrial habitat could be converted it would be too far inland to truly offset the loss and the new site would become part of an estuarine system rather than open bay system.

Resolution 2: 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 the agency uses 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). This assessment methodology applies a ratio to the number of open bay bottom HUs, as determined by the application of surrogate HSI scores, to estimate the equivalent HUs of oyster reef. Oyster reef was selected as the equivalent habitat because of its high productivity in the open bay bottom system. The ratio of average productivity across all three trophic levels between subtidal flat (open bay bottom) and oyster reef is estimated to be 8.9 to 1 (Peterson *et al.* 2007), meaning that 8.9 HUs for open bay bottom would be equal to one habitat unit of oyster reef.

4.0 MODELING RESULTS

Individual species HSI scores were generated for each measure location using the species-specific spreadsheet calculators. The HSI scores were then multiplied by the acreages to calculate the Habitat Units (HUs). HUs represent a numerical combination of quality (i.e. Habitat Suitability Index) and quantity (acres) existing at any given point in time.

HUs represent a single point in time; however, the impacts of any of the proposed actions would occur over the entire planning horizon (50 years). To account for the value of change over time, when HSI scores are not available for each year of analysis, the cumulative HUs are calculated using a formula that requires only the target year (TY) and the area estimates (USFWS 1980). The following formula was used:

$$\int_0^T HU\,dt = (T_2 - T_1)\left[\left(\frac{A_1H_1 + A_2H_2}{3}\right) + \left(\frac{A_2H_1 + A_1H_2}{6}\right)\right]$$

Where:

$$\int_0^T HU\,dt = Cumulative\,HUs$$

T1= first target year of time interval

T2 = last target year of time interval

A1 = area of available habitat at beginning of time interval

A2= area of available habitat as the end of time interval

H1 = Habitat Suitability Index at the beginning of time interval

H2 = Habitat Suitability Index at the end of time interval

3 and 6 = constants derived from integration of HSI x Area for the interval between any two target years

This formula was developed to precisely calculate cumulative HUs when either HSI or area or both change over a time interval, which is common when dealing with the unevenness found in nature. HU gains or losses are annualized by summing the cumulative HUs calculated using the above equation across all target years in the period of analysis and dividing the total (cumulative HUs) by the number of years in the planning horizon (i.e. 50 years). This calculation results in the Average Annual Habitat Units (AAHUs) (USFWS 1980).

The impact of a project can be quantified by subtracting the FWP scenarios benefits/impacts from the FWOP benefits/impacts. The difference in AAHUs between the FWOP and the FWP represents the net impact attributable to the project in terms of habitat quantity and quality, where a positive number results in net benefits and a negative result in net loss.

The following sections show the remaining and net change value of habitats within the study area under the FWOP and FWP at three TYs. Attachment A includes a copy of the spreadsheets used to calculate AAHUs.

4.1 ECOSYSTEM RESTORATION

Each of the six alternatives presented in section 1.2.1 contain one or more of eight measures. Table 6 shows a summary of the AAHUs of all models for each measure, while Table 7 shows the AAHUs for selected TYs for each measure by species model.

Table 6. Net Change in AAHUs by Measure

Measure	FWOP (AAHUs)	FWP (AAHUs)	Net Change (AAHUs)	Acres
G-28 Bolivar Peninsula and West Bay GIWW Shoreline and Island Protection				
American Oyster	0.0	8.5	8.5	18.0
Brown Pelican	1.6	203.8	202.2	326.0
Brown Shrimp (BU)	0.0	747.1	747.1	664.0
Brown Shrimp (Accretion)	0.0	187.4	187.4	203.0
Brown Shrimp (Protection)	247.0	375.2	128.2	395.0
American Alligator (Protection)	16.5	38.5	22.0	47.0
Total	265.1	1,560.5	1,295.4	1,653.0
B-2 Follets Island Gulf Beach and Dune Restoration				
Kemp's Ridley Sea Turtle	6.4	246.5	240.1	691.0
Total	6.4	246.5	240.1	691.0
B-12 Bastrop Bay, Oyster Lake, West Bay, and GIWW Shoreline Protection*				
American Oyster	0.0	1.2	1.2	2.0
Brown Shrimp (BU)	0.0	962.3	962.3	551.0
Brown Shrimp (Accretion)	0.0	120.0	120.0	130.0
Brown Shrimp (Protection)	189.6	393.3	203.7	414.0
American Alligator (Protection)	9.4	19.6	10.3	24.0
Total	199.0	1,496.4	1,297.5	1,121.0
M-8 East Matagorda Bay Shoreline Protection				
American Oyster	0.0	6.8	6.8	15.0
Brown Pelican	0.0	61.9	61.9	96.0
Brown Shrimp (BU)	0.0	225.8	225.8	237
Brown Shrimp (Accretion)	0.0	58.6	58.6	65.0
Brown Shrimp (Protection)	148.0	250.3	102.3	275.0
American Alligator (Passive)	37.7	63.8	26.1	78.0

Measure	**FWOP (AAHUs)**	**FWP (AAHUs)**	**Net Change (AAHUs)**	**Acres**
Total	185.7	667.2	481.5	766.0
CA-5 Keller Bay Restoration				
American Oyster	0.0	1.9	1.9	4.0
Spotted Seatrout	1.6	239.8	238.2	296.0
Total	1.6	241.7	240.1	300.0
CA-6 Powderhorn Shoreline Protection and Wetland Restoration				
Brown Shrimp (BU)	900.7	919.1	18.4	2,416.0
Total	900.7	919.1	18.4	2,416.0
SP-1 Redfish Bay Protection and Enhancement				
American Oyster	0.0	0.5	0.5	2.0
Brown Pelican	0.5	264.6	264.1	423.0
Spotted Seatrout	19.8	3,255.6	3,235.9	3,028.0
Total	20.3	3,520.7	3,500.5	3,453.0
W-3 Port Mansfield Channel, Island Rookery, and Hydrologic Restoration				
Brown Pelican	0.0	22.0	22.0	28.0
Kemp's Ridley Sea Turtle	3.9	152.1	148.2	497.0
Spotted Seatrout	26,088.2	39,854.6	13,766.3	56,333.0
Total	26,092.1	40,028.7	13,936.5	56,858.0

Table 7. Modeling Results for Each 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	0.0	10.2	10.2	0.0	8.1	8.1	0.0	7.4	7.4
Brown Pelican	15.0	7.1	212.3	205.2	0.0	203.9	203.9	0.0	200.0	200.0
Brown Shrimp (BU)	0.0	0.0	418.3	418.3	0.0	972.3	972.3	0.0	788.6	786.6
Brown Shrimp (Accretion)	0.0	0.0	189.2	189.2	0.0	189.2	189.2	0.0	189.2	189.2
Brown Shrimp (Protection)	368.2	373.6	379.0	5.4	264.9	373.6	108.7	0	373.6	373.6
American Alligator (Protection)	38.5	38.5	38.5	0.0	9.0	38.5	29.5	0	38.5	38.5
B-2 Follets Island Gulf Beach and Dune Restoration										
Kemp's Ridley Sea Turtle	98.0	58.0	608.0	550.0	49.0	441.8	392.8	46.0	216.2	170.2
B-12 Bastrop Bay, Oyster Lake, West Bay, and GIWW Shoreline Protection*										
American Oyster	0	0	1	1	0	1	1	0	1	1
Brown Shrimp (BU)	0	0	347	347	0	1,180	1,180	0	1,517	1,517
Brown Shrimp (Accretion)	0	0	121	121	0	121	121	0	121	121
Brown Shrimp (Protection)	386	392	397	5	136	392	256	0	392	392
American Alligator (Protection)	19.6	19.6	19.6	0.0	6.6	19.6	13.0	0	19.6	19.6
M-8 East Matagorda Bay Shoreline Protection										
American Oyster	0.0	0.0	8.1	8.1	0.0	6.8	6.8	0.0	5.5	5.5
Brown Pelican	0.0	0.0	67.9	67.9	0.0	62.2	62.2	0.0	55.9	55.9

Target Year (TY)	Existing Condition	TY 1 (2035)			TY 31 (2065)			TY 51 (2085)		
		FWOP	FWP	Change	FWOP	FWP	Change	FWOP	FWP	Change
Brown Shrimp (BU)	0.0	0.0	149.3	149.3	0.0	225.5	225.5	0.0	357.8	357.8
Brown Shrimp (Accretion)	0.0	0.0	60.3	60.3	0.0	58.9	58.9	0.0	58.1	58.1
Brown Shrimp (Protection)	256.7	255.0	255.0	0.0	139.5	249.0	109.5	0.0	246.0	246.0
American Alligator (Protection)	63.8	63.8	63.8	0.0	36.0	63.8	27.8	0.0	63.8	63.8
CA-5 Keller Bay Restoration										
American Oyster	0.0	0.0	2.5	2.5	0.0	2.1	2.1	0.0	1.7	1.7
Spotted Seatrout	239.8	0.0	239.8	239.8	0.0	239.8	239.8	0.0	239.8	239.8
CA-6 Powderhorn Shoreline Protection and Wetland Restoration										
Brown Shrimp (BU)	610.7	1136.2	1197.2	61.0	1137.2	1137.2	0.0	124.0	124.0	0.0
SP-1 Redfish Bay Protection and Enhancement										
American Oyster	0.0	0.0	0.7	0.7	0.0	0.5	0.5	0.0	0.4	0.4
Brown Pelican	74.5	0.0	267.7	267.7	0.0	266.3	266.6	0.0	265.0	265.0
Spotted Seatrout	3,027.9	0.0	3,257.9	3,257.9	0.0	3,257.9	3,257.9	0.0	3,257.9	3,257.9
W-3 Port Mansfield Channel, Island Rookery, and Hydrologic Restoration										
Brown Pelican	0.49	0.0	23.0	23.0	0.0	23.0	23.0	0.0	23.0	23.0
Kemp's Ridley Sea Turtle	143.0	42.0	437.0	395.0	17.0	225.0	208.0	15.0	152.0	137.0
Spotted Seatrout	38,384.2	37,786.4	46,756.4	8,970.0	24,687.3	39,275.6	14,588.3	12,066.3	30,848.4	18,782.1

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

The results presented in the previous tables were then used to determine the net change in AAHUs by alternative. The AAHU for each species model was added together for each TY. The AAHUs summed by measure (Table 6) were then appropriately added to each alternative (Table 8) to identify the total AAHUs of each alternative (Table 9). As can be expected, implementation of Alternative 1 would produce the most benefits because it has the most measures. These benefit values were used in the CE/ICA analysis. Discussion of the CE/ICA is available in Appendix E-3 of the Feasibility Main Report.

Table 8. ER Measures by Alternative

Alt	G-28	B-2	B-12	M-8	CA-5	CA-6	SP-1	W-3	Total
Alt 1	1,295.4	240.1	1,297.5	481.5	240.1	18.4	3,500.5	13,936.6	21,010.1
Alt 2	--	240.1	1,297.5	--	--	18.4	--	13,936.6	15,492.6
Alt 3	1,295.4	240.1	0	0	0	0	0	13,936.6	15,472.1
Alt 4	1,295.4	0	1,297.5	481.5	240.1	18.4	3,500.5	13,936.6	20,770.0
Alt 5	1,295.4	240.1	1,297.5	--	--	--	--	--	2,833
Alt 6	1,295.4	240.1	1,297.5	--	--	18.4	--	--	2,851.4

Table 9. Net AAHUs for Each Alternative

Alternative	Net Change in AAHUs	Acres (FWP 2035)
Alt 1	21,010.1	67,258.0
Alt 2	15,492.6	61,086.0
Alt 3	15,472.1	59,202.0
Alt 4	20,770.0	9,709.0
Alt 5	2,833.0	3,465.0
Alt 6	2,851.4	5,881.0

4.1.1 Qualitative Benefits of the ER Measures

While the ecological modeling undertaken for the ER measures captured many of the benefits that would be provided by the breakwaters, there would also be additional qualitative benefits beyond those quantified by the ecological modeling. These breakwaters would provide far reaching benefits to thousands of acres of coastal marsh, seagrasses, coastal barriers, and shorelines. Some examples of these benefits include a reduction in turbidities, stabilization of habitats through the reduction of wave energy, provide habitat, and stabilize the interface between the bay and marsh habitats.

In addition to the specific benefits listed above, the breakwaters would help stabilize shorelines which are in most cases the distal edge of large complex estuarine systems. These ecosystems are integrally related and instability or degradation of a portion of any portion of these systems can have negative effects which cascade throughout these systems. The stabilization of these shorelines would also make them more resilient to anthropogenic activities (*e.g.* ship wakes or dredging) and coastal storms which can result in massive erosion over a short period of time.

The State's Bureau of Economic Geology and TCEQ have documented endemic shoreline erosion and high turbidities throughout the Coastal zones in Texas. Elevated turbidity prevents light from penetrating the water column and contributes to the reduction of the biological productivity for these systems. The breakwaters included in the final plan would reduce turbidity in two ways, first by reducing fetch and ship wakes and second, by helping to trap and hold sediment that washes over or through the structures.

Several studies conducted by NOAA, Ducks Unlimited, the USACE, and the University of South Alabama (Scyphers *et al.* 2014) have demonstrated that breakwaters used to stabilize degraded estuarine shorelines can provide high quality habitat for sessile organisms like oysters and numerous small or juvenile fish and crustacean species. Breakwaters are constructed using rip-rap, concrete domes, or reef balls which provide hard substrate and crevices for habitat. These studies demonstrate that ecologically degraded shorelines can be augmented with breakwaters to increase species richness and diversity. Examples of benefits provided by sessile bivalves like oysters and mussels include water filtration, benthic-pelagic coupling, enhanced denitrification and ecological services (Scyphers *et al.* 2014). The breakwater structures also provide additional loafing habitat for migratory and resident coastal birds.

Breakwaters also reduce wave energies that caused degradation or prevent the colonization of important vegetation species in shallow estuaries. Several examples, including along the GIWW and the J.D. Murphree WMA have resulted in large scale colonization of marsh grass species between newly installed breakwaters and the existing shoreline. These areas were not planted or augmented other than the newly installed breakwaters reduced the wave energy. In some areas this can cause a domino effect because the structure of the vegetation also reduces wave energy and the benefits can extend far beyond the structures themselves. While it is almost certain to happen given the length of the ER measures, predicting exactly where it will occur is difficult and there for was not included in the ER modeling.

Most of the breakwaters included in the final plan are situated at the Interface between the bay and marsh habitat. This interface is a critical area that can influence larval recruitment of the larger interior systems. Many commercially and recreationally important species like the brown shrimp, white shrimp, blue crab, spotted seatrout, redfish, flounder, and croaker rely on these habitats as nurseries and foraging areas. If the shorelines along the channels and shorelines that lead into the marshes are degraded it could discourage recruitment or use which could substantially reduce the potential capacities for these important species.

The ER measures that contain breakwaters are in close proximity to the following protected areas: McFaddin NWR, the Anahuac NWR, the Brazoira NWR, the San Bernard NWR, the Big Boggy NWR, the Aransas NWR, the Candy Cain Abshier WMA, the Justin Hurst WMA, and the Powderhorn WMA. Those NWRs and WMAs are adjacent to or nearby the GIWW and total approximately 342,000 acres which is comprised of restored, scarce, or highly valuable habitats that support numerous resident species, migratory avian species, and endangered species. The benefits that these breakwaters would have to the overall health of these ecosystems is immeasurable and of national significance.

4.2 CSRM

CSRM impact assessments addressed direct and indirect impacts of implementing the action. Direct impacts are those that are caused by the action and occur at the same time and place, while indirect impacts are those caused by the action but occur later in time or further removed in distance.

4.2.1 Impact Assessment of Open Bay Bottom Habitat

After the area of permanent loss was identified at each location, the HUs were calculated by multiplying the acreage by the surrogate HSI score of 1.0. This resulted in the total HUs/AAHUs under the existing and FWOP condition and the loss expected under the FWP condition (Table 10).

Table 10. Net Change in AAHU to Open Bay Bottom

Measure	Existing/FWOP				FWP				Net Change (AAHU)
	Acres	**HSI**	**HUs**	**AAHU***	**Acres**	**HSI**	**HUs**	**AAHU**	
Bolivar Roads Gate System	117.0	1.0	117.0	117.0	117.0	0.0	0.0	0.0	-117.0
Galveston Ring Barrier System	23.0	1.0	23.0	23.0	23.0	0.0	0.0	0.0	-23.0
Clear Lake Gate System	6.1	1.0	6.1	6.1	6.1	0.0	0.0	0.0	-6.1
Dickinson Bayou Gate System	15.5	1.0	15.5	15.5	15.5	0.0	0.0	0.0	-15.5
Total				**161.6**				**0.0**	**-161.6**

* HUs remain the same in all TYs; therefore, the AAHU is the same as the HU.

To these values, the meta-analysis methodology was employed which involved applying an 8.9 to 1 ratio (8.9 HUs for open bay bottom would be equal to one habitat unit of oyster reef) to the number of open bay bottom HUs to determine the estimate of the equivalent HUs. . A total of 17.4 AAHUs of equivalent oyster reef would require mitigation (Table 11).

Table 11. Results of without project condition habitat unit conversion for Open Bay Bottom without project

Measure	Open Bay Bottom Loss (Net AAHU)	Conversion Ratio (Open Bay Bottom: Oyster Reef)	Equivalent Oyster Reef (Net AAHU)
Bolivar Roads Gate System	-117.0	8.9:1	-13.1
Galveston Ring Barrier System	-23.0	8.9:1	-2.6
Clear Lake Gate System	-6.1	8.9:1	-0.7
Dickinson Bayou Gate System	-15.5	8.9:1	-1.7
Total:	**-161.6**		**-18.1**

4.2.2 Impact Assessment of Other Habitats

The post-TSP CSRM HEP analysis was performed on Alternative B Modified in February/March 2020 to evaluate impacts to ecological resources under baseline, FWOP, and FWP conditions. The Galveston Seawall Improvements and the non-structural features of the alternative would not have any impact to ecosystems since all work would be completed within urbanized areas and where existing hardened structures exist.

No modeling was completed for the South Padre Island or Bolivar Peninsula and West Galveston Island Beach and Dune Improvements components of the CSRM actions because these would not be expected to result in any adverse impacts that would require mitigation. Both measures would be expected to produce benefits similar to ER measures; however, the benefit to the habitat is considered an ancillary benefit and is therefore not included in calculating the NED plan.

Table 12. Net Change in AAHUs by Measure

	FWOP (AAHUs)	FWP (AAHUs)	Net Change (AAHUs)	Acres
Bolivar Roads Gate Structure				
Brown Shrimp (Direct)	17.0	0.0	-17.0	78.0
Brown Shrimp (Indirect)	790.6	2.3	-788.3	1,148.0
American Alligator	12.2	0.2	-12.0	78.0
Total	819.8	2.5	-817.3	1,304.0
Galveston Ring Barrier				
Brown Shrimp	37.4	0.1	-37.3	44.0
American Alligator	8.9	0.1	-8.8	50.0
Total	46.3	0.2	-46.1	94.0

Dickinson Bay Surge Gate				
Brown Shrimp	3.7	0.0	-3.7	8.0
American Oyster	1.0	0.0	-1.0	2.0
Total	4.66	0.0	-4.66	10.0
Clear Lake Surge Gate				
Brown Shrimp	1.9	0.0	-1.9	4.0
American Oyster	1.8	0.0	-1.8	4.0
Total	3.7	0.0	-3.7	8.0

Table 13. Modeling Results for Each 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	0.0	-12.5	25.0	0.0	-25.0	7.5	0.0	-7.5
American Alligator	25.6	32.2	0.0	-32.2	3.3	0.0	-3.3	3.0	0.0	-3.0
Galveston Ring Barrier										
Brown Shrimp	14.0	41.5	0.0	-41.5	53.2	0.0	-53.2	3.0	0.0	-3.0
American Alligator	9.3	12.2	0.0	-12.2	1.9	0.0	-1.9	1.6	0.0	1.6
Dickson Bay Surge Gate										
Brown Shrimp	4.6	4.2	0.0	-4.2	3.5	0.0	-3.5	3.2	0.0	-3.2
American Oyster	1.3	1.1	0.0	-1.1	0.9	0.0	-0.9	0.8	0.0	-0.8
Clear Lake Surge Gate										
Brown Shrimp	2.3	2.2	0.0	-2.2	1.8	0.0	-1.8	1.7	0.0	-1.7
American Oyster	2.4	2.1	0.0	-2.1	1.7	0.0	-1.7	1.5	0.0	-1.5
Indirect Impacts										
Tidal Amplitude										
Brown Shrimp	229.6	229.6	0.0	-229.6	1,070.1	0.0	-1,070.1	989.3	0.0	-989.3

As summarized in Table 14, a net loss in AAHUs indicates unavoidable impacts which would require mitigation. Based on the results of the modeling, mitigation will be required for 1,577.6 acres of direct and indirect impacts to wetlands, open bay bottom, and oyster reefs

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 Storm Surge Barrier System

Impact	Acres	AAHUs
Direct		
Palustrine Wetlands	128.0	-20.8
Estuarine Wetlands	134.0	-59.9
Open Bay Bottom	161.6	-18.1
Oyster	6.0	-2.8
Total Direct Impacts	429.6	-101.6
Indirect		
Tidal Prism Change	1,148.0	-788.3
Total Indirect Impacts	1,148.0	-788.3
Total Impacts	1,577.6	-880.9

4.3 MITIGATION

Nine sites were identified as potential mitigation sites. The following results show the HEP analysis completed for each site. This analysis was completed to confirm that sufficient mitigation locations exist and to understand the potential cost of mitigation in relation to overall project costs.

Table 15. Potential Lift (Net Change in AAHUs) that Can Be Gained at Each of the Mitigation Sites

Mitigation Location	AAHUs	Acreage
Estuarine	**876.2**	**1,299**
Horseshoe Lake Site 1-3 (Direct Impacts)	37.6	62.0
Sievers Cove (Direct and Indirect Impacts)	491.8	667.0
Greens Lake (Indirect Impacts)	340.7	562.0
Clear Lake (Direct Impacts)	2.1	3.0
Dickinson Bayou (Direct Impacts)	4.0	6.0
Palustrine	**20.8**	**32.0**
Marquette (Direct Impacts)	20.8	32.0
Oyster	**20.5**	**45.0**
Evia Island (Direct Impacts)	14.2	30.0
Dickinson Bayou (Direct Impacts)	3.0	7.0
Alligator Point (Direct Impacts)	4.3	10.0

Table 16. Mitigation Summary

Mitigation	Acres	AAHUs
Direct		
Palustrine	32.0	20.8
Estuarine	92.0	59.9
Oyster (Open Bay Bottom)	40.0	18.5
Oyster	7.0	3.0
Total Direct Mitigation	171.0	102.2
Indirect		
Estuarine (Tidal Prism Change)	1,207.0	816.3
Total Indirect Mitigation	1,207.0	816.3
Total Mitigation	**1,378.0**	**918.5**

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ATTACHMENT A

Modeling Spreadsheets for ER, CSRM, and Mitigation Measures

Bolivar Roads Gate System

Impact Modeling

Bolivar Roads Navigation Gate & Tie-In Structures (Direct Impacts) -- Estuarine Marsh

Project: Bolivar Roads Navigation Gate & Tie-In Structures

Brown Shrimp HSI Model Spreadsheet

Condition: Future Without Project

Variable			SI		SI		SI
		TY 0		TY 1		TY 31	
	Acreage by TY	78		107		163	
V1	% of estuary covered by vegetation (marsh and seagrass).	3	0.03	4	0.04	6	0.06
V2	Substrate Composition	soft bc	1.00	soft bc	1.00	soft bc	1.00
V3	Mean salinity - spring	18	1.00	18	1.00	19	1.00
V4	Mean water temperature - spring	24	1	24	1	24	1
		HSI=	0.10	HSI=	0.12	HSI=	0.15
		vba fn	#NAME?		######		######

Condition: Future With Project

Variable			SI		SI		SI
		TY 0		TY 1		TY 31	
	Acreage by TY	78		0		0	
V1	% of estuary covered by vegetation (marsh and seagrass).	3	0.03	0	0.00	0	0.00
V2	Substrate Composition	soft bc	1.00	soft bc	1.00	soft botto	1.00
V3	Mean salinity - spring	18	1.00	18	1.00	19	1.00
V4	Mean water temperature - spring	24	1	24	1	24	1
		HSI=	0.10	HSI=	0.00	HSI=	0.00
		vba fn	######		######		######

Condition: Future Without Project

Variable			SI		SI		SI
		TY 51		TY		TY	
		75					
V1	% of estuary covered by vegetation (marsh and seagrass).	3	0.03				
V2	Substrate Composition	soft bc	1.00				
V3	Mean salinity - spring	19	1.00				
V4	Mean water temperature - spring	24	1				
		HSI=	0.10	HSI=		HSI=	
		vba fn	#NAME?		######		######

Condition: Future With Project

Variable			SI		SI		SI
		TY 51		TY		TY	
		0					
V1	% of estuary covered by vegetation (marsh and seagrass).	0	0.00				
V2	Substrate Composition	soft bc	1.00				
V3	Mean salinity - spring	19	1.00				
V4	Mean water temperature - spring	24	1				
		HSI=	0.00	HSI=		HSI=	
		vba fn	######		######		######

Condition: Future Without Project

Variable			SI		SI		SI
		TY		TY		TY	
V1	% of estuary covered by vegetation (marsh and seagrass).						
V2	Substrate Composition						
V3	Mean salinity - spring						
V4	Mean water temperature - spring						
		HSI=		HSI=		HSI=	
		vba fn	#NAME?		######		######

Condition: Future With Project

Variable			SI		SI		SI
		TY		TY		TY	
V1	% of estuary covered by vegetation (marsh and seagrass).						
V2	Substrate Composition						
V3	Mean salinity - spring						
V4	Mean water temperature - spring						
		HSI=		HSI=		HSI=	
		vba fn	######		######		######

Assumptions/Notes:

- Cover types calculated using NOAA CCAP 2010 landcover dataset and NOAA marsh migration datasets
- There is a significant jump in estuarine emergent wetland acres between TY 0 and TY 1. This was seen when calculating cover types for ER measures as well. This is due to the change in cover type datasets between baseline and FWOP/FWP
- FWOP conditions assume nothing is constructed and estuarine emergent wetland migration layers are used as is based on changes of SLR
- FWP conditions assume all cover type acres turn to "infrastructure" by 2035 and remain that way through the end of the project life 2085
- Assuming soft bottom substrate for open water, estuarine, and developed areas because model does not allow this to be broken out. Substrate is held constant.
- Temperature remains the same through the end of the project life
- 20% increase applied to baseline salinties from 2017-2085

-Important to note that by TY 51, spring salinity variable is 38.2 ppt which is above that of seawter (32 ppt)

Acreage Calculations

FWOP		FWP	
TY 0		TY 0	
Develc	27.184	Develop	27.18399
Open \	2639.3	Open W	2639.337
Pal. W	78.421	Pal. We	78.42103
Est. W	78.422	Est. We	78.42195
Ratio	**2.857**	**Ratio**	**2.856962**
TY 1		TY 1	
Develc	5.0355	Develop	0
Open \	2613.5	Open W	0
Pal. W	98.112	Pal. We	0
Est. W	106.71	Est. We	0
Ratio	**3.9279**	**Ratio**	**#DIV/0!**
TY 31		TY 31	
Develc	4.0077	Develop	0
Open \	2646.4	Open W	0
Pal. W	9.8515	Pal. We	0
Est. W	163.14	Est. We	0
Ratio	**6.1326**	**Ratio**	**#DIV/0!**
TY 51		TY 51	
Develc	3.8079	Develop	0
Open \	2736	Open W	0
Pal. W	8.7149	Pal. We	0
Est. W	74.812	Est. We	0
Ratio	**2.7219**	**Ratio**	**#DIV/0!**

Bolivar Roads Navigation Gate & Tie-In Structures (Direct Impacts) -- Estuarine Marsh

Brown Shrimp HSI Model Spreadsheet

Condition: Future Without Project

TY	Acres	HSI	Total HUs	Cumulative HUs
0	78	0.10	7.53	
1	107	0.12	12.51	9.92
31	163	0.15	24.98	552.28
51	75	0.10	7.24	305.59
Max TY=	**51**		**AAHUs=**	**17.0**

Condition: Future With Project

TY	Acres	HSI	Total HUs	Cumulative HUs
0	78	0.10	7.53	
1	0	0.00	0.00	2.51
31	0	0.00	0.00	0.00
51	0	0.00	0.00	0.00
Max TY=	**51**		**AAHUs=**	**0.0**

Net Change in AAHUs due to Project

Future With Project AAHUs	0.0
Future Without Project AAHUs	17.0
Net Change	-17.0

Bolivar Roads Navigation Gate & Tie-In Structures (Indirect Impacts) -- Estuarine Marsh

Project: Bolivar Roads Navigation Gate & Tie-In Structures

Brown Shrimp HSI Model Spreadsheet

Condition: Future Without Project

Variable			TY 0		TY 1		TY 31
Acreage by TY			1148		1148		1148
			SI		SI		SI
V1	% of estuary covered by vegetation (marsh and seagrass).	10	0.10	10	0.10	90	0.90
V2	Substrate Composition	muddy	0.80	muddy	0.80	soft bo	1.00
V3	Mean salinity - spring	18	1.00	18	1.00	19	1.00
V4	Mean water temperature - spring	24	1	24	1	24	1
		HSI=	**0.20**	HSI=	**0.20**	HSI=	**0.93**
		vba fn	**0.22**		**0.22**		**0.87**

Condition: Future With Project

Variable			TY 0		TY 1		TY 31
Acreage by TY			1148		0		0
			SI		SI		SI
V1	% of estuary covered by vegetation (marsh and seagrass).	10	0.10	10	0.10	90	0.90
V2	Substrate Composition	muddy	0.80	muddy	0.80	soft bo	1.00
V3	Mean salinity - spring	18	1.00	18	1.00	19	1.00
V4	Mean water temperature - spring	24	1	24	1	24	1
		HSI=	**0.20**	HSI=	**0.20**	HSI=	**0.93**
		vba fn	**0.22**		**0.13**		**0.93**

Condition: Future Without Project

Variable			TY 51		TY		TY
			1148				
			SI		SI		SI
V1	% of estuary covered by vegetation (marsh and seagrass).	80	0.80				
V2	Substrate Composition	soft bo	1.00				
V3	Mean salinity - spring	19	1.00				
V4	Mean water temperature - spring	24	1				
		HSI=	**0.86**	HSI=		HSI=	
		vba fn	**0.86**		**V1_ENTRY**		**V1_ENTRY**

Condition: Future With Project

Variable			TY 51		TY		TY
			0				
			SI		SI		SI
V1	% of estuary covered by vegetation (marsh and seagrass).	90	0.90				
V2	Substrate Composition	soft bo	1.00				
V3	Mean salinity - spring	19	1.00				
V4	Mean water temperature - spring	24	1				
		HSI=	**0.93**	HSI=		HSI=	
		vba fn	**0.87**		**V1_ENTRY**		**V1_ENTRY**

Condition: Future Without Project

Variable			TY		TY		TY
			SI		SI		SI
V1	% of estuary covered by vegetation (marsh and seagrass).						
V2	Substrate Composition						
V3	Mean salinity - spring						
V4	Mean water temperature - spring						
		HSI=		HSI=		HSI=	
		vba fn	**V1_ENTRY**		**V1_ENTRY**		**V1_ENTRY**

Condition: Future With Project

Variable			TY		TY		TY
			SI		SI		SI
V1	% of estuary covered by vegetation (marsh and seagrass).						
V2	Substrate Composition						
V3	Mean salinity - spring						
V4	Mean water temperature - spring						
		HSI=		HSI=		HSI=	
		vba fn	**V1_ENTRY**		**V1_ENTRY**		**V1_ENTRY**

Assumptions/Notes:

- Cover types calculated using NOAA CCAP 2010 landcover dataset and NOAA marsh migration datasets
- There is a significant jump in estuarine emergent wetland acres between TY 0 and TY 1. This was seen when calculating cover types for ER measures as well. This is due to the change in cover type datasets between baseline and FWOP/FWP
- FWOP conditions assume nothing is constructed and estuarine emergent wetland migration layers are used as is based on changes of SLR
- FWP conditions assume all cover type acres turn to "infrastructure" by 2035 and remain that way through the end of the project life 2085
- Assuming soft bottom substrate for open water, estuarine, and developed areas because model does not allow this to be broken out. Substrate is held constant.
- Temperature remains the same through the end of the project life
- 20% increase applied to baseline salinties from 2017-2085

-Important to note that by TY 51, spring salinity variable is 38.2 ppt which is above that of seawter (32 ppt)

Habitat Ratios

FWOP		FWP	
TY 0		TY 0	
Develop	27.18	Develo	27.184
Open W	2639	Open \	2639.34
Pal. We	78.42	Pal. W	78.421
Est. We	78.42	Est. W	78.4219
Ratio	**2.857**	**Ratio**	**2.85696**
TY 1		TY 1	
Develop	5.036	Develo	0
Open W	2614	Open \	0
Pal. We	98.11	Pal. W	0
Est. We	106.7	Est. W	0
Ratio	**3.928**	**Ratio**	**#DIV/0!**
TY 31		TY 31	
Develop	4.008	Develo	0
Open W	2646	Open \	0
Pal. We	9.852	Pal. W	0
Est. We	163.1	Est. W	0
Ratio	**6.133**	**Ratio**	**#DIV/0!**
TY 51		TY 51	
Develop	3.808	Develo	0
Open W	2736	Open \	0
Pal. We	8.715	Pal. W	0
Est. We	74.81	Est. W	0
Ratio	**2.722**	**Ratio**	**#DIV/0!**

Bolivar Roads Navigation Gate & Tie-In Structures (Indirect Impacts) -- Estuarine Marsh

Brown Shrimp HSI Model Spreadsheet

Condition: Future Without Project

TY	Acres	HSI	Total HUs	Cumulative HUs
0	1148	0.20	229.60	
1	1148	0.20	229.60	229.60
31	1148	0.93	1070.13	19495.96
51	1148	0.86	989.32	20594.47
Max TY=	**51**		**AAHUs=**	**790.6**

Condition: Future With Project

TY	Acres	HSI	Total HUs	Cumulative HUs
0	1148	0.20	229.60	
1	0	0.20	0.00	114.80
31	0	0.93	0.00	0.00
51	0	0.93	0.00	0.00
Max TY=	**51**		**AAHUs=**	**2.3**

Net Change in AAHUs due to Project

Future With Project AAHUs	2.3
Future Without Project AAHUs	790.6
Net Change	-788.3

Bolivar Roads Gate & Tie-Ins (Direct Impacts) -- Palustrine Wetlands

Project: Bolivar Roads Gate & Tie-Ins

Acres

American alligator HSI Model Spreadsheet

Acres

Condition: Future Without Project

Variable		TY 0	SI	TY 1	SI	TY 31	SI
V1	% wetland that is open water (ponds, bayous, canals).	10	0.50	10	0.50	10	0.50
V2	% open water in bayous, canals or > 1.2m deep	5	0.50	5	0.50	5	0.50
V3	Interspersion Class	Low	0.20	Low	0.20	Low	0.20
V4	% ponded area >=15 cm deep (May - September)	10	0.1	10	0.1	10	0.1
V5	% substrate exposed at MLT (May - Sep) - Tidal only						
	CI (tidal) | CI (non-tidal)		0.2154		0.2154		0.2154
		HSI=	0.3282	HSI=	0.3282	HSI=	0.3282

Condition: Future With Project

Variable		TY 0	SI	TY 1	SI	TY 31	SI
V1	% wetland that is open water (ponds, bayous, canals).	10	0.50	0	0.00	0	0.00
V2	% open water in bayous, canals or > 1.2m deep	5	0.50	0	0.00	0	0.00
V3	Interspersion Class	Low	0.20	Low	0.20	Low	0.20
V4	% ponded area >=15 cm deep (May - September)	10	0.1	0	0	0	0
V5	% substrate exposed at MLT (May - Sep) - Tidal only						
	CI (tidal) | CI (non-tidal)		0.2154		0		0
		HSI=	0.3282	HSI=	0	HSI=	0

Condition: Future Without Project

Variable		TY 51	SI	TY	SI	TY	SI
V1	% wetland that is open water (ponds, bayous, canals).	10	0.50				
V2	% open water in bayous, canals or > 1.2m deep	5	0.50				
V3	Interspersion Class	Low	0.20				
V4	% ponded area >=15 cm deep (May - September)	10	0.1				
V5	% substrate exposed at MLT (May - Sep) - Tidal only						
	CI (tidal) | CI (non-tidal)		0.2154				
		HSI=	0.3282	HSI=		HSI=	

Condition: Future With Project

Variable		TY 51	SI	TY	SI	TY	SI
V1	% wetland that is open water (ponds, bayous, canals).	0	0.00				
V2	% open water in bayous, canals or > 1.2m deep	0	0.00				
V3	Interspersion Class	Low	0.20				
V4	% ponded area >=15 cm deep (May - September)	0	0				
V5	% substrate exposed at MLT (May - Sep) - Tidal only						
	CI (tidal) | CI (non-tidal)		0				
		HSI=	0	HSI=		HSI=	

Condition: Future Without Project

Variable		TY	SI	TY	SI	TY	SI
V1	% wetland that is open water (ponds, bayous, canals).						
V2	% open water in bayous, canals or > 1.2m deep						
V3	Interspersion Class						
V4	% ponded area >=15 cm deep (May - September)						
V5	% substrate exposed at MLT (May - Sep) - Tidal only						
	CI (tidal) | CI (non-tidal)						
		HSI=		HSI=		HSI=	

Condition: Future With Project

Variable		TY	SI	TY	SI	TY	SI
V1	% wetland that is open water (ponds, bayous, canals).						
V2	% open water in bayous, canals or > 1.2m deep						
V3	Interspersion Class						
V4	% ponded area >=15 cm deep (May - September)						
V5	% substrate exposed at MLT (May - Sep) - Tidal only						
	CI (tidal) | CI (non-tidal)						
		HSI=		HSI=		HSI=	

Bolivar Roads Gate & Tie-Ins (Direct Impacts) -- Palustrine Wetlands

American alligator HSI Model Spreadsheet

Condition: Future Without Project

TY	Acres	HSI	Total HUs	Cumulative HUs
0	78	0.33	25.60	
1	98	0.33	32.16	28.88
31	10	0.33	3.28	531.70
51	9	0.33	2.95	62.36
Max TY=	**51**		**AAHUs=**	**12.2**

Condition: Future With Project

TY	Acres	HSI	Total HUs	Cumulative HUs
0	78	0.33	25.60	
1	0	0.00	0.00	8.53
31	0	0.00	0.00	0.00
51	0	0.00	0.00	0.00
Max TY=	**51**		**AAHUs=**	**0.2**

Net Change in AAHUs due to Project

Future With Project AAHUs	0.2
Future Without Project AAHUs	12.2
Net Change	-12.0

N

Legend

- Developed/Upland
- Estuarine Emergent Wetland
- Palustrine Emergent Wetland
- Open Water

USACE COASTAL TEXAS PROTECTION AND RESTORATION STUDY

Bolivar Roads Gate

Post-TSP CSRM HEP Analysis

FN JOB NO	TGL18185
FILE NAME	CoastalEIS_Bolivar Roads.mxd
DATE	3/18/2020
SCALE	1:77,000
DESIGNED	KLC

Figure 1
Baseline (TY 0)
Cover Types

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NAD 1983 StatePlane Texas Central FIPS 4203 Feet

N

Legend

- Developed/Upland
- Estuarine Emergent Wetland
- Palustrine Emergent Wetland
- Open Water

USACE COASTAL TEXAS PROTECTION AND RESTORATION STUDY

Bolivar Roads Gate
Post-TSP CSRM HEP Analysis

FN JOB NO	TGL18185
FILE NAME	CoastalEIS_Bolivar Roads.mxd
DATE	3/18/2020
SCALE	1:77,000
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Figure 2
FWOP 2035 (TY 1)
Cover Types

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NAD 1983 StatePlane Texas Central FIPS 4203 Feet

N

Legend

- Developed/Upland
- Estuarine Emergent Wetland
- Palustrine Emergent Wetland
- Open Water

USACE COASTAL TEXAS PROTECTION AND RESTORATION STUDY

Bolivar Roads Gate

Post-TSP CSRM HEP Analysis

FN JOB NO	TGL18185
FILE NAME	CoastalEIS_Bolivar Roads.mxd
DATE	3/18/2020
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Figure 3

FWOP 2065 (TY 31)

Cover Types

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NAD 1983 StatePlane Texas Central FIPS 4203 Feet

N

Legend
- Developed/Upland
- Estuarine Emergent Wetland
- Palustrine Emergent Wetland
- Open Water

USACE COASTAL TEXAS PROTECTION AND RESTORATION STUDY

Bolivar Roads Gate
Post-TSP CSRM HEP Analysis

FN JOB NO	TGL18185
FILE NAME	CoastalEIS_Bolivar Roads.mxd
DATE	3/18/2020
SCALE	1:77,000
DESIGNED	KLC

Figure 4
FWOP 2085 (TY 51)
Cover Types

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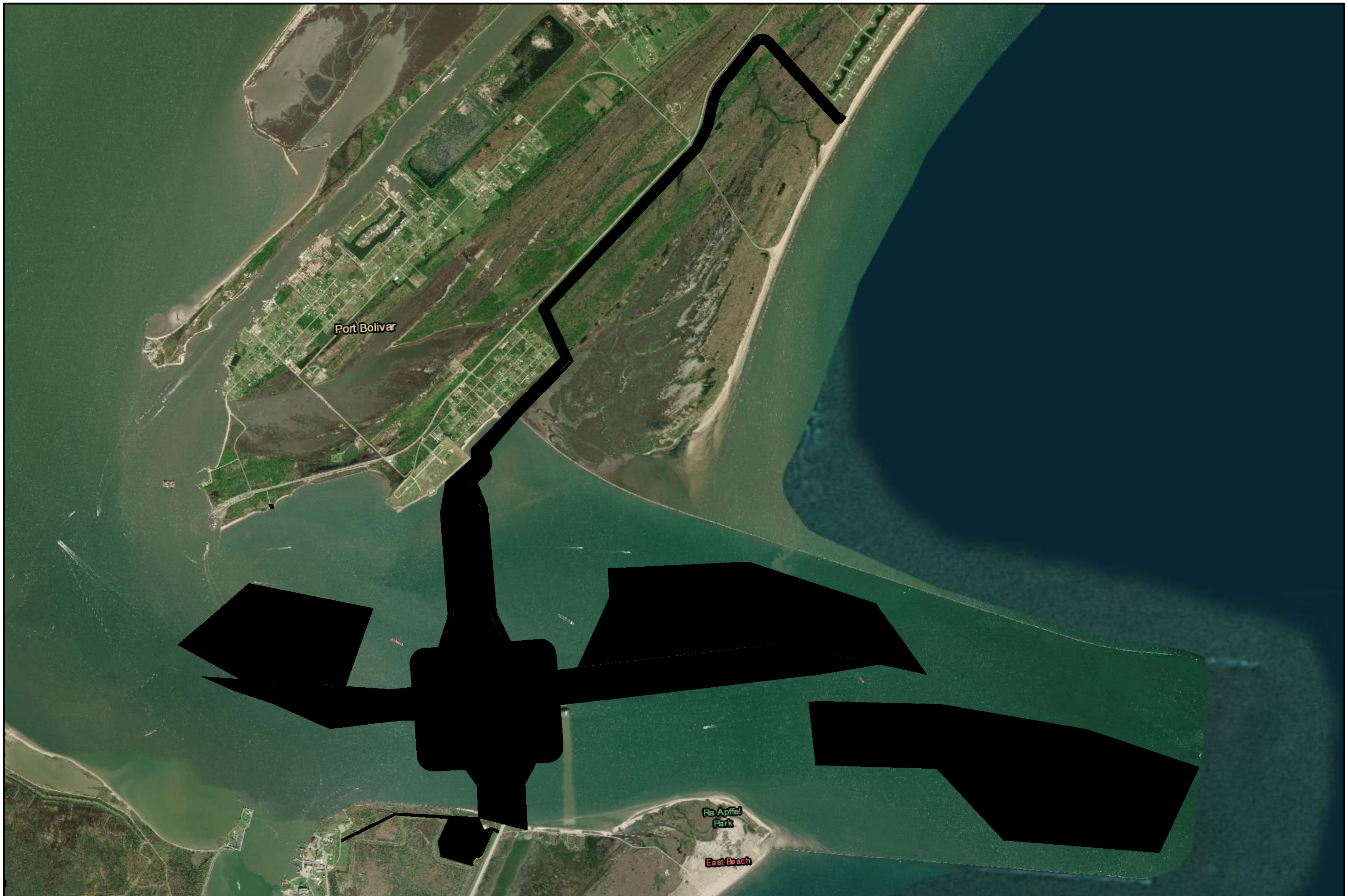
NAD 1983 StatePlane Texas Central FIPS 4203 Feet



N

Legend

FWP Galveston Ring Barrier - Infrastructure

USACE COASTAL TEXAS PROTECTION AND RESTORATION STUDY

Bolivar Roads Gate
Post-TSP CSRM HEP Analysis

FN JOB NO	TGL18185
FILE NAME	CoastalEIS_Bolivar Roads.mxd
DATE	3/18/2020
SCALE	1:77,000
DESIGNED	KLC

Figure 5
FWP 2035-2085
Cover Types

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NAD 1983 StatePlane Texas Central FIPS 4203 Feet

Galveston Ring Barrier System

Impact Modeling

Galveston Ring Barrier (Direct Impacts) -- Estuarine Marsh

Project: Galveston Ring Barrier

Brown Shrimp HSI Model Spreadsheet

Condition: Future Without Project

Variable		TY	0	TY	1	TY	31
	Acreage by TY		44		79		97
			SI		SI		SI
V1	% of estuary covered by vegetation (marsh and seagrass).	18	0.18	39	0.39	41	0.41
V2	Substrate Composition	soft bo	1.00	soft bo	1.00	soft bo	1.00
V3	Mean salinity - spring	23.5	0.93	24.7	0.91	28	0.84
V4	Mean water temperature - spring	21.9	1	21.9	1	21.9	1
		HSI=	0.32	HSI=	0.53	HSI=	0.55
		vba fn	0.32		0.53		0.51

Condition: Future With Project

Variable		TY	0	TY	1	TY	31
	Acreage by TY		44		0		0
			SI		SI		SI
V1	% of estuary covered by vegetation (marsh and seagrass).	18	0.18	0	0.00	0	0.00
V2	Substrate Composition	soft bo	1.00	soft bott	1.00	soft bo	1.00
V3	Mean salinity - spring	23.5	0.93	24.7	0.91	28	0.84
V4	Mean water temperature - spring	21.9	1	21.9	1	21.9	1
		HSI=	0.32	HSI=	0.00	HSI=	0.00
		vba fn	0.32		0.00		0.00

Condition: Future Without Project

Variable		TY	51	TY		TY	
			21				
			SI		SI		SI
V1	% of estuary covered by vegetation (marsh and seagrass).	6	0.06				
V2	Substrate Composition	soft bo	1.00				
V3	Mean salinity - spring	32.7	0.66				
V4	Mean water temperature - spring	21.9	1				
		HSI=	0.15	HSI=		HSI=	
		vba fn	0.15		V1_ENTRY		V1_ENTRY

Condition: Future With Project

Variable		TY	51	TY		TY	
			0				
			SI		SI		SI
V1	% of estuary covered by vegetation (marsh and seagrass).	0	0.00				
V2	Substrate Composition	soft bo	1.00				
V3	Mean salinity - spring	32.7	0.66				
V4	Mean water temperature - spring	21.9	1				
		HSI=	0.00	HSI=		HSI=	
		vba fn	0.00		V1_ENTRY		V1_ENTRY

Condition: Future Without Project

Variable		TY		TY		TY	
			SI		SI		SI
V1	% of estuary covered by vegetation (marsh and seagrass).						
V2	Substrate Composition						
V3	Mean salinity - spring						
V4	Mean water temperature - spring						
		HSI=		HSI=		HSI=	
		vba fn	V1_ENTRY		V1_ENTRY		V1_ENTRY

Condition: Future With Project

Variable		TY		TY		TY	
			SI		SI		SI
V1	% of estuary covered by vegetation (marsh and seagrass).						
V2	Substrate Composition						
V3	Mean salinity - spring						
V4	Mean water temperature - spring						
		HSI=		HSI=		HSI=	
		vba fn	V1_ENTRY		V1_ENTRY		V1_ENTRY

Assumptions/Notes:

- Cover types calculated using NOAA CCAP 2010 landcover dataset and NOAA marsh migration datasets
- There is a significant jump in estuarine emergent wetland acres between TY 0 and TY 1. This was seen when calculating cover types for ER measures as well. This is due to the change in cover type datasets between baseline and FWOP/FWP
- FWOP conditions assume nothing is constructed and estuarine emergent wetland migration layers are used as is based on changes of SLR
- FWP conditions assume all cover type acres turn to "infrastructure" by 2035 and remain that way through the end of the project life 2085
- Assuming soft bottom substrate for open water, estuarine, and developed areas because model does not allow this to be broken out. Substrate is held constant.
- Temperature remains the same through the end of the project life
- 20% increase applied to baseline salinties from 2017-2085
- Important to note that by TY 51, spring salinity variable is 38.2 ppt which is above that of seawter (32 ppt)
- Acres of wetland within federal placement area not accounted for and/or included in cover type analysis

Habitat Ratios

FWOP		FWP	
TY 0		TY 0	
Develop	140.36	Develo	140.36
Open W	108.89	Open \	108.89
Pal. Wet	50.31	Pal. W	50.31
Est. Wet	43.91	Est. W	43.91
Ratio	**18**	**Ratio**	**18**
TY 1		TY 1	
Develop	121.88	Develo	0.00
Open W	77.66	Open \	0.00
Pal. Wet	65.66	Pal. W	0.00
Est. Wet	77.82	Est. W	0.00
Ratio	**39**	**Ratio**	**#DIV/0!**
TY 31		TY 31	
Develop	121.92	Develo	0.00
Open W	115.91	Open \	0.00
Pal. Wet	10.32	Pal. W	0.00
Est. Wet	96.40	Est. W	0.00
Ratio	**41**	**Ratio**	**#DIV/0!**
TY 51		TY 51	
Develop	121.91	Develo	0.00
Open W	194.67	Open \	0.00
Pal. Wet	8.71	Pal. W	0.00
Est. Wet	19.52	Est. W	0.00
Ratio	**6**	**Ratio**	**#DIV/0!**

Galveston Ring Barrier (Direct Impacts) -- Estuarine Marsh

Brown Shrimp HSI Model Spreadsheet

Condition: Future Without Project

TY	Acres	HSI	Total HUs	Cumulative HUs
0	44	0.32	14.00	
1	78	0.53	41.54	26.55
31	96	0.55	53.20	1419.46
51	20	0.15	2.99	459.79
Max TY=	**51**		**AAHUs=**	**37.4**

Net Change in AAHUs due to Project

Future With Project AAHUs	0.1
Future Without Project AAHUs	37.4
Net Change	-37.3

Condition: Future With Project

TY	Acres	HSI	Total HUs	Cumulative HUs
0	44	0.32	14.00	
1	0	0.00	0.00	4.67
31	0	0.00	0.00	0.00
51	0	0.00	0.00	0.00
Max TY=	**51**		**AAHUs=**	**0.1**

Galveston Ring Barrier (Direct Impacts) -- Palustrine Marsh

Project: Galveston Ring Levee corrected

Acres

American alligator HSI Model Spreadsheet

Acres

Condition: Future Without Project

Variable		TY	0	TY	1	TY	31
			SI		SI		SI
V1	% wetland that is open water (ponds, bayous, canals).	10	0.50	10	0.50	10	0.50
V2	% open water in bayous, canals or > 1.2m deep	5	0.50	5	0.50	5	0.50
V3	Interspersion Class	Low	0.20	Low	0.20	Low	0.20
V4	% ponded area >=15 cm deep (May - September)	10	0.1	10	0.1	10	0.1
V5	% substrate exposed at MLT (May - Sep) - Tidal only						
	CI (tidal) | CI (non-tidal)		0.2154		0.2154		0.2154
		HSI=	0.3282	HSI=	0.3282	HSI=	0.3282

Condition: Future With Project

Variable		TY	0	TY	1	TY	31
			SI		SI		SI
V1	% wetland that is open water (ponds, bayous, canals).	10	0.50	0	0.00	0	0.00
V2	% open water in bayous, canals or > 1.2m deep	5	0.50	0	0.00	0	0.00
V3	Interspersion Class	Low	0.20	Low	0.20	Low	0.20
V4	% ponded area >=15 cm deep (May - September)	10	0.1	0	0	0	0
V5	% substrate exposed at MLT (May - Sep) - Tidal only						
	CI (tidal) | CI (non-tidal)		0.2154		0		0
		HSI=	0.3282	HSI=	0	HSI=	0

Condition: Future Without Project

Variable		TY	51	TY		TY	
			SI		SI		SI
V1	% wetland that is open water (ponds, bayous, canals).	10	0.50				
V2	% open water in bayous, canals or > 1.2m deep	5	0.50				
V3	Interspersion Class	Low	0.20				
V4	% ponded area >=15 cm deep (May - September)	10	0.1				
V5	% substrate exposed at MLT (May - Sep) - Tidal only						
	CI (tidal) | CI (non-tidal)		0.2154				
		HSI=	0.3282	HSI=		HSI=	

Condition: Future With Project

Variable		TY	51	TY		TY	
			SI		SI		SI
V1	% wetland that is open water (ponds, bayous, canals).	0	0.00				
V2	% open water in bayous, canals or > 1.2m deep	0	0.00				
V3	Interspersion Class	Low	0.20				
V4	% ponded area >=15 cm deep (May - September)	0	0				
V5	% substrate exposed at MLT (May - Sep) - Tidal only						
	CI (tidal) | CI (non-tidal)		0				
		HSI=	0	HSI=		HSI=	

Condition: Future Without Project

Variable		TY		TY		TY	
			SI		SI		SI
V1	% wetland that is open water (ponds, bayous, canals).						
V2	% open water in bayous, canals or > 1.2m deep						
V3	Interspersion Class						
V4	% ponded area >=15 cm deep (May - September)						
V5	% substrate exposed at MLT (May - Sep) - Tidal only						
	CI (tidal) | CI (non-tidal)						
		HSI=		HSI=		HSI=	

Condition: Future With Project

Variable		TY		TY		TY	
			SI		SI		SI
V1	% wetland that is open water (ponds, bayous, canals).						
V2	% open water in bayous, canals or > 1.2m deep						
V3	Interspersion Class						
V4	% ponded area >=15 cm deep (May - September)						
V5	% substrate exposed at MLT (May - Sep) - Tidal only						
	CI (tidal) | CI (non-tidal)						
		HSI=		HSI=		HSI=	

Galveston Ring Barrier (Direct Impacts) -- Palustrine Marsh

American alligator HSI Model Spreadsheet

Condition: Future Without Project

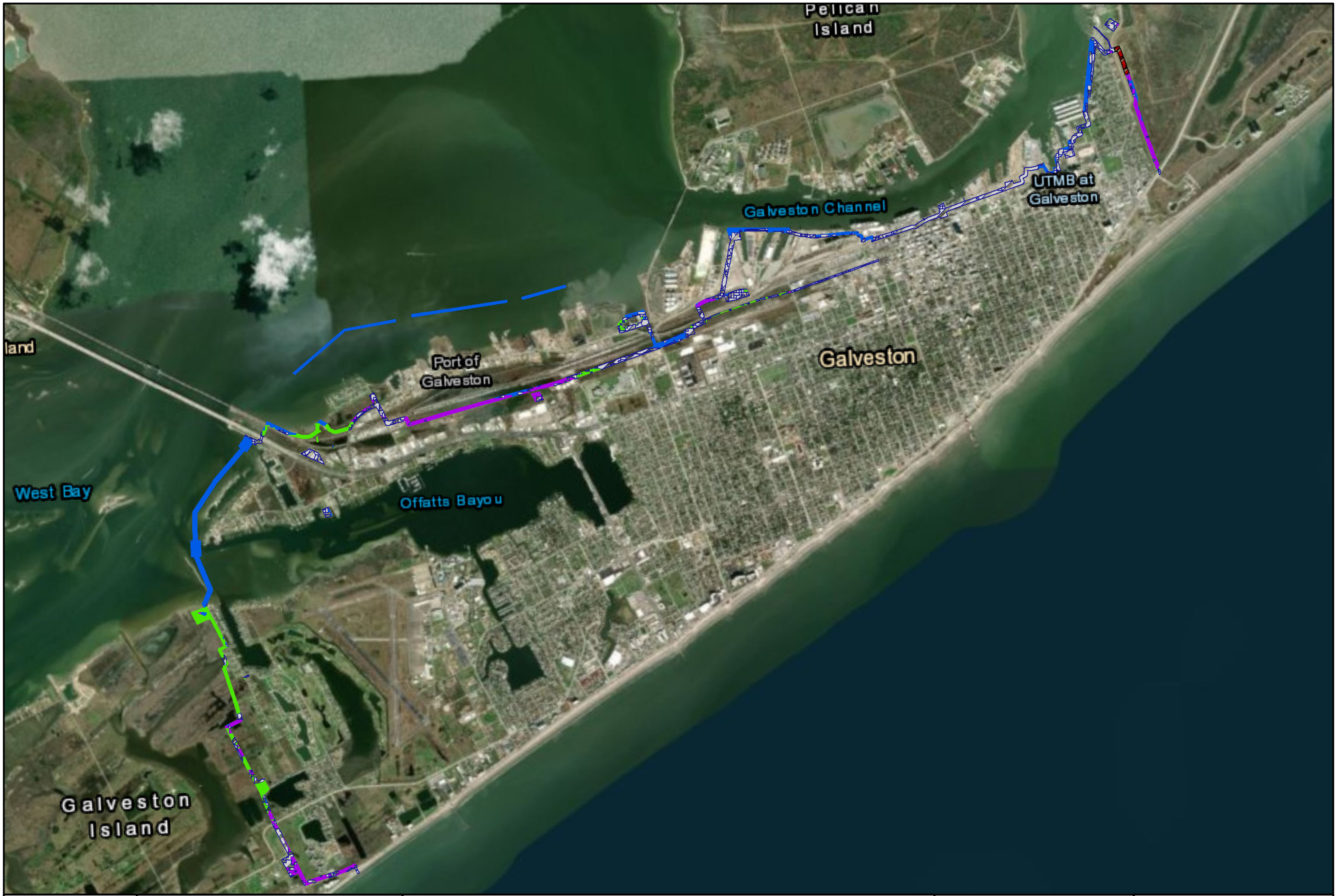
TY	Acres	HSI	Total HUs	Cumulative HUs
0	50	0.33	16.41	
1	66	0.33	21.66	19.04
31	10	0.33	3.28	374.16
51	9	0.33	2.95	62.36
Max TY=	**51**		**AAHUs=**	**8.9**

Condition: Future With Project

TY	Acres	HSI	Total HUs	Cumulative HUs
0	50	0.33	16.41	
1	0	0.00	0.00	5.47
31	0	0.00	0.00	0.00
51	0	0.00	0.00	0.00
Max TY=	**51**		**AAHUs=**	**0.1**

Net Change in AAHUs due to Project

Future With Project AAHUs	0.1
Future Without Project AAHUs	8.9
Net Change	-8.8



N

Legend

- Placement Area
- Developed/Upland
- Estuarine Emergent Wetland
- Palustrine Emergent Wetland
- Open Water

USACE COASTAL TEXAS PROTECTION AND RESTORATION STUDY

Galveston Ring Barrier
Post-TSP CSRM HEP Analysis

FN JOB NO	TGL18185
FILE NAME	CoastalEIS_Galv Ring Barrier.mxd
DATE	4/3/2020
SCALE	1:77,000
DESIGNED	KLC

Figure 1
Baseline (TY 0) Cover Types

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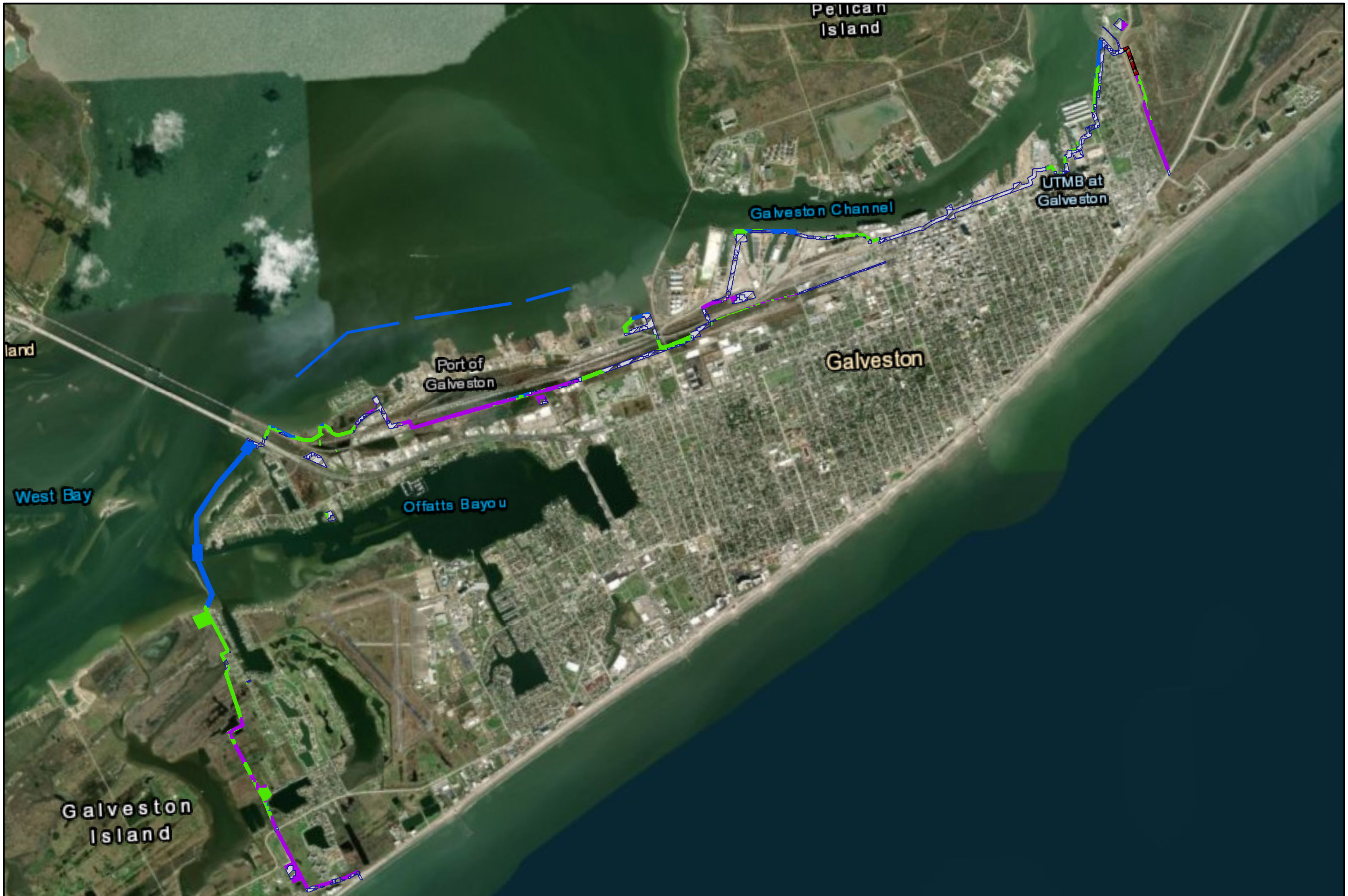
NAD 1983 StatePlane Texas Central FIPS 4203 Feet



Legend
- Placement Area
- Developed/Upland
- Estuarine Emergent Wetland
- Palustrine Emergent Wetland
- Open Water

USACE COASTAL TEXAS PROTECTION AND RESTORATION STUDY

Galveston Ring Barrier
Post-TSP CSRM HEP Analysis

FN JOB NO	TGL18185
FILE NAME	CoastalEIS_Galv Ring Barrier.mxd
DATE	4/3/2020
SCALE	1:77,000
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Figure 2
2035 FWOP
Cover Types

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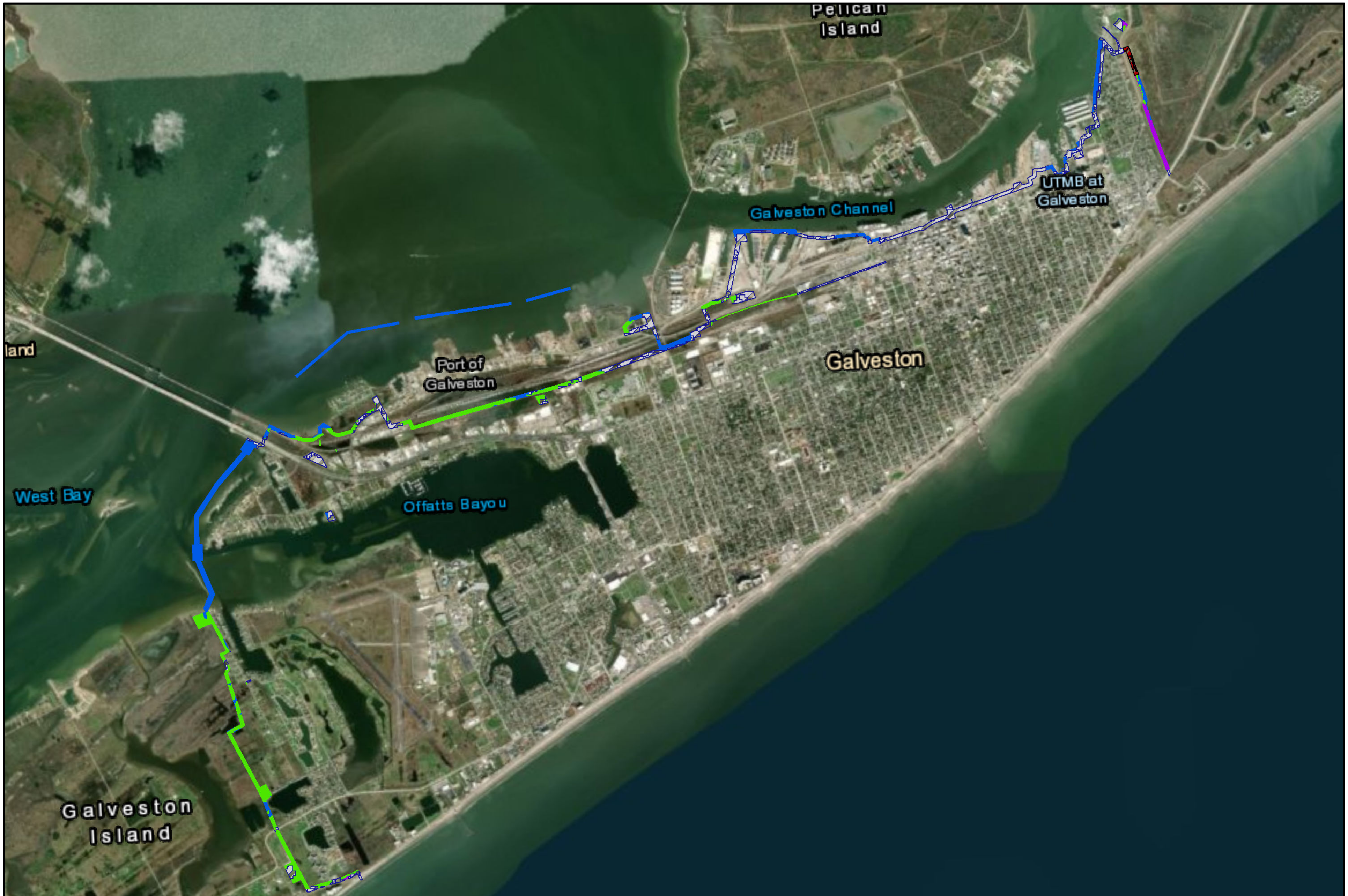
NAD 1983 StatePlane Texas Central FIPS 4203 Feet



N

Legend

- Placement Area
- Developed/Upland
- Estuarine Emergent Wetland
- Palustrine Emergent Wetland
- Open Water

USACE COASTAL TEXAS PROTECTION AND RESTORATION STUDY

Galveston Ring Barrier
Post-TSP CSRM HEP Analysis

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FILE NAME	CoastalEIS_Galv Ring Barrier.mxd
DATE	4/3/2020
SCALE	1:77,000
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Figure 3
2065 FWOP Cover Types

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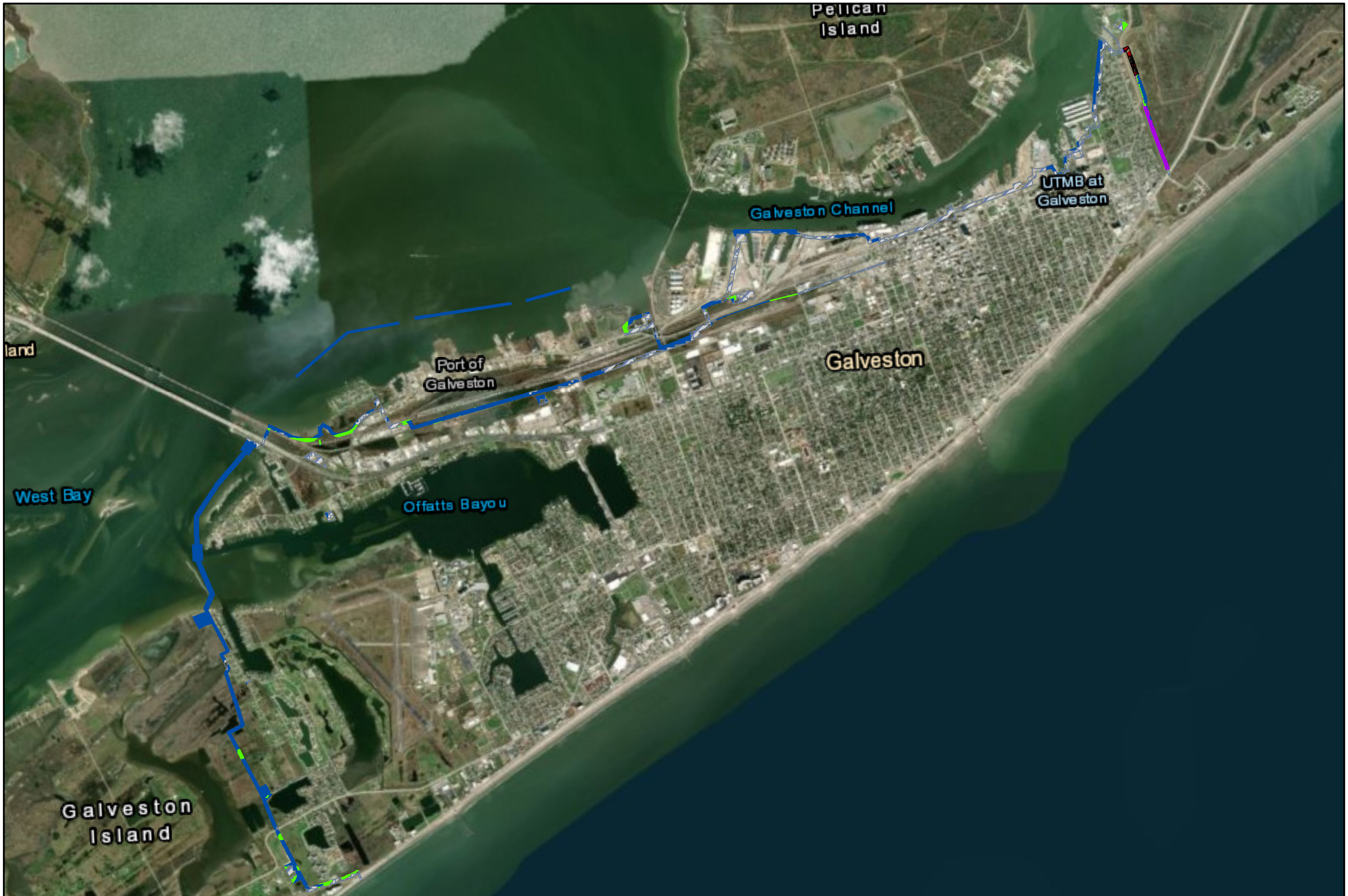
NAD 1983 StatePlane Texas Central FIPS 4203 Feet



N

Legend

- Placement Area
- Developed/Upland
- Estuarine Emergent Wetland
- Palustrine Emergent Wetland
- Open Water

USACE COASTAL TEXAS PROTECTION AND RESTORATION STUDY

Galveston Ring Barrier
Post-TSP CSRM HEP Analysis

FN JOB NO	TGL18185
FILE NAME	CoastalEIS_Galv Ring Barrier.mxd
DATE	4/3/2020
SCALE	1:77,000
DESIGNED	KLO

Figure 4
2085 FWOP
Cover Types

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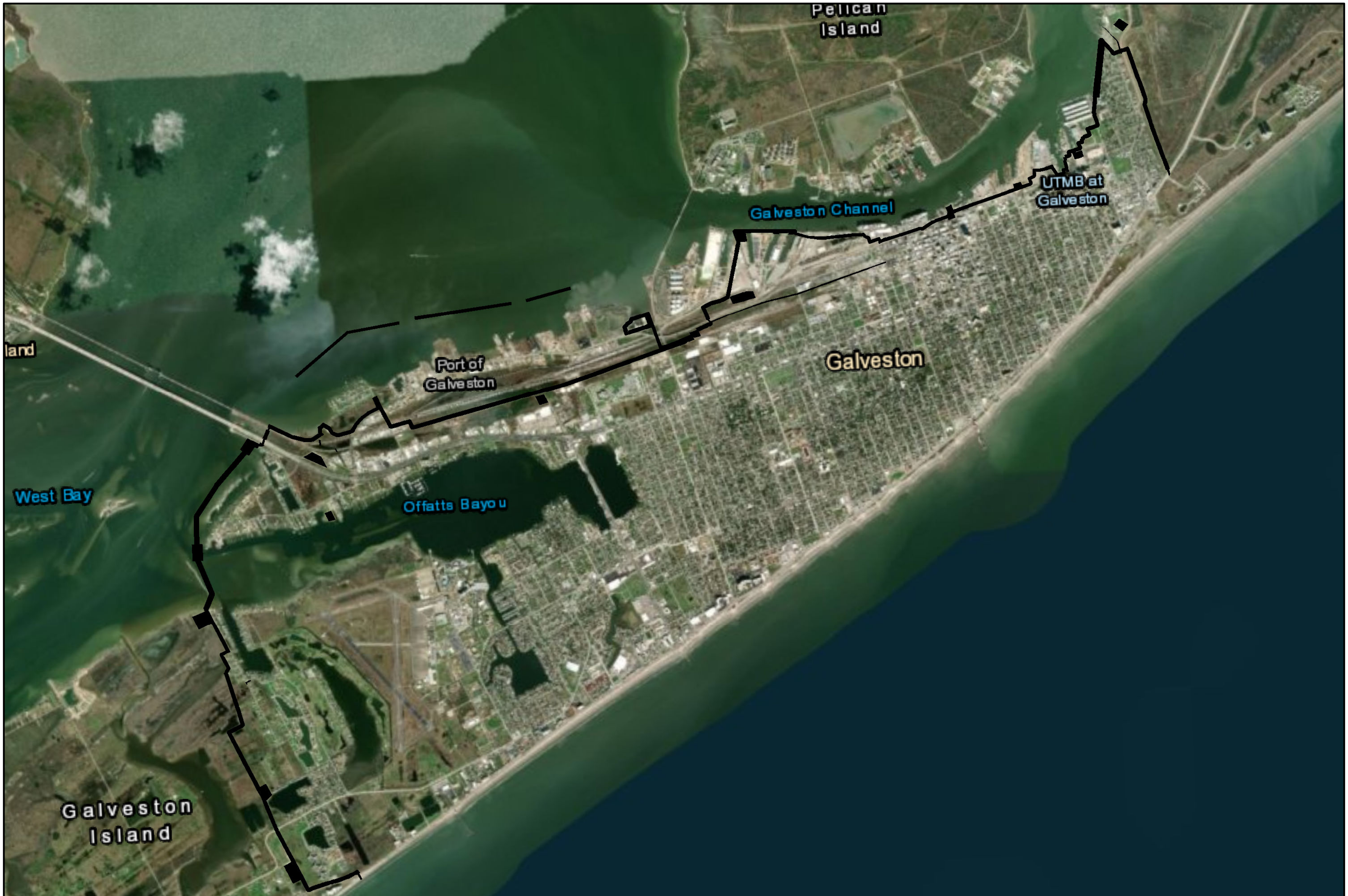
NAD 1983 StatePlane Texas Central FIPS 4203 Feet



N

Legend

Galveston Ring Barrier Infrastructure

USACE COASTAL TEXAS PROTECTION
AND RESTORATION STUDY

Galveston Ring Barrier
Post-TSP CSRM HEP Analysis

FN JOB NO	TGL18185
FILE NAME	CoastalEIS_Galv Ring Barrier.mxd
DATE	4/3/2020
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Figure 5
2035-2085 FWP
Cover Types

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NAD 1983 StatePlane Texas Central FIPS 4203 Feet

Dickinson Bay Surge Gate

Impact Modeling

Dickinson Bayou Surge Gate (Direct Impacts) -- Estuarine Marsh

Project: Dickinson Bayou Gate Estuarine Wetland Impacts

Brown Shrimp HSI Model Spreadsheet

Condition: Future Without Project

		TY	0	**TY**	1	**TY**	31
	Acreage by TY		7.8		7.8		7.8
Variable			**SI**		**SI**		**SI**
V1	% of estuary covered by vegetation (marsh and seagrass).	50	0.50	40	0.40	30	0.30
V2	Substrate Composition	soft bo	1.00	soft bo	1.00	soft bo	1.00
V3	Mean salinity - spring	18	1.00	18	1.00	19	1.00
V4	Mean water temperature - spring	24	1	24	1	24	1
		HSI=	**0.63**	HSI=	**0.54**	HSI=	**0.45**
		vba fn	**0.63**		**0.54**		**0.42**

Condition: Future With Project

		TY	0	**TY**	1	**TY**	31
	Acreage by TY		7.8		0		0
Variable			**SI**		**SI**		**SI**
V1	% of estuary covered by vegetation (marsh and seagrass).	50	0.50	0	0.00	0	0.00
V2	Substrate Composition	soft bo	1.00	soft bo	1.00	soft bo	1.00
V3	Mean salinity - spring	18	1.00	18	1.00	19	1.00
V4	Mean water temperature - spring	24	1	24	1	24	1
		HSI=	**0.63**	HSI=	**0.00**	HSI=	**0.00**
		vba fn	**0.63**		**0.00**		**0.00**

Condition: Future Without Project

		TY	51	**TY**		**TY**	
			7.8				
Variable			**SI**		**SI**		**SI**
V1	% of estuary covered by vegetation (marsh and seagrass).	30	0.30				
V2	Substrate Composition	soft bo	1.00				
V3	Mean salinity - spring	19	1.00				
V4	Mean water temperature - spring	24	1				
		HSI=	**0.45**	HSI=		HSI=	
		vba fn	**0.45**		**V1_ENTRY**		**V1_ENTRY**

Condition: Future With Project

		TY	51	**TY**		**TY**	
			0				
Variable			**SI**		**SI**		**SI**
V1	% of estuary covered by vegetation (marsh and seagrass).	0	0.00				
V2	Substrate Composition	soft bo	1.00				
V3	Mean salinity - spring	19	1.00				
V4	Mean water temperature - spring	24	1				
		HSI=	**0.00**	HSI=		HSI=	
		vba fn	**0.00**		**V1_ENTRY**		**V1_ENTRY**

Condition: Future Without Project

		TY		**TY**		**TY**	
Variable			**SI**		**SI**		**SI**
V1	% of estuary covered by vegetation (marsh and seagrass).						
V2	Substrate Composition						
V3	Mean salinity - spring						
V4	Mean water temperature - spring						
		HSI=		HSI=		HSI=	
		vba fn	**V1_ENTRY**		**V1_ENTRY**		**V1_ENTRY**

Condition: Future With Project

		TY		**TY**		**TY**	
Variable			**SI**		**SI**		**SI**
V1	% of estuary covered by vegetation (marsh and seagrass).						
V2	Substrate Composition						
V3	Mean salinity - spring						
V4	Mean water temperature - spring						
		HSI=		HSI=		HSI=	
		vba fn	**V1_ENTRY**		**V1_ENTRY**		**V1_ENTRY**

Assumptions/Notes:

- Cover types calculated using NOAA CCAP 2010 landcover dataset and NOAA marsh migration datasets
- There is a significant jump in estuarine emergent wetland acres between TY 0 and TY 1. This was seen when calculating cover types for ER measures as well. This is due to the change in cover type datasets between baseline and FWOP/FWP
- FWOP conditions assume nothing is constructed and estuarine emergent wetland migration layers are used as is based on changes of SLR
- FWP conditions assume all cover type acres turn to "infrastructure" by 2035 and remain that way through the end of the project life 2085
- Assuming soft bottom substrate for open water, estuarine, and developed areas because model does not allow this to be broken out. Substrate is held constant.
- Temperature remains the same through the end of the project life
- 20% increase applied to baseline salinities from 2017-2085

-Important to note that by TY 51, spring salinity variable is 38.2 ppt which is above that of seawter (32 ppt)

Habitat Type Calculation

FWOP		FWP	
TY 0		TY 0	
Develop	27.18	Develo	27.184
Open W	2639	Open \	2639.3
Pal. We	78.42	Pal. W	78.421
Est. We	78.42	Est. W	78.422
Ratio	**2.857**	**Ratio**	**2.857**
TY 1		TY 1	
Develop	5.036	Develo	0
Open W	2614	Open \	0
Pal. We	98.11	Pal. W	0
Est. We	106.7	Est. W	0
Ratio	**3.928**	**Ratio**	**######**
TY 31		TY 31	
Develop	4.008	Develo	0
Open W	2646	Open \	0
Pal. We	9.852	Pal. W	0
Est. We	163.1	Est. W	0
Ratio	**6.133**	**Ratio**	**######**
TY 51		TY 51	
Develop	3.808	Develo	0
Open W	2736	Open \	0
Pal. We	8.715	Pal. W	0
Est. We	74.81	Est. W	0
Ratio	**2.722**	**Ratio**	**######**

Dickinson Bayou Surge Gate (Direct Impacts) -- Estuarine Marsh

Brown Shrimp HSI Model Spreadsheet

Condition: Future Without Project

TY	Acres	HSI	Total HUs	Cumulative HUs
0	8	0.58	4.56	
1	8	0.54	4.23	4.40
31	8	0.45	3.50	115.95
51	8	0.42	3.24	67.40
Max TY=	**51**		AAHUs=	**3.7**

Condition: Future With Project

TY	Acres	HSI	Total HUs	Cumulative HUs
0	8	0.58	4.56	
1	0	0.00	0.00	1.52
31	0	0.00	0.00	0.00
51	0	0.00	0.00	0.00
Max TY=	**51**		AAHUs=	**0.0**

Net Change in AAHUs due to Project

Future With Project AAHUs	0.0
Future Without Project AAHUs	3.7
Net Change	-3.7

Dickinson Bayou Surge Gate (Direct Impacts) -- Oyster Habitat

Project: Dickinson Bayou Gate Oyster Impact

American Oyster HSI Model Spreadsheet

Acres 2

Condition: Future Without Project		TY	0	TY	1	TY	31
Variable			**SI**		**SI**		**SI**
V1	Percent cultch cover	100	1.00	100	1.00	100	1.00
V2	Mean salinity during spawning season	27	0.56	28	0.48	31	0.26
V3	Minimum annual salinity	12	1	12	1	13	1
V4	Annual mean salinity	24	0.32	26	0.22	28	0.16
		HSI=	**0.65**	HSI=	**0.57**	HSI=	**0.45**

Acres 0

Condition: Future With Project		TY	0	TY	1	TY	31
Variable			**SI**		**SI**		**SI**
V1	Percent cultch cover	0	0.00	0	0.00	0	0.00
V2	Mean salinity during spawning season	27	0.56	28	0.48	31	0.26
V3	Minimum annual salinity	12	1	12	1	13	1
V4	Annual mean salinity	24	0.32	26	0.22	28	0.16
		HSI=	**0.00**	HSI=	**0.00**	HSI=	**0.00**

Condition: Future Without Project		TY	51	TY		TY	
Variable			**SI**		**SI**		**SI**
V1	Percent cultch cover	100	1.00				
V2	Mean salinity during spawning season	32	0.22				
V3	Minimum annual salinity	14	1				
V4	Annual mean salinity	29	0.13				
		HSI=	**0.41**	HSI=		HSI=	

Condition: Future With Project		TY	51	TY		TY	
Variable			**SI**		**SI**		**SI**
V1	Percent cultch cover	0	0.00				
V2	Mean salinity during spawning season	32	0.22				
V3	Minimum annual salinity	14	1				
V4	Annual mean salinity	29	0.13				
		HSI=	**0.00**	HSI=		HSI=	

Condition: Future Without Project		TY		TY		TY	
Variable			**SI**		**SI**		**SI**
V1	Percent cultch cover						
V2	Mean salinity during spawning season						
V3	Minimum annual salinity						
V4	Annual mean salinity						
		HSI=		HSI=		HSI=	

Condition: Future With Project		TY		TY		TY	
Variable			**SI**		**SI**		**SI**
V1	Percent cultch cover						
V2	Mean salinity during spawning season						
V3	Minimum annual salinity						
V4	Annual mean salinity						
		HSI=		HSI=		HSI=	

Dickinson Bayou Surge Gate (Direct Impacts) -- Oyster Habitat

American Oyster HSI Model Spreadsheet

Condition: Future Without Project

TY	Acres	HSI	Total HUs	Cumulative HUs
0	2	0.65	1.30	
1	2	0.57	1.14	1.22
31	2	0.45	0.90	30.61
51	2	0.41	0.82	17.26
Max TY=	51		**AAHUs=**	0.96

Net Change in AAHUs due to Project

Future With Project AAHUs	0.00
Future Without Project AAHUs	0.96
Net Change	**-0.96**

Condition: Future With Project

TY	Acres	HSI	Total HUs	Cumulative HUs
0	0	0.00	0.00	
1	0	0.00	0.00	0.00
31	0	0.00	0.00	0.00
51	0	0.00	0.00	0.00
Max TY=	51		**AAHUs=**	0.00

Clear Lake Surge Gate

Impact Modeling

Clear Lake Surge Gate (Direct Impacts) -- Estuarine Marsh

Project: Clear Lake Gate Estuarine Wetland Impacts

Brown Shrimp HSI Model Spreadsheet

Condition: Future Without Project

		TY		TY		TY	
		0		1		31	
Acreage by TY		4		4		4	
Variable			SI		SI		SI
V1	% of estuary covered by vegetation (marsh and seagrass).	50	0.50	40	0.40	30	0.30
V2	Substrate Composition	muddy	0.80	soft bc	1.00	soft bc	1.00
V3	Mean salinity - spring	18	1.00	18	1.00	19	1.00
V4	Mean water temperature - spring	24	1	24	1	24	1
		HSI=	0.58	HSI=	0.54	HSI=	0.45
		vba fn	######		######		######

Condition: Future With Project

		TY		TY		TY	
		0		1		31	
Acreage by TY		4		0		0	
Variable			SI		SI		SI
V1	% of estuary covered by vegetation (marsh and seagrass).	50	0.50	0	0.00	0	0.00
V2	Substrate Composition	muddy	0.80	muddy	0.80	muddy	0.80
V3	Mean salinity - spring	18	1.00	18	1.00	19	1.00
V4	Mean water temperature - spring	24	1	24	1	24	1
		HSI=	0.58	HSI=	0.00	HSI=	0.00
		vba fn	######		0.00		0.00

Condition: Future Without Project

		TY		TY		TY	
		51					
		4					
Variable			SI		SI		SI
V1	% of estuary covered by vegetation (marsh and seagrass).	30	0.30				
V2	Substrate Composition	muddy	0.80				
V3	Mean salinity - spring	19	1.00				
V4	Mean water temperature - spring	24	1				
		HSI=	0.42	HSI=		HSI=	
		vba fn	######		V1_ENTRY		V1_ENTRY

Condition: Future With Project

		TY		TY		TY	
		51					
		0					
Variable			SI		SI		SI
V1	% of estuary covered by vegetation (marsh and seagrass).	0	0.00				
V2	Substrate Composition	muddy	0.80				
V3	Mean salinity - spring	19	1.00				
V4	Mean water temperature - spring	24	1				
		HSI=	0.00	HSI=		HSI=	
		vba fn	0.00		V1_ENTRY		V1_ENTRY

Condition: Future Without Project

		TY		TY		TY	
Variable			SI		SI		SI
V1	% of estuary covered by vegetation (marsh and seagrass).						
V2	Substrate Composition						
V3	Mean salinity - spring						
V4	Mean water temperature - spring						
		HSI=		HSI=		HSI=	
		vba fn	V1_ENTRY		V1_ENTRY		V1_ENTRY

Condition: Future With Project

		TY		TY		TY	
Variable			SI		SI		SI
V1	% of estuary covered by vegetation (marsh and seagrass).						
V2	Substrate Composition						
V3	Mean salinity - spring						
V4	Mean water temperature - spring						
		HSI=		HSI=		HSI=	
		vba fn	V1_ENTRY		V1_ENTRY		V1_ENTRY

Assumptions/Notes:

- Cover types calculated using NOAA CCAP 2010 landcover dataset and NOAA marsh migration datasets
- There is a significant jump in estuarine emergent wetland acres between TY 0 and TY 1. This was seen when calculating cover types for ER measures as well. This is due to the change in cover type datasets between baseline and FWOP/FWP
- FWOP conditions assume nothing is constructed and estuarine emergent wetland migration layers are used as is based on changes of SLR
- FWP conditions assume all cover type acres turn to "infrastructure" by 2035 and remain that way through the end of the project life 2085
- Assuming soft bottom substrate for open water, estuarine, and developed areas because model does not allow this to be broken out. Substrate is held constant.
- Temperature remains the same through the end of the project life
- 20% increase applied to baseline salinties from 2017-2085

-Important to note that by TY 51, spring salinity variable is 38.2 ppt which is above that of seawter (32 ppt)

Habitat Ratios

FWOP		FWP	
TY 0		TY 0	
Develop	27.18	Develc	27.18399
Open W	2639	Open \	2639.337
Pal. We	78.42	Pal. W	78.42103
Est. Wet	78.42	Est. W	78.42195
Ratio	**2.857**	**Ratio**	**2.856962**
TY 1		TY 1	
Develop	5.036	Develc	0
Open W	2614	Open \	0
Pal. We	98.11	Pal. W	0
Est. Wet	106.7	Est. W	0
Ratio	**3.928**	**Ratio**	**#DIV/0!**
TY 31		TY 31	
Develop	4.008	Develc	0
Open W	2646	Open \	0
Pal. We	9.852	Pal. W	0
Est. Wet	163.1	Est. W	0
Ratio	**6.133**	**Ratio**	**#DIV/0!**
TY 51		TY 51	
Develop	3.808	Develc	0
Open W	2736	Open \	0
Pal. We	8.715	Pal. W	0
Est. Wet	74.81	Est. W	0
Ratio	**2.722**	**Ratio**	**#DIV/0!**

Clear Lake Surge Gate (Direct Impacts) -- Estuarine Marsh

Brown Shrimp HSI Model Spreadsheet

Condition: Future Without Project

TY	Acres	HSI	Total HUs	Cumulative HUs
0	4	0.58	2.34	
1	4	0.54	2.17	2.26
31	4	0.45	1.79	59.46
51	4	0.42	1.66	34.57
Max TY=	**51**		**AAHUs=**	**1.9**

Condition: Future With Project

TY	Acres	HSI	Total HUs	Cumulative HUs
0	4	0.58	2.34	
1	0	0.00	0.00	0.78
31	0	0.00	0.00	0.00
51	0	0.00	0.00	0.00
Max TY=	**51**		**AAHUs=**	**0.0**

Net Change in AAHUs due to Project

Future With Project AAHUs	0.0
Future Without Project AAHUs	1.9
Net Change	-1.9

Clear Lake Surge Gate (Direct Impacts) -- Oyster Habitat

Project: Clear Lake Gate Oyster Impact

American Oyster HSI Model Spreadsheet

Acres 3.7

Condition: Future Without Project		TY	0	TY	1	TY	31
Variable			**SI**		**SI**		**SI**
V1	Percent cultch cover	100	1.00	100	1.00	100	1.00
V2	Mean salinity during spawning season	27	0.56	28	0.48	31	0.26
V3	Minimum annual salinity	12	1	12	1	13	1
V4	Annual mean salinity	24	0.32	26	0.22	28	0.16
		HSI=	**0.65**	HSI=	**0.57**	HSI=	**0.45**

Condition: Future Without Project		TY	51	TY		TY	
Variable			**SI**		**SI**		**SI**
V1	Percent cultch cover	100	1.00				
V2	Mean salinity during spawning season	32	0.22				
V3	Minimum annual salinity	14	1				
V4	Annual mean salinity	29	0.13				
		HSI=	**0.41**	HSI=		HSI=	

Condition: Future Without Project		TY		TY		TY	
Variable			**SI**		**SI**		**SI**
V1	Percent cultch cover						
V2	Mean salinity during spawning season						
V3	Minimum annual salinity						
V4	Annual mean salinity						
		HSI=		HSI=		HSI=	

Acres 0

Condition: Future With Project		TY	0	TY	1	TY	31
Variable			**SI**		**SI**		**SI**
V1	Percent cultch cover	0	0.00	0	0.00	0	0.00
V2	Mean salinity during spawning season	27	0.56	28	0.48	31	0.26
V3	Minimum annual salinity	12	1	12	1	13	1
V4	Annual mean salinity	24	0.32	26	0.22	28	0.16
		HSI=	**0.00**	HSI=	**0.00**	HSI=	**0.00**

Condition: Future With Project		TY	51	TY		TY	
Variable			**SI**		**SI**		**SI**
V1	Percent cultch cover	0	0.00				
V2	Mean salinity during spawning season	32	0.22				
V3	Minimum annual salinity	14	1				
V4	Annual mean salinity	29	0.13				
		HSI=	**0.00**	HSI=		HSI=	

Condition: Future With Project		TY		TY		TY	
Variable			**SI**		**SI**		**SI**
V1	Percent cultch cover						
V2	Mean salinity during spawning season						
V3	Minimum annual salinity						
V4	Annual mean salinity						
		HSI=		HSI=		HSI=	

Clear Lake Surge Gate (Direct Impacts) -- Oyster Habitat

American Oyster HSI Model Spreadsheet

Condition: Future Without Project

TY	Acres	HSI	Total HUs	Cumulative HUs
0	4	0.65	2.41	
1	4	0.57	2.10	2.26
31	4	0.45	1.67	56.62
51	4	0.41	1.52	31.93
Max TY=	51		**AAHUs=**	1.78

Net Change in AAHUs due to Project

Future With Project AAHUs	0.00
Future Without Project AAHUs	1.78
Net Change	**-1.78**

Condition: Future With Project

TY	Acres	HSI	Total HUs	Cumulative HUs
0	0	0.00	0.00	
1	0	0.00	0.00	0.00
31	0	0.00	0.00	0.00
51	0	0.00	0.00	0.00
Max TY=	51		**AAHUs=**	0.00

Estuarine Mitigation Sites

Habitat Modeling

Project: Horseshoe Lake Estuarine Mitigation Site

Brown Shrimp HSI Model Spreadsheet

Acres: 62 (Future Without Project) | Acres: 62 (Future With Project)

Condition: Future Without Project

Variable		TY 0	SI	TY 1	SI	TY 10	SI
V1	% of estuary covered by vegetation (marsh and seagrass).	10	0.10	10	0.10	10	0.10
V2	Substrate Composition	muddy	0.80	muddy	0.80	muddy	0.80
V3	Mean salinity - spring	18	1.00	18	1.00	19	1.00
V4	Mean water temperature - spring	24	1	24	1	24	1
		HSI=	0.20	HSI=	0.20	HSI=	0.20

Condition: Future With Project

Variable		TY 0	SI	TY 1	SI	TY 10	SI
V1	% of estuary covered by vegetation (marsh and seagrass).	10	0.10	10	0.10	10	0.10
V2	Substrate Composition	muddy	0.80	muddy	0.80	muddy	0.80
V3	Mean salinity - spring	18	1.00	18	1.00	19	1.00
V4	Mean water temperature - spring	24	1	24	1	24	1
		HSI=	0.20	HSI=	0.20	HSI=	0.20

Condition: Future Without Project

Variable		TY 11	SI	TY 61	SI	TY	SI
V1	% of estuary covered by vegetation (marsh and seagrass).	10	0.10	10	0.10		
V2	Substrate Composition	muddy	0.80	muddy	0.80		
V3	Mean salinity - spring	19	1.00	23	0.94		
V4	Mean water temperature - spring	24	1	24	1		
		HSI=	0.20	HSI=	0.20	HSI=	

Condition: Future With Project

Variable		TY 11	SI	TY 61	SI	TY	SI
V1	% of estuary covered by vegetation (marsh and seagrass).	90	0.90	90	0.90		
V2	Substrate Composition	soft bo	1.00	soft bo	1.00		
V3	Mean salinity - spring	19	1.00	23	0.94		
V4	Mean water temperature - spring	24	1	24	1		
		HSI=	0.93	HSI=	0.93	HSI=	

Condition: Future Without Project

Variable		TY	SI	TY	SI	TY	SI
V1	% of estuary covered by vegetation (marsh and seagrass).						
V2	Substrate Composition						
V3	Mean salinity - spring						
V4	Mean water temperature - spring						
		HSI=		HSI=		HSI=	

Condition: Future With Project

Variable		TY	SI	TY	SI	TY	SI
V1	% of estuary covered by vegetation (marsh and seagrass).						
V2	Substrate Composition						
V3	Mean salinity - spring						
V4	Mean water temperature - spring						
		HSI=		HSI=		HSI=	

Brown Shrimp HSI Model Spreadsheet

Condition: Future Without Project

TY	Acres	HSI	Total HUs	Cumulative HUs
0	62	0.20	12.40	
1	62	0.20	12.40	12.40
10	62	0.20	12.40	111.60
11	62	0.20	12.40	12.40
61	62	0.20	12.40	620.00
Max TY=	**61**		**AAHUs=**	**12.4**

Condition: Future With Project

TY	Acres	HSI	Total HUs	Cumulative HUs
0	62	0.20	12.40	
1	62	0.20	12.40	12.40
10	62	0.20	12.40	111.60
11	62	0.93	57.79	35.10
61	62	0.93	57.79	2889.73
Max TY=	**61**		**AAHUs=**	**50.0**

Net Change in AAHUs due to Project

Future With Project AAHUs	50.0
Future Without Project AAHUs	12.4
Net Change	37.6

Project: Sievers Cove Estuarine Mitigation Site

Brown Shrimp HSI Model Spreadsheet

Acres: 667

Condition: Future Without Project

Variable		TY 0	SI	TY 1	SI	TY 10	SI
V1	% of estuary covered by vegetation (marsh and seagrass).	10	0.10	10	0.10	10	0.10
V2	Substrate Composition	muddy	0.80	muddy	0.80	muddy	0.80
V3	Mean salinity - spring	18	1.00	18	1.00	19	1.00
V4	Mean water temperature - spring	24	1	24	1	24	1
		HSI=	**0.20**	HSI=	**0.20**	HSI=	**0.20**

Condition: Future Without Project

Variable		TY 11	SI	TY 61	SI	TY	SI
V1	% of estuary covered by vegetation (marsh and seagrass).	0	0.00	0	0.00		
V2	Substrate Composition	muddy	0.80	muddy	0.80		
V3	Mean salinity - spring	19	1.00	23	0.94		
V4	Mean water temperature - spring	24	1	24	1		
		HSI=	**0.00**	HSI=	**0.00**	HSI=	

Condition: Future Without Project

Variable		TY	SI	TY	SI	TY	SI
V1	% of estuary covered by vegetation (marsh and seagrass).						
V2	Substrate Composition						
V3	Mean salinity - spring						
V4	Mean water temperature - spring						
		HSI=		HSI=		HSI=	

Acres: 667

Condition: Future With Project

Variable		TY 0	SI	TY 1	SI	TY 10	SI
V1	% of estuary covered by vegetation (marsh and seagrass).	0	0.00	0	0.00	0	0.00
V2	Substrate Composition	muddy	0.80	muddy	0.80	muddy	0.80
V3	Mean salinity - spring	18	1.00	18	1.00	19	1.00
V4	Mean water temperature - spring	24	1	24	1	24	1
		HSI=	**0.00**	HSI=	**0.00**	HSI=	**0.00**

Condition: Future With Project

Variable		TY 11	SI	TY 61	SI	TY	SI
V1	% of estuary covered by vegetation (marsh and seagrass).	90	0.90	90	0.90		
V2	Substrate Composition	soft bo	1.00	soft bo	1.00		
V3	Mean salinity - spring	19	1.00	23	0.94		
V4	Mean water temperature - spring	24	1	24	1		
		HSI=	**0.93**	HSI=	**0.93**	HSI=	

Condition: Future With Project

Variable		TY	SI	TY	SI	TY	SI
V1	% of estuary covered by vegetation (marsh and seagrass).						
V2	Substrate Composition						
V3	Mean salinity - spring						
V4	Mean water temperature - spring						
		HSI=		HSI=		HSI=	

Brown Shrimp HSI Model Spreadsheet

Condition: Future Without Project

TY	Acres	HSI	Total HUs	Cumulative HUs
0	667	0.20	133.40	
1	667	0.20	133.40	133.40
10	667	0.20	133.40	1200.60
11	667	0.00	0.00	66.70
61	667	0.00	0.00	0.00
Max TY=	**61**		**AAHUs=**	**23.0**

Condition: Future With Project

TY	Acres	HSI	Total HUs	Cumulative HUs
0	667	0.00	0.00	
1	667	0.00	0.00	0.00
10	667	0.00	0.00	0.00
11	667	0.93	621.76	310.88
61	667	0.93	621.76	31087.86
Max TY=	**61**		**AAHUs=**	**514.7**

Net Change in AAHUs due to Project

Future With Project AAHUs	514.7
Future Without Project AAHUs	23.0
Net Change	491.8

Project: Greens Lake Estuarine Mitigation Site

Brown Shrimp HSI Model Spreadsheet

Acres 562

Condition: Future Without Project

Variable		TY 0	SI	TY 1	SI	TY 10	SI
V1	% of estuary covered by vegetation (marsh and seagrass).	10	0.10	10	0.10	10	0.10
V2	Substrate Composition	muddy	0.80	muddy	0.80	muddy	0.80
V3	Mean salinity - spring	18	1.00	18	1.00	19	1.00
V4	Mean water temperature - spring	24	1	24	1	24	1
		HSI=	0.20	HSI=	0.20	HSI=	0.20

Acres 562

Condition: Future With Project

Variable		TY 0	SI	TY 1	SI	TY 10	SI
V1	% of estuary covered by vegetation (marsh and seagrass).	10	0.10	10	0.10	10	0.10
V2	Substrate Composition	muddy	0.80	muddy	0.80	muddy	0.80
V3	Mean salinity - spring	18	1.00	18	1.00	19	1.00
V4	Mean water temperature - spring	24	1	24	1	24	1
		HSI=	0.20	HSI=	0.20	HSI=	0.20

Condition: Future Without Project

Variable		TY 11	SI	TY 61	SI	TY	SI
V1	% of estuary covered by vegetation (marsh and seagrass).	10	0.10	10	0.10		
V2	Substrate Composition	muddy	0.80	muddy	0.80		
V3	Mean salinity - spring	19	1.00	23	0.94		
V4	Mean water temperature - spring	24	1	24	1		
		HSI=	0.20	HSI=	0.20	HSI=	

Condition: Future With Project

Variable		TY 11	SI	TY 61	SI	TY	SI
V1	% of estuary covered by vegetation (marsh and seagrass).	90	0.90	90	0.90		
V2	Substrate Composition	soft bo	1.00	soft bo	1.00		
V3	Mean salinity - spring	19	1.00	23	0.94		
V4	Mean water temperature - spring	24	1	24	1		
		HSI=	0.93	HSI=	0.93	HSI=	

Condition: Future Without Project

Variable		TY	SI	TY	SI	TY	SI
V1	% of estuary covered by vegetation (marsh and seagrass).						
V2	Substrate Composition						
V3	Mean salinity - spring						
V4	Mean water temperature - spring						
		HSI=		HSI=		HSI=	

Condition: Future With Project

Variable		TY	SI	TY	SI	TY	SI
V1	% of estuary covered by vegetation (marsh and seagrass).						
V2	Substrate Composition						
V3	Mean salinity - spring						
V4	Mean water temperature - spring						
		HSI=		HSI=		HSI=	

Brown Shrimp HSI Model Spreadsheet

Condition: Future Without Project

TY	Acres	HSI	Total HUs	Cumulative HUs
0	562	0.20	112.40	
1	562	0.20	112.40	112.40
10	562	0.20	112.40	1011.60
11	562	0.20	112.40	112.40
61	562	0.20	112.40	5620.00
Max TY=	**61**		**AAHUs=**	**112.4**

Condition: Future With Project

TY	Acres	HSI	Total HUs	Cumulative HUs
0	562	0.20	112.40	
1	562	0.20	112.40	112.40
10	562	0.20	112.40	1011.60
11	562	0.93	523.88	318.14
61	562	0.93	523.88	26193.97
Max TY=	**61**		**AAHUs=**	**453.1**

Net Change in AAHUs due to Project

Future With Project AAHUs	453.1
Future Without Project AAHUs	112.4
Net Change	340.7

Project: Clear Lake Estuarine Mitigation Site

Brown Shrimp HSI Model Spreadsheet

Acres: 3

Condition: Future Without Project

Variable		TY 0	SI	TY 1	SI	TY 10	SI
V1	% of estuary covered by vegetation (marsh and seagrass).	10	0.10	10	0.10	10	0.10
V2	Substrate Composition	muddy	0.80	muddy	0.80	muddy	0.80
V3	Mean salinity - spring	18	1.00	18	1.00	19	1.00
V4	Mean water temperature - spring	24	1	24	1	24	1
		HSI=	0.20	HSI=	0.20	HSI=	0.20

Acres: 3

Condition: Future With Project

Variable		TY 0	SI	TY 1	SI	TY 10	SI
V1	% of estuary covered by vegetation (marsh and seagrass).	10	0.10	10	0.10	10	0.10
V2	Substrate Composition	muddy	0.80	muddy	0.80	muddy	0.80
V3	Mean salinity - spring	18	1.00	18	1.00	19	1.00
V4	Mean water temperature - spring	24	1	24	1	24	1
		HSI=	0.20	HSI=	0.20	HSI=	0.20

Condition: Future Without Project

Variable		TY 11	SI	TY 61	SI	TY	SI
V1	% of estuary covered by vegetation (marsh and seagrass).	10	0.10	0	0.00		
V2	Substrate Composition	muddy	0.80	muddy	0.80		
V3	Mean salinity - spring	19	1.00	23	0.94		
V4	Mean water temperature - spring	24	1	24	1		
		HSI=	0.20	HSI=	0.00	HSI=	

Condition: Future With Project

Variable		TY 11	SI	TY 61	SI	TY	SI
V1	% of estuary covered by vegetation (marsh and seagrass).	90	0.90	90	0.90		
V2	Substrate Composition	soft bo	1.00	soft bo	1.00		
V3	Mean salinity - spring	19	1.00	23	0.94		
V4	Mean water temperature - spring	24	1	24	1		
		HSI=	0.93	HSI=	0.93	HSI=	

Condition: Future Without Project

Variable		TY	SI	TY	SI	TY	SI
V1	% of estuary covered by vegetation (marsh and seagrass).						
V2	Substrate Composition						
V3	Mean salinity - spring						
V4	Mean water temperature - spring						
		HSI=		HSI=		HSI=	

Condition: Future With Project

Variable		TY	SI	TY	SI	TY	SI
V1	% of estuary covered by vegetation (marsh and seagrass).						
V2	Substrate Composition						
V3	Mean salinity - spring						
V4	Mean water temperature - spring						
		HSI=		HSI=		HSI=	

Brown Shrimp HSI Model Spreadsheet

Condition: Future Without Project

TY	Acres	HSI	Total HUs	Cumulative HUs
0	3	0.20	0.60	
1	3	0.20	0.60	0.60
10	3	0.20	0.60	5.40
11	3	0.20	0.60	0.60
61	3	0.00	0.00	15.00
Max TY=	**61**		**AAHUs=**	**0.4**

Condition: Future With Project

TY	Acres	HSI	Total HUs	Cumulative HUs
0	3	0.20	0.60	
1	3	0.20	0.60	0.60
10	3	0.20	0.60	5.40
11	3	0.93	2.80	1.70
61	3	0.93	2.80	139.83
Max TY=	**61**		**AAHUs=**	**2.4**

Net Change in AAHUs due to Project

Future With Project AAHUs	2.4
Future Without Project AAHUs	0.4
Net Change	2.1

Project: Dickinson Bayou Estuarine Mitigation Site

Brown Shrimp HSI Model Spreadsheet

Future Without Project

Acres: 6

Condition: Future Without Project

Variable		TY 0	SI	TY 1	SI	TY 10	SI
V1	% of estuary covered by vegetation (marsh and seagrass).	10	0.10	10	0.10	10	0.10
V2	Substrate Composition	muddy	0.80	muddy	0.80	muddy	0.80
V3	Mean salinity - spring	18	1.00	18	1.00	19	1.00
V4	Mean water temperature - spring	24	1	24	1	24	1
		HSI=	0.20	HSI=	0.20	HSI=	0.20

Condition: Future Without Project

Variable		TY 11	SI	TY 61	SI	TY	SI
V1	% of estuary covered by vegetation (marsh and seagrass).	10	0.10	0	0.00		
V2	Substrate Composition	muddy	0.80	muddy	0.80		
V3	Mean salinity - spring	19	1.00	23	0.94		
V4	Mean water temperature - spring	24	1	24	1		
		HSI=	0.20	HSI=	0.00	HSI=	

Condition: Future Without Project

Variable		TY	SI	TY	SI	TY	SI
V1	% of estuary covered by vegetation (marsh and seagrass).						
V2	Substrate Composition						
V3	Mean salinity - spring						
V4	Mean water temperature - spring						
		HSI=		HSI=		HSI=	

Future With Project

Acres: 5.8

Condition: Future With Project

Variable		TY 0	SI	TY 1	SI	TY 10	SI
V1	% of estuary covered by vegetation (marsh and seagrass).	10	0.10	10	0.10	10	0.10
V2	Substrate Composition	muddy	0.80	muddy	0.80	muddy	0.80
V3	Mean salinity - spring	18	1.00	18	1.00	19	1.00
V4	Mean water temperature - spring	24	1	24	1	24	1
		HSI=	0.20	HSI=	0.20	HSI=	0.20

Condition: Future With Project

Variable		TY 11	SI	TY 61	SI	TY	SI
V1	% of estuary covered by vegetation (marsh and seagrass).	90	0.90	90	0.90		
V2	Substrate Composition	soft bo	1.00	soft bo	1.00		
V3	Mean salinity - spring	19	1.00	23	0.94		
V4	Mean water temperature - spring	24	1	24	1		
		HSI=	0.93	HSI=	0.93	HSI=	

Condition: Future With Project

Variable		TY	SI	TY	SI	TY	SI
V1	% of estuary covered by vegetation (marsh and seagrass).						
V2	Substrate Composition						
V3	Mean salinity - spring						
V4	Mean water temperature - spring						
		HSI=		HSI=		HSI=	

Brown Shrimp HSI Model Spreadsheet

Condition: Future Without Project

TY	Acres	HSI	Total HUs	Cumulative HUs
0	6	0.20	1.16	
1	6	0.20	1.16	1.16
10	6	0.20	1.16	10.44
11	6	0.20	1.16	1.16
61	6	0.00	0.00	29.00
Max TY=	**61**		**AAHUs=**	**0.7**

Condition: Future With Project

TY	Acres	HSI	Total HUs	Cumulative HUs
0	6	0.20	1.16	
1	6	0.20	1.16	1.16
10	6	0.20	1.16	10.44
11	6	0.93	5.41	3.28
61	6	0.93	5.41	270.33
Max TY=	**61**		**AAHUs=**	**4.7**

Net Change in AAHUs due to Project

Future With Project AAHUs	4.7
Future Without Project AAHUs	0.7
Net Change	4.0

Palustrine Mitigation Sites

Habitat Modeling

Project: Marquette Mitigation Site (Palustrine Mitigation)

American alligator HSI Model Spreadsheet

Acres

Condition: Future Without Project

Variable		TY	0	TY	1	TY	10
			SI		SI		SI
V1	% wetland that is open water (ponds, bayous, canals).	5	0.25	5	0.25	5	0.25
V2	% open water in bayous, canals or > 1.2m deep	0	0.00	0	0.00	0	0.00
V3	Interspersion Class	Low	0.20	Low	0.20	Low	0.20
V4	% ponded area >=15 cm deep (May - September)	5	0.05	5	0.05	5	0.05
V5	% substrate exposed at MLT (May - Sep) - Tidal only						
	CI (tidal) | CI (non-tidal)		0.1357		0.1357		0.1357
		HSI=	0	HSI=	0	HSI=	0

Condition: Future With Project

Variable		TY	0	TY	1	TY	10
			SI		SI		SI
V1	% wetland that is open water (ponds, bayous, canals).	5	0.25	5	0.25	5	0.25
V2	% open water in bayous, canals or > 1.2m deep	0	0.00	0	0.00	0	0.00
V3	Interspersion Class	Low	0.20	Low	0.20	Low	0.20
V4	% ponded area >=15 cm deep (May - September)	5	0.05	5	0.05	5	0.05
V5	% substrate exposed at MLT (May - Sep) - Tidal only						
	CI (tidal) | CI (non-tidal)		0.1357		0.1357		0.1357
		HSI=	0	HSI=	0	HSI=	0

Condition: Future Without Project

Variable		TY	11	TY	51	TY	
			SI		SI		SI
V1	% wetland that is open water (ponds, bayous, canals).	5	0.25	5	0.25		
V2	% open water in bayous, canals or > 1.2m deep	0	0.00	0	0.00		
V3	Interspersion Class	Low	0.20	Low	0.20		
V4	% ponded area >=15 cm deep (May - September)	5	0.05	5	0.05		
V5	% substrate exposed at MLT (May - Sep) - Tidal only						
	CI (tidal) | CI (non-tidal)		0.1357		0.1357		
		HSI=	0	HSI=	0	HSI=	

Condition: Future With Project

Variable		TY	11	TY	51	TY	
			SI		SI		SI
V1	% wetland that is open water (ponds, bayous, canals).	30	1.00	30	1.00		
V2	% open water in bayous, canals or > 1.2m deep	10	1.00	10	1.00		
V3	Interspersion Class	Medium	0.50	Mediu	0.50		
V4	% ponded area >=15 cm deep (May - September)	60	0.6	60	0.6		
V5	% substrate exposed at MLT (May - Sep) - Tidal only						
	CI (tidal) | CI (non-tidal)		0.6694		0.6694		
		HSI=	0.8182	HSI=	0.8182	HSI=	

Condition: Future Without Project

Variable		TY		TY		TY	
			SI		SI		SI
V1	% wetland that is open water (ponds, bayous, canals).						
V2	% open water in bayous, canals or > 1.2m deep						
V3	Interspersion Class						
V4	% ponded area >=15 cm deep (May - September)						
V5	% substrate exposed at MLT (May - Sep) - Tidal only						
	CI (tidal) | CI (non-tidal)						
		HSI=		HSI=		HSI=	

Condition: Future With Project

Variable		TY		TY		TY	
			SI		SI		SI
V1	% wetland that is open water (ponds, bayous, canals).						
V2	% open water in bayous, canals or > 1.2m deep						
V3	Interspersion Class						
V4	% ponded area >=15 cm deep (May - September)						
V5	% substrate exposed at MLT (May - Sep) - Tidal only						
	CI (tidal) | CI (non-tidal)						
		HSI=		HSI=		HSI=	

American alligator HSI Model Spreadsheet

Condition: Future Without Project

TY	Acres	HSI	Total HUs	Cumulative HUs
0	20	0.00	0.00	
1	20	0.00	0.00	0.00
10	20	0.00	0.00	0.00
11	20	0.00	0.00	0.00
51	20	0.00	0.00	0.00
Max TY=	**51**		**AAHUs=**	**0.0**

Condition: Future With Project

TY	Acres	HSI	Total HUs	Cumulative HUs
0	20	0.00	0.00	
1	20	0.00	0.00	0.00
10	20	0.00	0.00	0.00
11	32	0.82	26.18	11.45
51	32	0.82	26.18	1047.28
Max TY=	**51**		**AAHUs=**	**20.8**

Net Change in AAHUs due to Project

Future With Project AAHUs	20.8
Future Without Project AAHUs	0.0
Net Change	20.8

Oyster Mitigation Sites

Habitat Modeling

American Oyster HSI Model Spreadsheet

Project: Evia Island Oyster Mitigation Site

Acres 30

Condition: Future Without Project

Variable		TY 0	SI	TY 1	SI	TY 31	SI
V1	Percent cultch cover	0	0.00	0	0.00	0	0.00
V2	Mean salinity during spawning season	27	0.56	28	0.48	31	0.26
V3	Minimum annual salinity	12	1	12	1	13	1
V4	Annual mean salinity	24	0.32	26	0.22	28	0.16
		HSI=	**0.00**	HSI=	**0.00**	HSI=	**0.00**

Condition: Future Without Project

Variable		TY 51	SI	TY	SI	TY	SI
V1	Percent cultch cover	0	0.00				
V2	Mean salinity during spawning season	32	0.22				
V3	Minimum annual salinity	14	1				
V4	Annual mean salinity	29	0.13				
		HSI=	**0.00**	HSI=		HSI=	

Condition: Future Without Project

Variable		TY	SI	TY	SI	TY	SI
V1	Percent cultch cover						
V2	Mean salinity during spawning season						
V3	Minimum annual salinity						
V4	Annual mean salinity						
		HSI=		HSI=		HSI=	

Acres 30

Condition: Future With Project

Variable		TY 0	SI	TY 1	SI	TY 31	SI
V1	Percent cultch cover	0	0.00	100	1.00	100	1.00
V2	Mean salinity during spawning season	27	0.56	28	0.48	31	0.26
V3	Minimum annual salinity	12	1	12	1	13	1
V4	Annual mean salinity	24	0.32	26	0.22	28	0.16
		HSI=	**0.00**	HSI=	**0.57**	HSI=	**0.45**

Condition: Future With Project

Variable		TY 51	SI	TY	SI	TY	SI
V1	Percent cultch cover	100	1.00				
V2	Mean salinity during spawning season	32	0.22				
V3	Minimum annual salinity	14	1				
V4	Annual mean salinity	29	0.13				
		HSI=	**0.41**	HSI=		HSI=	

Condition: Future With Project

Variable		TY	SI	TY	SI	TY	SI
V1	Percent cultch cover						
V2	Mean salinity during spawning season						
V3	Minimum annual salinity						
V4	Annual mean salinity						
		HSI=		HSI=		HSI=	

American Oyster HSI Model Spreadsheet

Condition: Future Without Project

TY	Acres	HSI	Total HUs	Cumulative HUs
0	30	0.00	0.00	
1	30	0.00	0.00	0.00
31	30	0.00	0.00	0.00
51	30	0.00	0.00	0.00
Max TY=	51		AAHUs=	0.00

Condition: Future With Project

TY	Acres	HSI	Total HUs	Cumulative HUs
0	0	0.00	0.00	
1	30	0.57	17.06	5.69
31	30	0.45	13.55	459.08
51	30	0.41	12.34	258.86
Max TY=	51		AAHUs=	14.19

Net Change in AAHUs due to Project

Future With Project AAHUs	14.19
Future Without Project AAHUs	0.00
Net Change	**14.19**

American Oyster HSI Model Spreadsheet

Project: Dickinson Bayou Oyster Mitigation Site

Acres 7

Condition: Future Without Project

Variable		TY 0	SI	TY 1	SI	TY 10	SI
V1	Percent cultch cover	0	0.00	0	0.00	0	0.00
V2	Mean salinity during spawning season	27	0.56	28	0.48	31	0.26
V3	Minimum annual salinity	12	1	12	1	13	1
V4	Annual mean salinity	24	0.32	26	0.22	28	0.16
		HSI=	**0.00**	HSI=	**0.00**	HSI=	**0.00**

Condition: Future Without Project

Variable		TY 11	SI	TY 61	SI	TY	SI
V1	Percent cultch cover	0	0.00	0	0.00		
V2	Mean salinity during spawning season	32	0.22	32	0.22		
V3	Minimum annual salinity	14	1	14	1		
V4	Annual mean salinity	29	0.13	29	0.13		
		HSI=	**0.00**	HSI=	**0.00**	HSI=	

Condition: Future Without Project

Variable		TY	SI	TY	SI	TY	SI
V1	Percent cultch cover						
V2	Mean salinity during spawning season						
V3	Minimum annual salinity						
V4	Annual mean salinity						
		HSI=		HSI=		HSI=	

Acres 7

Condition: Future With Project

Variable		TY 0	SI	TY 1	SI	TY 10	SI
V1	Percent cultch cover	0	0.00	100	1.00	100	1.00
V2	Mean salinity during spawning season	27	0.56	28	0.48	31	0.26
V3	Minimum annual salinity	12	1	12	1	13	1
V4	Annual mean salinity	24	0.32	26	0.22	28	0.16
		HSI=	**0.00**	HSI=	**0.57**	HSI=	**0.45**

Condition: Future With Project

Variable		TY 11	SI	TY 61	SI	TY	SI
V1	Percent cultch cover	100	1.00	100	1.00		
V2	Mean salinity during spawning season	32	0.22	32	0.22		
V3	Minimum annual salinity	14	1	14	1		
V4	Annual mean salinity	29	0.13	29	0.13		
		HSI=	**0.41**	HSI=	**0.41**	HSI=	

Condition: Future With Project

Variable		TY	SI	TY	SI	TY	SI
V1	Percent cultch cover						
V2	Mean salinity during spawning season						
V3	Minimum annual salinity						
V4	Annual mean salinity						
		HSI=		HSI=		HSI=	

American Oyster HSI Model Spreadsheet

Condition: Future Without Project

TY	Acres	HSI	Total HUs	Cumulative HUs
0	7	0.00	0.00	
1	7	0.00	0.00	0.00
10	7	0.00	0.00	0.00
11	7	0.00	0.00	0.00
61	7	0.00	0.00	0.00
Max TY=	61		AAHUs=	0.00

Condition: Future With Project

TY	Acres	HSI	Total HUs	Cumulative HUs
0	0	0.00	0.00	
1	7	0.57	3.98	1.33
10	7	0.45	3.16	32.14
11	7	0.41	2.88	3.02
61	7	0.41	2.88	143.93
Max TY=	61		AAHUs=	2.96

Net Change in AAHUs due to Project

Future With Project AAHUs	2.96
Future Without Project AAHUs	0.00
Net Change	**2.96**

Project: Alligator Point Oyster Mitigation Site

American Oyster HSI Model Spreadsheet

Acres 10

Condition: Future Without Project		**TY** 0	**SI**	**TY** 1	**SI**	**TY** 10	**SI**
Variable							
V1	Percent cultch cover	0	0.00	0	0.00	0	0.00
V2	Mean salinity during spawning season	27	0.56	28	0.48	31	0.26
V3	Minimum annual salinity	12	1	12	1	13	1
V4	Annual mean salinity	24	0.32	26	0.22	28	0.16
		HSI=	**0.00**	HSI=	**0.00**	HSI=	**0.00**

Acres 10

Condition: Future With Project		**TY** 0	**SI**	**TY** 1	**SI**	**TY** 10	**SI**
Variable							
V1	Percent cultch cover	0	0.00	100	1.00	100	1.00
V2	Mean salinity during spawning season	27	0.56	28	0.48	31	0.26
V3	Minimum annual salinity	12	1	12	1	13	1
V4	Annual mean salinity	24	0.32	26	0.22	28	0.16
		HSI=	**0.00**	HSI=	**0.57**	HSI=	**0.45**

Condition: Future Without Project		**TY** 11	**SI**	**TY** 61	**SI**	**TY**	**SI**
Variable							
V1	Percent cultch cover	0	0.00	0	0.00		
V2	Mean salinity during spawning season	32	0.22	32	0.22		
V3	Minimum annual salinity	14	1	14	1		
V4	Annual mean salinity	29	0.13	29	0.13		
		HSI=	**0.00**	HSI=	**0.00**	HSI=	

Condition: Future With Project		**TY** 11	**SI**	**TY** 61	**SI**	**TY**	**SI**
Variable							
V1	Percent cultch cover	100	1.00	100	1.00		
V2	Mean salinity during spawning season	32	0.22	32	0.22		
V3	Minimum annual salinity	14	1	14	1		
V4	Annual mean salinity	29	0.13	29	0.13		
		HSI=	**0.41**	HSI=	**0.41**	HSI=	

Condition: Future Without Project		**TY**	**SI**	**TY**	**SI**	**TY**	**SI**
Variable							
V1	Percent cultch cover						
V2	Mean salinity during spawning season						
V3	Minimum annual salinity						
V4	Annual mean salinity						
		HSI=		HSI=		HSI=	

Condition: Future With Project		**TY**	**SI**	**TY**	**SI**	**TY**	**SI**
Variable							
V1	Percent cultch cover						
V2	Mean salinity during spawning season						
V3	Minimum annual salinity						
V4	Annual mean salinity						
		HSI=		HSI=		HSI=	

American Oyster HSI Model Spreadsheet

Condition: Future Without Project

TY	Acres	HSI	Total HUs	Cumulative HUs
0	10	0.00	0.00	
1	10	0.00	0.00	0.00
10	10	0.00	0.00	0.00
11	10	0.00	0.00	0.00
51	10	0.00	0.00	0.00
Max TY=	51		**AAHUs=**	0.00

Condition: Future With Project

TY	Acres	HSI	Total HUs	Cumulative HUs
0	0	0.00	0.00	
1	10	0.57	5.69	1.90
10	10	0.45	4.52	45.91
11	10	0.41	4.11	4.31
51	10	0.41	4.11	164.49
Max TY=	51		**AAHUs=**	4.25

Net Change in AAHUs due to Project

Future With Project AAHUs	4.25
Future Without Project AAHUs	0.00
Net Change	**4.25**

G-28

Habitat Modeling

G-28 -- Oyster Habitat

Project: G-28 American Oyster

American Oyster HSI Model Spreadsheet

Acres 0

Condition: Future Without Project		**TY** 0		**TY** 1		**TY** 31	
Variable			**SI**		**SI**		**SI**
V1	Percent cultch cover	0	0.00	0	0.00	0	0.00
V2	Mean salinity during spawning season	27	0.56	28	0.48	31	0.26
V3	Minimum annual salinity	12	1	12	1	13	1
V4	Annual mean salinity	24	0.32	26	0.22	28	0.16
		HSI=	**0.00**	HSI=	**0.00**	HSI=	**0.00**

Acres 18

Condition: Future With Project		**TY** 0		**TY** 1		**TY** 31	
Variable			**SI**		**SI**		**SI**
V1	Percent cultch cover	0	0.00	100	1.00	100	1.00
V2	Mean salinity during spawning season	27	0.56	28	0.48	31	0.26
V3	Minimum annual salinity	12	1	12	1	13	1
V4	Annual mean salinity	24	0.32	26	0.22	28	0.16
		HSI=	**0.00**	HSI=	**0.57**	HSI=	**0.45**

Condition: Future Without Project		**TY** 51		**TY**		**TY**	
Variable			**SI**		**SI**		**SI**
V1	Percent cultch cover	0	0.00				
V2	Mean salinity during spawning season	32	0.22				
V3	Minimum annual salinity	14	1				
V4	Annual mean salinity	29	0.13				
		HSI=	**0.00**	HSI=		HSI=	

Condition: Future With Project		**TY** 51		**TY**		**TY**	
Variable			**SI**		**SI**		**SI**
V1	Percent cultch cover	100	1.00				
V2	Mean salinity during spawning season	32	0.22				
V3	Minimum annual salinity	14	1				
V4	Annual mean salinity	29	0.13				
		HSI=	**0.41**	HSI=		HSI=	

Condition: Future Without Project		**TY**		**TY**		**TY**	
Variable			**SI**		**SI**		**SI**
V1	Percent cultch cover						
V2	Mean salinity during spawning season						
V3	Minimum annual salinity						
V4	Annual mean salinity						
		HSI=		HSI=		HSI=	

Condition: Future With Project		**TY**		**TY**		**TY**	
Variable			**SI**		**SI**		**SI**
V1	Percent cultch cover						
V2	Mean salinity during spawning season						
V3	Minimum annual salinity						
V4	Annual mean salinity						
		HSI=		HSI=		HSI=	

G-28 -- Oyster Habitat

American Oyster HSI Model Spreadsheet

Condition: Future Without Project

TY	Acres	HSI	Total HUs	Cumulative HUs
0	0	0.00	0.00	
1	0	0.00	0.00	0.00
31	0	0.00	0.00	0.00
51	0	0.00	0.00	0.00
Max TY=	51		**AAHUs=**	0.00

Condition: Future With Project

TY	Acres	HSI	Total HUs	Cumulative HUs
0	0	0.00	0.00	
1	18	0.57	10.23	3.41
31	18	0.45	8.13	275.45
51	18	0.41	7.40	155.31
Max TY=	51		**AAHUs=**	8.51

Net Change in AAHUs due to Project

Future With Project AAHUs	8.51
Future Without Project AAHUs	0.00
Net Change	**8.51**

G-28 -- Rookery Habitat

Project: G-28 Brown Pelican

Brown Pelican HSI Model Spreadsheet

What State is the Project Location TX

Acres 23

Condition: Future Without Project

Variable		TY 0	SI	TY 1	SI	TY 31	SI
V1	Island surface area	Greater than 8 ha (19.8 ac)	0.40	Less than 2 ha (4.9 ac)	0.40	Less than 2 ha (4.9 ac)	0.40
V2	Distance of island from mainland*	0.18	0.45	0.18	0.45	0.18	0.45
V3	Distance of island from nearest human activity center*	4.5	1.00	4.5	1.00	4.5	1.00
V4 (WDY)							
V4	Percent of Island surface area at least 0.6 m elevation	100	1.00	100	1.00	0	0.00
		HSI=	0.65	HSI=	0.65	HSI=	0.00

Acres 326

Condition: Future With Project

Variable		TY 0	SI	TY 1	SI	TY 31	SI
V1	Island surface area	Greater than 8 ha (19.8 ac)	0.40	Greater than 8 ha (19.8 ac)	0.40	Greater than 8 ha (19.8 ac)	0.40
V2	Distance of island from mainland*	0.18	0.45	0.18	0.45	0.18	0.45
V3	Distance of island from nearest human activity center*	4.5	1.00	4.5	1.00	4.5	1.00
V4 (WDY)							
V4	Percent of Island surface area at least 0.6 m elevation	100	1.00	96	1.00	98	1.00
		HSI=	0.65	HSI=	0.65	HSI=	0.65

Condition: Future Without Project

Variable		TY 51	SI	TY	SI	TY	SI
V1	Island surface area	Less than 2 ha (4.9 ac)	0.40				
V2	Distance of island from mainland*	0.18	0.45				
V3	Distance of island from nearest human activity center*	4.5	1.00				
V4 (WDY)							
V4	Percent of Island surface area at least 0.6 m elevation	0	0.00				
		HSI=	0.00	HSI=		HSI=	

Condition: Future With Project

Variable		TY 51	SI	TY	SI	TY	SI
V1	Island surface area	Greater than 8 ha (19.8 ac)	0.40				
V2	Distance of island from mainland*	0.18	0.45				
V3	Distance of island from nearest human activity center*	4.5	1.00				
V4 (WDY)							
V4	Percent of Island surface area at least 0.6 m elevation	96	1.00				
		HSI=	0.65	HSI=		HSI=	

Condition: Future Without Project

Variable		TY	SI	TY	SI	TY	SI
V1	Island surface area						
V2	Distance of island from mainland*						
V3	Distance of island from nearest human activity center*						
V4 (WDY)							
V4	Percent of Island surface area at least 0.6 m elevation						
		HSI=		HSI=		HSI=	

Condition: Future With Project

Variable		TY	SI	TY	SI	TY	SI
V1	Island surface area						
V2	Distance of island from mainland*						
V3	Distance of island from nearest human activity center*						
V4 (WDY)							
V4	Percent of Island surface area at least 0.6 m elevation						
		HSI=		HSI=		HSI=	

* Measured as a straight-line distance in km.

G-28 -- Rookery Habitat

Brown Pelican HSI Model Spreadsheet

Condition: Future Without Project

TY	Acres	HSI	Total HUs	Cumulative HUs
0	23	0.65	14.98	
1	11	0.65	7.13	11.05
31	0	0.00	0.00	71.26
51	0	0.00	0.00	0.00
Max TY=	**51**		AAHUs=	1.61

Condition: Future With Project

TY	Acres	HSI	Total HUs	Cumulative HUs
0	23	0.65	14.98	
1	326	0.65	212.34	113.66
31	313	0.65	203.87	6243.24
51	307	0.65	199.97	4038.40
Max TY=	**51**		AAHUs=	203.83

Net Change in AAHUs due to Project

Future With Project AAHUs	203.83
Future Without Project AAHUs	1.61
Net Change	202.22

G-28 -- Estuarine Marsh Habitat (Direct Benefits of Marsh Nourishment)

Project: G-28 Bolivar Peninsula and West Bay GIWW Shoreline and Island Protection (Marsh Nourishment)

Brown Shrimp HSI Model Spreadsheet

Condition: Future Without Project

		TY	0	TY	1	TY	31
	Acreage by TY		664		664		1043
Variable			**SI**		**SI**		**SI**
V1	% of estuary covered by vegetation (marsh and seagrass).	0	0.00	0	0.00	0	0.00
V2	Substrate Composition	soft bo	1.00	soft bo	1.00	soft bo	1.00
V3	Mean salinity - spring	18	1.00	19	1.00	21	0.98
V4	Mean water temperature - spring	24	1	24	1	24	1
		HSI=	**0.00**	HSI=	**0.00**	HSI=	**0.00**
		vba fn	0.00		0.00		0.00

Condition: Future With Project

		TY	0	TY	1	TY	31
	Acreage by TY		664		664		1043
Variable			**SI**		**SI**		**SI**
V1	% of estuary covered by vegetation (marsh and seagrass).	0	0.00	50	0.50	90	0.90
V2	Substrate Composition	soft bo	1.00	soft bo	1.00	soft bo	1.00
V3	Mean salinity - spring	18	1.00	19	1.00	21	0.98
V4	Mean water temperature - spring	24	1	24	1	24	1
		HSI=	**0.00**	HSI=	**0.63**	HSI=	**0.93**
		vba fn	0.00		0.37		0.93

Condition: Future Without Project

		TY	51	TY		TY	
			846				
Variable			**SI**		**SI**		**SI**
V1	% of estuary covered by vegetation (marsh and seagrass).	0	0.00				
V2	Substrate Composition	soft bo	1.00				
V3	Mean salinity - spring	22	0.96				
V4	Mean water temperature - spring	24	1				
		HSI=	**0.00**	HSI=		HSI=	
		vba fn	0.00		V1_ENTRY		V1_ENTRY

Condition: Future With Project

		TY	51	TY		TY	
			846				
Variable			**SI**		**SI**		**SI**
V1	% of estuary covered by vegetation (marsh and seagrass).	90	0.90				
V2	Substrate Composition	soft bo	1.00				
V3	Mean salinity - spring	22	0.96				
V4	Mean water temperature - spring	24	1				
		HSI=	**0.93**	HSI=		HSI=	
		vba fn	0.87		V1_ENTRY		V1_ENTRY

Condition: Future Without Project

		TY		TY		TY	
Variable			**SI**		**SI**		**SI**
V1	% of estuary covered by vegetation (marsh and seagrass).						
V2	Substrate Composition						
V3	Mean salinity - spring						
V4	Mean water temperature - spring						
		HSI=		HSI=		HSI=	
		vba fn	V1_ENTRY		V1_ENTRY		V1_ENTRY

Condition: Future With Project

		TY		TY		TY	
Variable			**SI**		**SI**		**SI**
V1	% of estuary covered by vegetation (marsh and seagrass).						
V2	Substrate Composition						
V3	Mean salinity - spring						
V4	Mean water temperature - spring						
		HSI=		HSI=		HSI=	
		vba fn	V1_ENTRY		V1_ENTRY		V1_ENTRY

G-28 -- Estuarine Marsh Habitat (Direct Benefits of Marsh Nourishment)

Brown Shrimp HSI Model Spreadsheet

Condition: Future Without Project

TY	Acres	HSI	Total HUs	Cumulative HUs
0	664	0.00	0.00	
1	664	0.00	0.00	0.00
31	1043	0.00	0.00	0.00
51	846	0.00	0.00	0.00
Max TY=	**51**		**AAHUs=**	**0.0**

Condition: Future With Project

TY	Acres	HSI	Total HUs	Cumulative HUs
0	664	0.00	0.00	
1	664	0.63	418.29	209.15
31	1043	0.93	972.25	20285.52
51	846	0.93	788.62	17608.69
Max TY=	**51**		**AAHUs=**	**747.1**

Net Change in AAHUs due to Project

Future With Project AAHUs	747.1
Future Without Project AAHUs	0.0
Net Change	747.1

G-28 -- Estuarine Marsh Habitat (Passive Benefits of Breakwater Accretion of Marsh)

Brown Shrimp HSI Model Spreadsheet

Project: G-28 Bolivar Peninsula and West Bay GIWW Shoreline and Island Protection (Breakwaters-Accretion)

Condition: Future Without Project							
		TY	0	**TY**	1	**TY**	31
	Acreage by TY		203		203		203
Variable			**SI**		**SI**		**SI**
V1	% of estuary covered by vegetation (marsh and seagrass).	0	0.00	0	0.00	0	0.00
V2	Substrate Composition	soft bo	1.00	soft bo	1.00	soft bo	1.00
V3	Mean salinity - spring	18	1.00	19	1.00	21	0.98
V4	Mean water temperature - spring	24	1	24	1	24	1
		HSI=	**0.00**	**HSI=**	**0.00**	**HSI=**	**0.00**
		vba fn	**######**		**######**		**######**

Condition: Future With Project							
		TY	0	**TY**	1	**TY**	31
	Acreage by TY		203		203		203
Variable			**SI**		**SI**		**SI**
V1	% of estuary covered by vegetation (marsh and seagrass).	0	0.00	90	0.90	90	0.90
V2	Substrate Composition	soft bo	1.00	soft bo	1.00	soft bo	1.00
V3	Mean salinity - spring	18	1.00	18	1.00	18	1.00
V4	Mean water temperature - spring	24	1	24	1	24	1
		HSI=	**0.00**	**HSI=**	**0.93**	**HSI=**	**0.93**
		vba fn	**#NAME?**		**#NAME?**		**#NAME?**

Condition: Future Without Project							
		TY	51	**TY**		**TY**	
			203				
Variable			**SI**		**SI**		**SI**
V1	% of estuary covered by vegetation (marsh and seagrass).	0	0.00				
V2	Substrate Composition	soft bo	1.00				
V3	Mean salinity - spring	22	0.96				
V4	Mean water temperature - spring	24	1				
		HSI=	**0.00**	**HSI=**		**HSI=**	
		vba fn	**0.00**		**V1_ENTRY**		**V1_ENTRY**

Condition: Future With Project							
		TY	51	**TY**		**TY**	
			203				
Variable			**SI**		**SI**		**SI**
V1	% of estuary covered by vegetation (marsh and seagrass).	90	0.90				
V2	Substrate Composition	soft bo	1.00				
V3	Mean salinity - spring	18	1.00				
V4	Mean water temperature - spring	24	1				
		HSI=	**0.93**	**HSI=**		**HSI=**	
		vba fn	**#NAME?**		**V1_ENTRY**		**V1_ENTRY**

Condition: Future Without Project							
		TY		**TY**		**TY**	
Variable			**SI**		**SI**		**SI**
V1	% of estuary covered by vegetation (marsh and seagrass).						
V2	Substrate Composition						
V3	Mean salinity - spring						
V4	Mean water temperature - spring						
		HSI=		**HSI=**		**HSI=**	
		vba fn	**V1_ENTRY**		**V1_ENTRY**		**V1_ENTRY**

Condition: Future With Project							
		TY		**TY**		**TY**	
Variable			**SI**		**SI**		**SI**
V1	% of estuary covered by vegetation (marsh and seagrass).						
V2	Substrate Composition						
V3	Mean salinity - spring						
V4	Mean water temperature - spring						
		HSI=		**HSI=**		**HSI=**	
		vba fn	**V1_ENTRY**		**V1_ENTRY**		**V1_ENTRY**

G-28 -- Estuarine Marsh Habitat (Passive Benefits of Breakwater Accretion of Marsh)

Brown Shrimp HSI Model Spreadsheet

Condition: Future Without Project

TY	Acres	HSI	Total HUs	Cumulative HUs
0	203	0.00	0.00	
1	203	0.00	0.00	0.00
31	203	0.00	0.00	0.00
51	203	0.00	0.00	0.00
Max TY=	**51**		**AAHUs=**	**0.0**

Condition: Future With Project

TY	Acres	HSI	Total HUs	Cumulative HUs
0	203	0.00	0.00	
1	203	0.93	189.23	94.62
31	203	0.93	189.23	5676.91
51	203	0.93	189.23	3784.61
Max TY=	**51**		**AAHUs=**	**187.4**

Net Change in AAHUs due to Project

Future With Project AAHUs	187.4
Future Without Project AAHUs	0.0
Net Change	187.4

G-28 -- Estuarine Marsh Habitat (Passive Benefits of Breakwater Erosion Reduction)

Project: G-28 Bolivar Peninsula and West Bay GIWW Shoreline and Island Protection (Breakwaters -- Erosion)

Brown Shrimp HSI Model Spreadsheet

Condition: Future Without Project

Variable			SI		SI		SI
		TY	0	TY	1	TY	31
	Acreage by TY		395		395		280
V1	% of estuary covered by vegetation (marsh and seagrass).	90	0.90	92	0.92	92	0.92
V2	Substrate Composition	soft bo	1.00	soft bo	1.00	soft bo	1.00
V3	Mean salinity - spring	18	1.00	19	1.00	21	0.98
V4	Mean water temperature - spring	24	1	24	1	24	1
		HSI=	**0.93**	HSI=	**0.95**	HSI=	**0.95**
		vba fn	0.93		0.95		0.88

Condition: Future With Project

Variable			SI		SI		SI
		TY	0	TY	1	TY	31
	Acreage by TY		395		395		395
V1	% of estuary covered by vegetation (marsh and seagrass).	90	0.90	94	0.94	92	0.92
V2	Substrate Composition	soft bo	1.00	soft bo	1.00	soft bo	1.00
V3	Mean salinity - spring	18	1.00	19	1.00	21	0.98
V4	Mean water temperature - spring	24	1	24	1	24	1
		HSI=	**0.93**	HSI=	**0.96**	HSI=	**0.95**
		vba fn	0.93		0.56		0.95

Condition: Future Without Project

Variable			SI		SI		SI
		TY	51	TY		TY	
			0				
V1	% of estuary covered by vegetation (marsh and seagrass).	92	0.92				
V2	Substrate Composition	soft bo	1.00				
V3	Mean salinity - spring	22	0.96				
V4	Mean water temperature - spring	24	1				
		HSI=	**0.95**	HSI=		HSI=	
		vba fn	0.95		V1_ENTRY		V1_ENTRY

Condition: Future With Project

Variable			SI		SI		SI
		TY	51	TY		TY	
			395				
V1	% of estuary covered by vegetation (marsh and seagrass).	92	0.92				
V2	Substrate Composition	soft bo	1.00				
V3	Mean salinity - spring	22	0.96				
V4	Mean water temperature - spring	24	1				
		HSI=	**0.95**	HSI=		HSI=	
		vba fn	0.88		V1_ENTRY		V1_ENTRY

Condition: Future Without Project

Variable			SI		SI		SI
		TY		TY		TY	
V1	% of estuary covered by vegetation (marsh and seagrass).						
V2	Substrate Composition						
V3	Mean salinity - spring						
V4	Mean water temperature - spring						
		HSI=		HSI=		HSI=	
		vba fn	V1_ENTRY		V1_ENTRY		V1_ENTRY

Condition: Future With Project

Variable			SI		SI		SI
		TY		TY		TY	
V1	% of estuary covered by vegetation (marsh and seagrass).						
V2	Substrate Composition						
V3	Mean salinity - spring						
V4	Mean water temperature - spring						
		HSI=		HSI=		HSI=	
		vba fn	V1_ENTRY		V1_ENTRY		V1_ENTRY

G-28 -- Estuarine Marsh Habitat (Passive Benefits of Breakwater Erosion Reduction)

Brown Shrimp HSI Model Spreadsheet

Condition: Future Without Project

TY	Acres	HSI	Total HUs	Cumulative HUs
0	395	0.93	368.21	
1	395	0.95	373.64	370.92
31	280	0.95	264.86	9577.53
51	0	0.95	0.00	2648.60
Max TY=	**51**		**AAHUs=**	**247.0**

Condition: Future With Project

TY	Acres	HSI	Total HUs	Cumulative HUs
0	395	0.93	368.21	
1	395	0.96	379.04	373.62
31	395	0.95	373.64	11290.19
51	395	0.95	373.64	7472.84
Max TY=	**51**		**AAHUs=**	**375.2**

Net Change in AAHUs due to Project

Future With Project AAHUs	375.2
Future Without Project AAHUs	247.0
Net Change	128.2

G-28 -- Palustrin Marsh Habitat (Passive Benefits of Breakwater Erosion Reduction)

Project: G-28- Bolivar Peninsula and West Bay GIWW Shoreline and Island Protection (Erosion)

American alligator HSI Model Spreadsheet

Acres 47

Condition: Future Without Project

Variable		TY 0	SI	TY 1	SI	TY 31	SI
V1	% wetland that is open water (ponds, bayous, canals).	30	1.00	30	1.00	30	1.00
V2	% open water in bayous, canals or > 1.2m deep	10	1.00	10	1.00	10	1.00
V3	Interspersion Class	Medium	0.50	Mediu	0.50	Mediu	0.50
V4	% ponded area >=15 cm deep (May - September)	60	0.6	60	0.6	60	0.6
V5	% substrate exposed at MLT (May - Sep) - Tidal only						
	CI (tidal) | CI (non-tidal)		0.6694		0.6694		0.6694
		HSI=	0.8182	HSI=	0.8182	HSI=	0.8182

Acres 47

Condition: Future With Project

Variable		TY 0	SI	TY 1	SI	TY 31	SI
V1	% wetland that is open water (ponds, bayous, canals).	30	1.00	30	1.00	30	1.00
V2	% open water in bayous, canals or > 1.2m deep	10	1.00	10	1.00	10	1.00
V3	Interspersion Class	Medium	0.50	Mediu	0.50	Mediu	0.50
V4	% ponded area >=15 cm deep (May - September)	60	0.6	60	0.6	60	0.6
V5	% substrate exposed at MLT (May - Sep) - Tidal only						
	CI (tidal) | CI (non-tidal)		0.6694		0.6694		0.6694
		HSI=	0.8182	HSI=	0.8182	HSI=	0.8182

Condition: Future Without Project

Variable		TY 51	SI	TY	SI	TY	SI
V1	% wetland that is open water (ponds, bayous, canals).	30	1.00				
V2	% open water in bayous, canals or > 1.2m deep	10	1.00				
V3	Interspersion Class	Medium	0.50				
V4	% ponded area >=15 cm deep (May - September)	60	0.6				
V5	% substrate exposed at MLT (May - Sep) - Tidal only						
	CI (tidal) | CI (non-tidal)		0.6694				
		HSI=	0.8182	HSI=		HSI=	

Condition: Future With Project

Variable		TY 51	SI	TY	SI	TY	SI
V1	% wetland that is open water (ponds, bayous, canals).	30	1.00				
V2	% open water in bayous, canals or > 1.2m deep	10	1.00				
V3	Interspersion Class	Medium	0.50				
V4	% ponded area >=15 cm deep (May - September)	60	0.6				
V5	% substrate exposed at MLT (May - Sep) - Tidal only						
	CI (tidal) | CI (non-tidal)		0.6694				
		HSI=	0.8182	HSI=		HSI=	

Condition: Future Without Project

Variable		TY	SI	TY	SI	TY	SI
V1	% wetland that is open water (ponds, bayous, canals).						
V2	% open water in bayous, canals or > 1.2m deep						
V3	Interspersion Class						
V4	% ponded area >=15 cm deep (May - September)						
V5	% substrate exposed at MLT (May - Sep) - Tidal only						
	CI (tidal) | CI (non-tidal)						
		HSI=		HSI=		HSI=	

Condition: Future With Project

Variable		TY	SI	TY	SI	TY	SI
V1	% wetland that is open water (ponds, bayous, canals).						
V2	% open water in bayous, canals or > 1.2m deep						
V3	Interspersion Class						
V4	% ponded area >=15 cm deep (May - September)						
V5	% substrate exposed at MLT (May - Sep) - Tidal only						
	CI (tidal) | CI (non-tidal)						
		HSI=		HSI=		HSI=	

G-28 -- Palustrin Marsh Habitat (Passive Benefits of Breakwater Erosion Reduction)

American alligator HSI Model Spreadsheet

Condition: Future Without Project

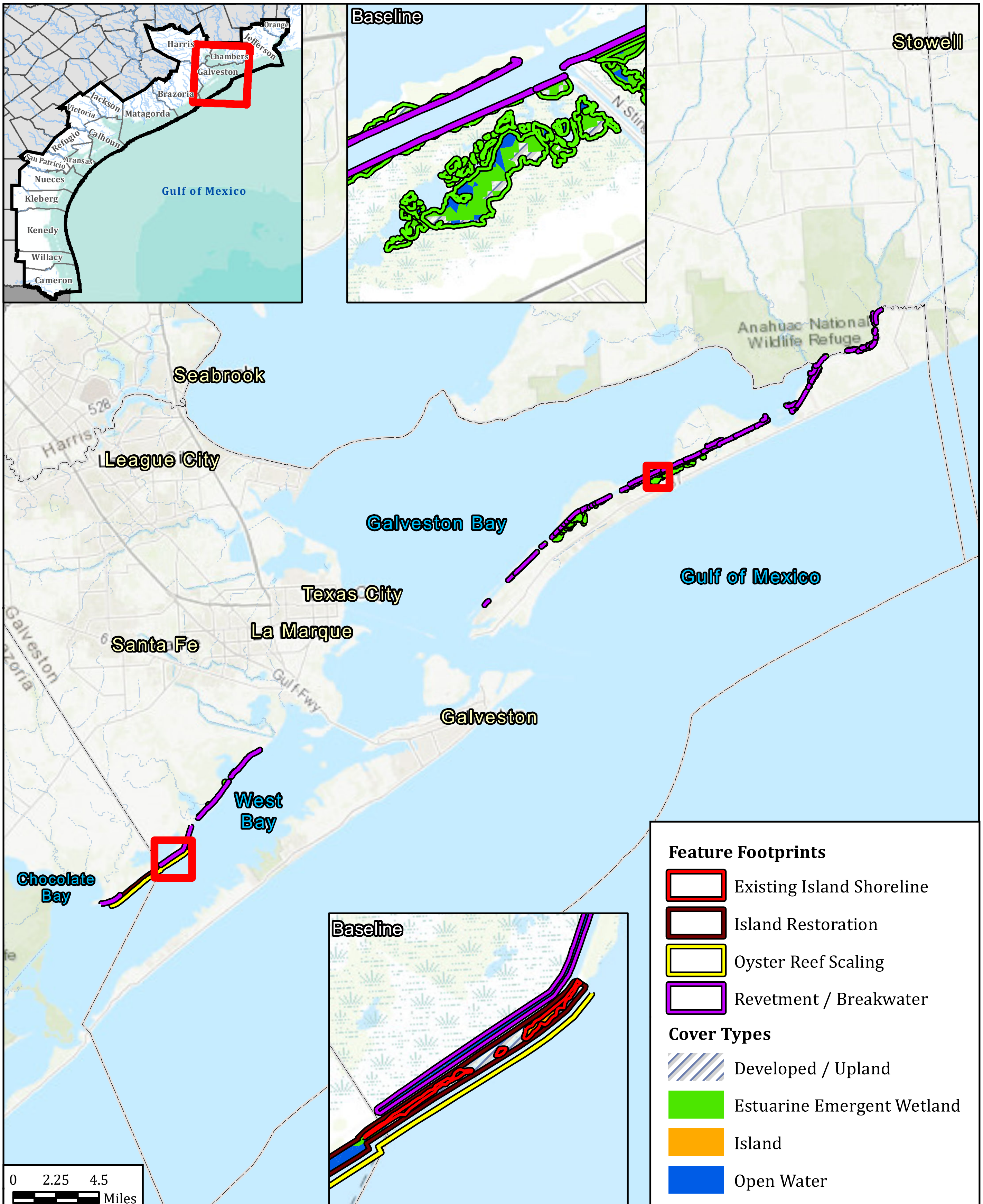
TY	Acres	HSI	Total HUs	Cumulative HUs
0	47	0.82	38.45	
1	47	0.82	38.45	38.45
31	11	0.82	9.00	711.82
51	0	0.82	0.00	90.00
Max TY=	**51**		**AAHUs=**	**16.5**

Condition: Future With Project

TY	Acres	HSI	Total HUs	Cumulative HUs
0	47	0.82	38.45	
1	47	0.82	38.45	38.45
31	47	0.82	38.45	1153.65
51	47	0.82	38.45	769.10
Max TY=	**51**		**AAHUs=**	**38.5**

Net Change in AAHUs due to Project

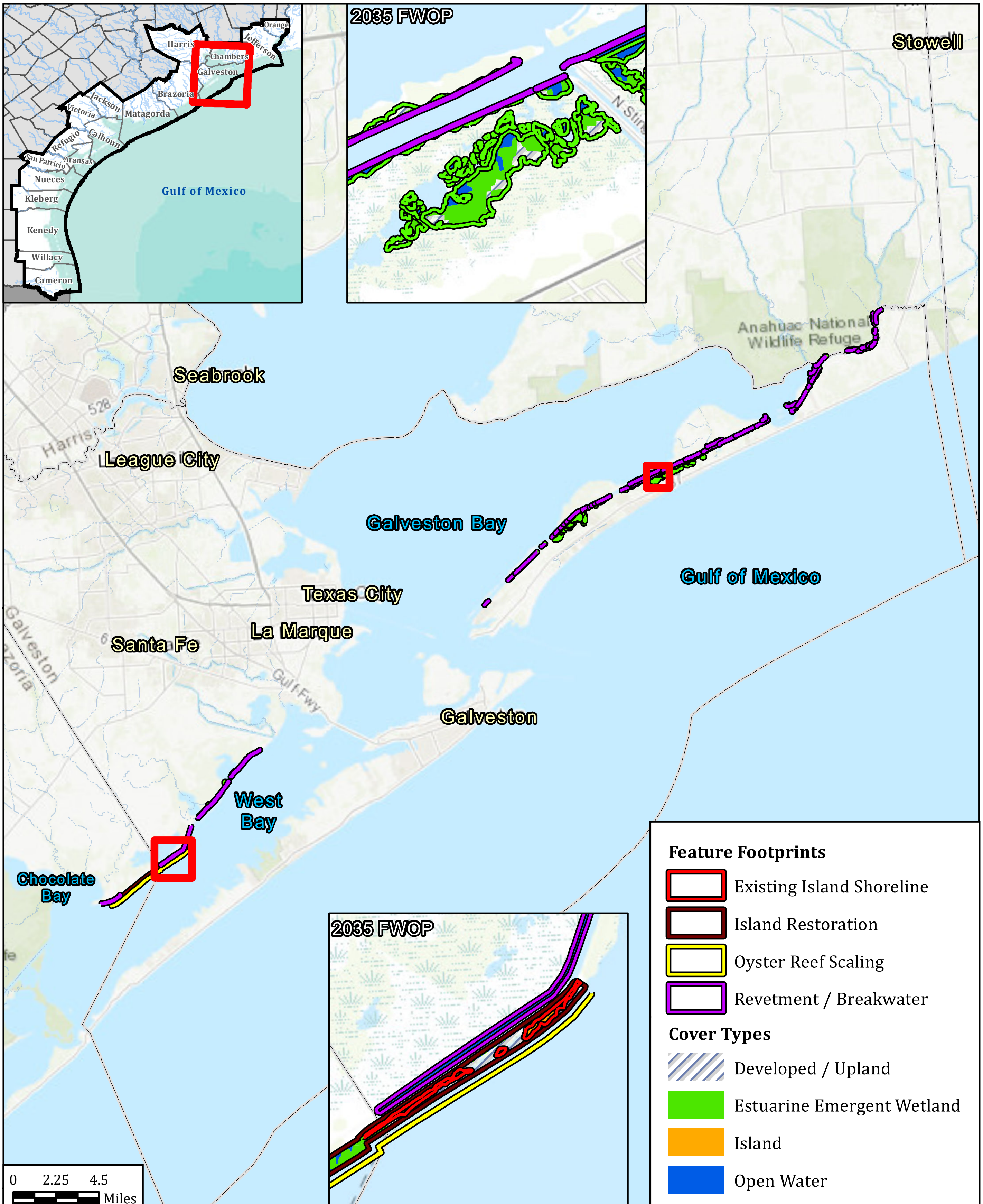
Future With Project AAHUs	38.5
Future Without Project AAHUs	16.5
Net Change	22.0



USACE COASTAL TEXAS PROTECTION AND RESTORATION STUDY		FN JOB NO TGL18185	1.0 FIGURE
		FILE NAME 1_G28_Mapbook.mxd	
		DATE 9/2/2020	
G-28 - Bolivar Peninsula and West Bay GIWW Shoreline and Island Protection Baseline Cover Types		SCALE 1:439,410	
		DESIGNED KLC	
		DRAFTED 02588	

Base Map: ESRI World Topographic Map Service

NAD 1983 StatePlane Texas Central FIPS 4203 Feet



N W E S

USACE COASTAL TEXAS
PROTECTION AND RESTORATION STUDY

G-28 - Bolivar Peninsula and West Bay
GIWW Shoreline and Island Protection 2035 FWOP Cover Types

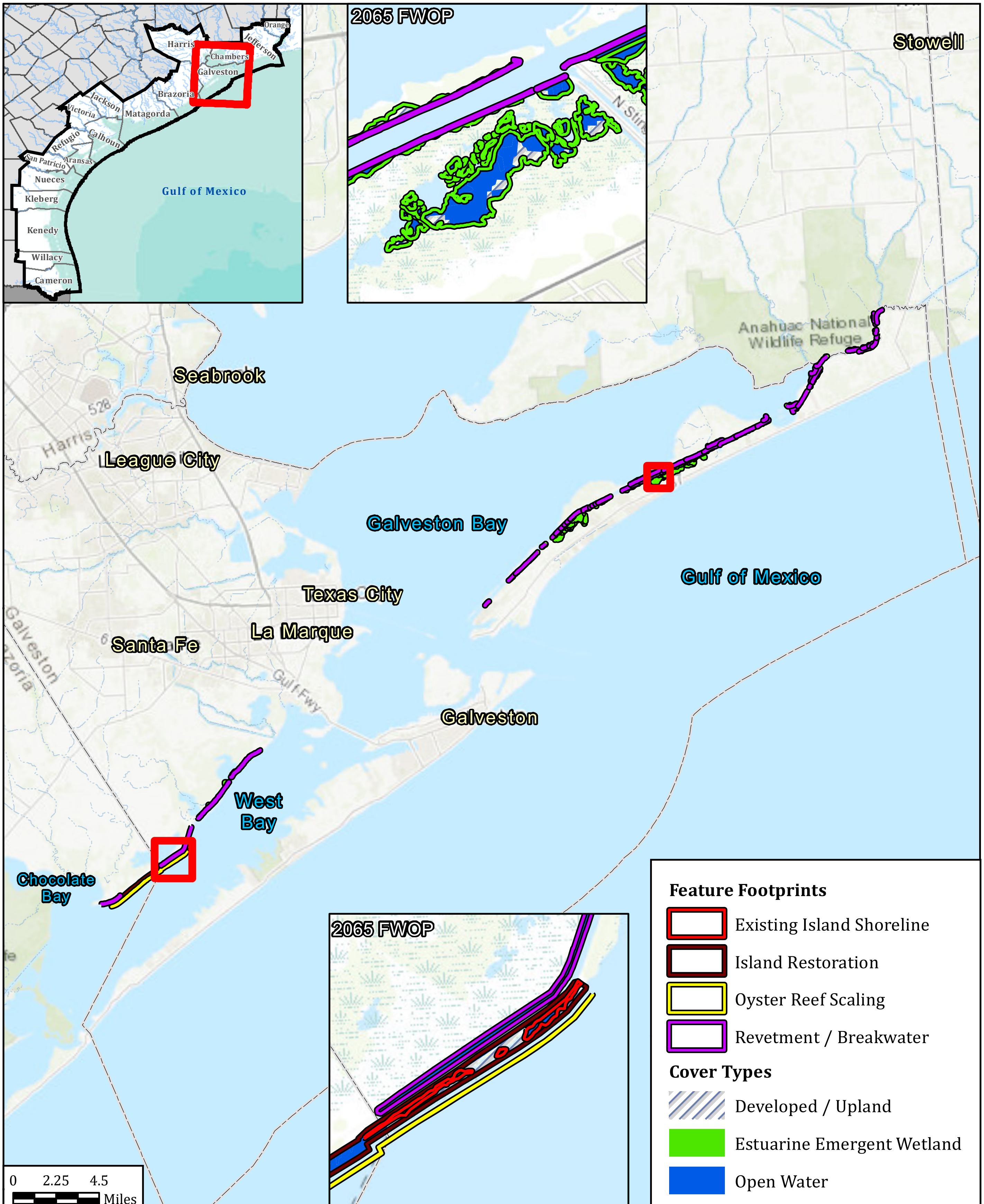
FN JOB NO	TGL18185
FILE NAME	1_G28_Mapbook.mxd
DATE	9/2/2020
SCALE	1:439,410
DESIGNED	KLC
DRAFTED	02588

1.1

FIGURE

Base Map: ESRI World Topographic Map Service

NAD 1983 StatePlane Texas Central FIPS 4203 Feet



USACE COASTAL TEXAS
PROTECTION AND RESTORATION STUDY

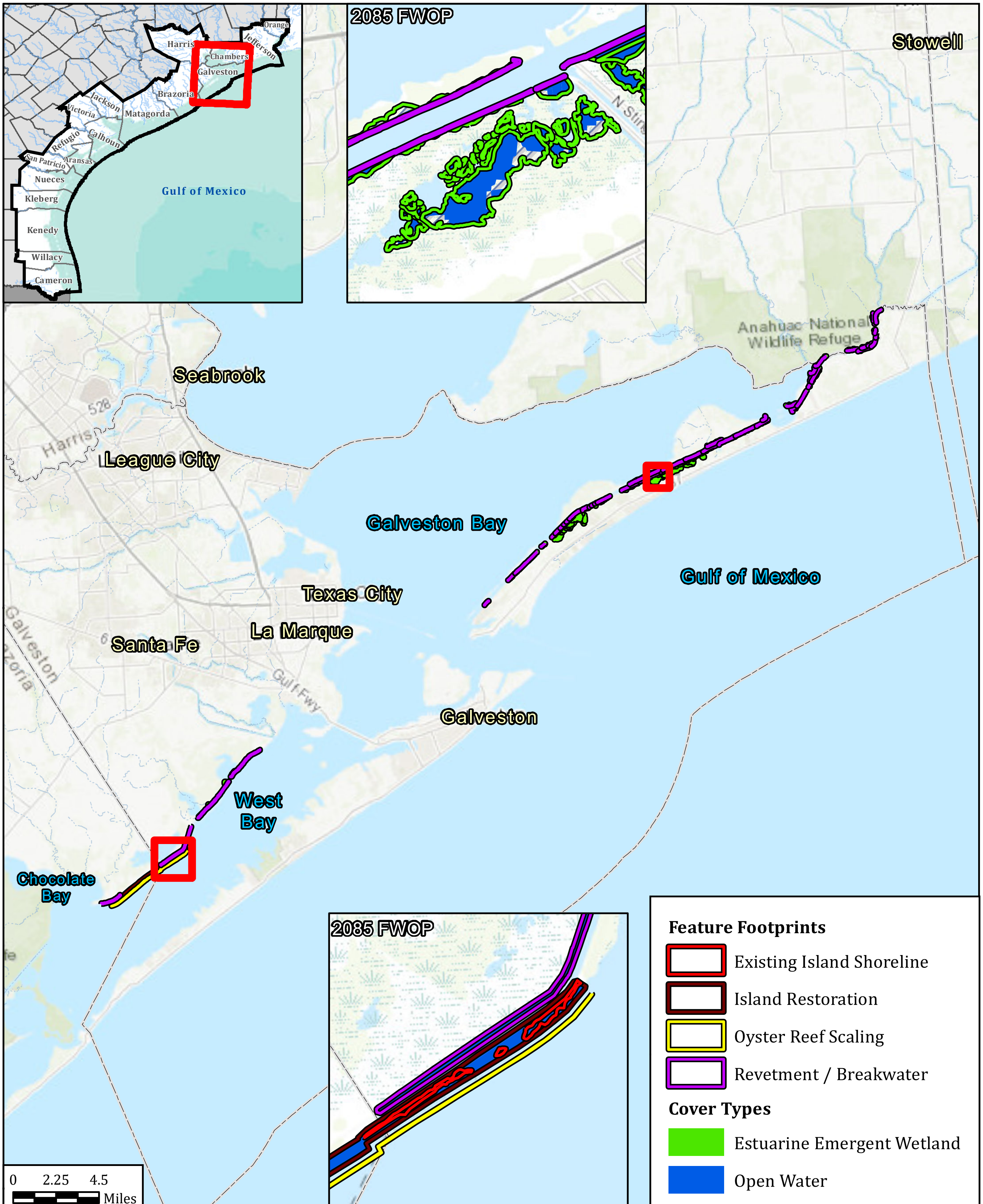
G-28 - Bolivar Peninsula and West Bay GIWW Shoreline and Island Protection 2065 FWOP Cover Types

FN JOB NO	TGL18185
FILE NAME	1_G28_Mapbook.mxd
DATE	9/2/2020
SCALE	1:439,410
DESIGNED	KLC
DRAFTED	02588

FIGURE 1.2

Base Map: ESRI World Topographic Map Service

NAD 1983 StatePlane Texas Central FIPS 4203 Feet



N W E S

USACE COASTAL TEXAS
PROTECTION AND RESTORATION STUDY

G-28 - Bolivar Peninsula and West Bay
GIWW Shoreline and Island Protection 2085 FWOP Cover Types

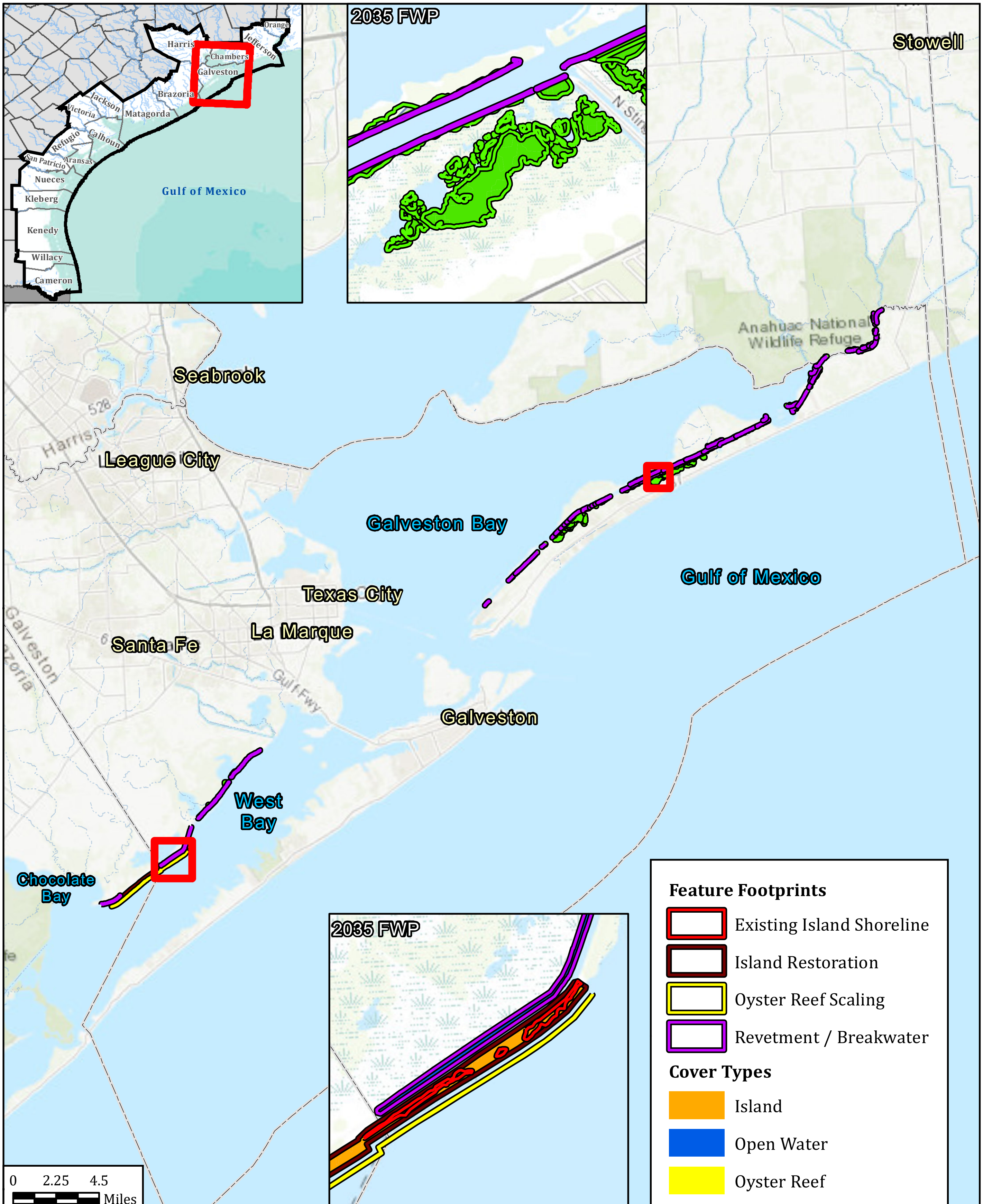
FN JOB NO	TGL18185
FILE NAME	1_G28_Mapbook.mxd
DATE	9/2/2020
SCALE	1:439,410
DESIGNED	KLC
DRAFTED	02588

1.3

FIGURE

Base Map: ESRI World Topographic Map Service

NAD 1983 StatePlane Texas Central FIPS 4203 Feet



N W E S

USACE COASTAL TEXAS
PROTECTION AND RESTORATION STUDY

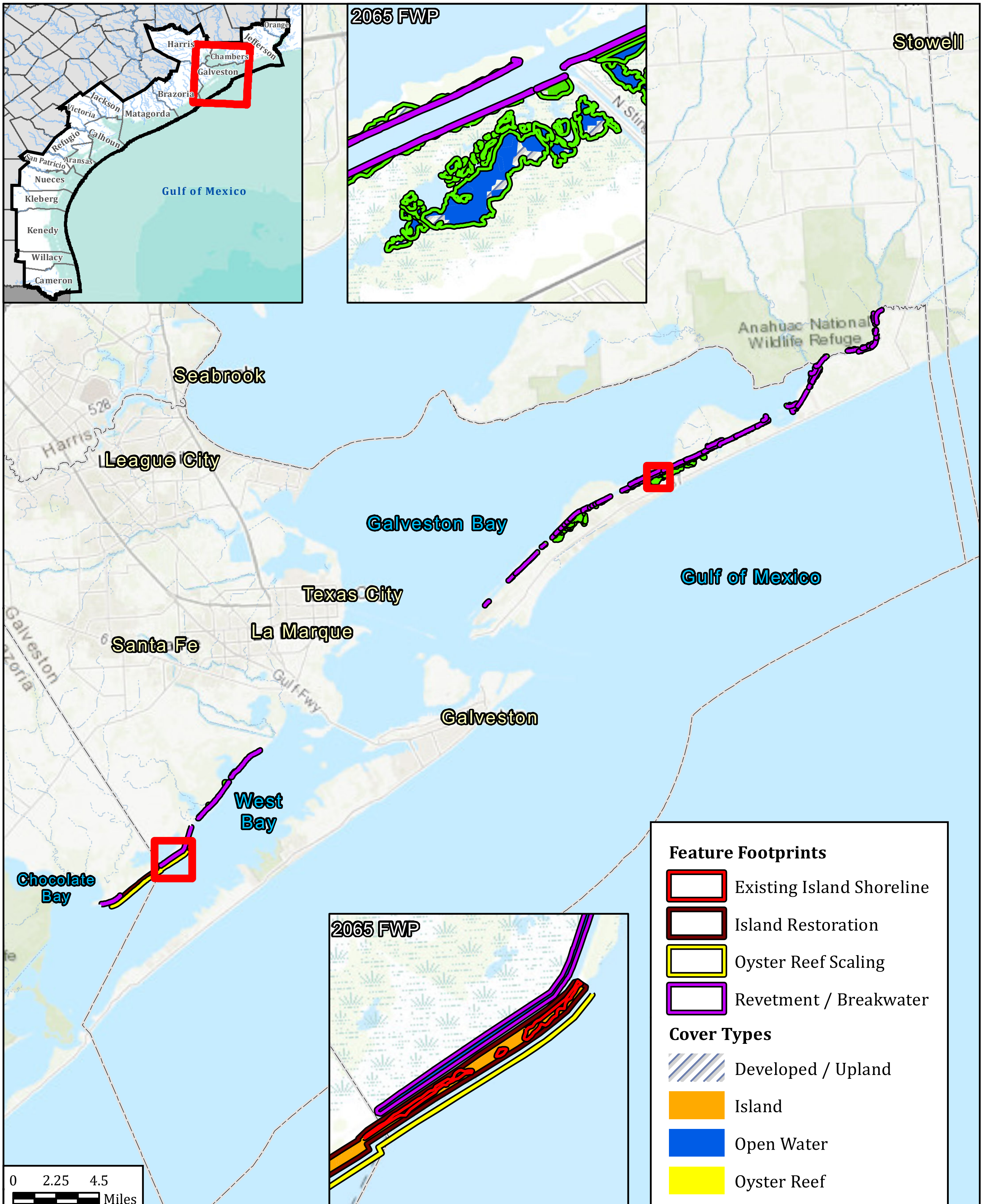
G-28 - Bolivar Peninsula and West Bay
GIWW Shoreline and Island Protection 2035 FWP Cover Types

FN JOB NO	TGL18185
FILE NAME	1_G28_Mapbook.mxd
DATE	9/2/2020
SCALE	1:439,410
DESIGNED	KLC
DRAFTED	02588

1.4
FIGURE

Base Map: ESRI World Topographic Map Service

NAD 1983 StatePlane Texas Central FIPS 4203 Feet



USACE COASTAL TEXAS
PROTECTION AND RESTORATION STUDY

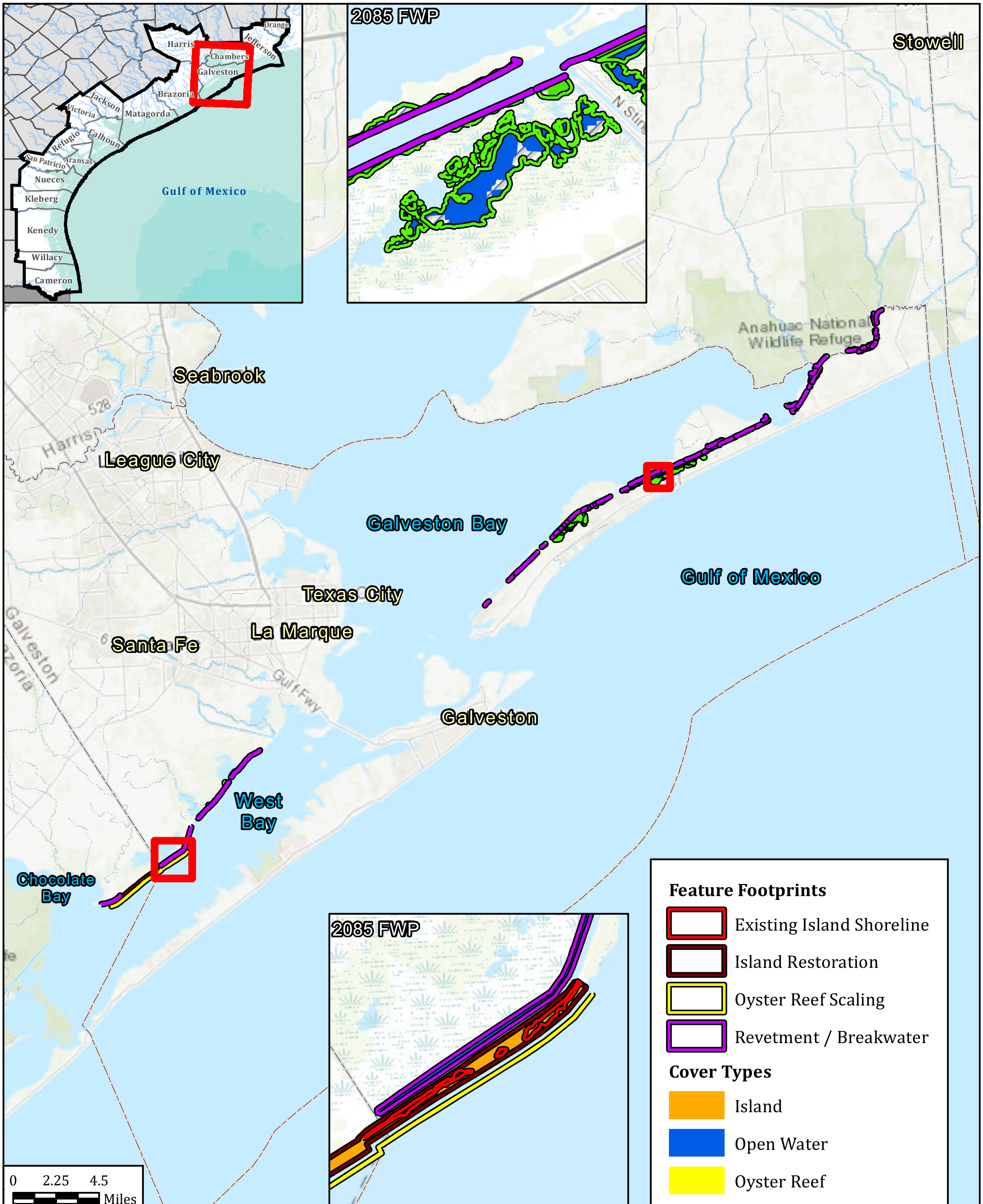
G-28 - Bolivar Peninsula and West Bay
GIWW Shoreline and Island Protection 2065 FWP Cover Types

FN JOB NO	TGL18185
FILE NAME	1_G28_Mapbook.mxd
DATE	9/2/2020
SCALE	1:439,410
DESIGNED	KLC
DRAFTED	02588

1.5
FIGURE

Base Map: ESRI World Topographic Map Service

NAD 1983 StatePlane Texas Central FIPS 4203 Feet



N W E S

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PROTECTION AND RESTORATION STUDY

G-28 - Bolivar Peninsula and West Bay
GIWW Shoreline and Island Protection 2085 FWP Cover Types

FN JOB NO	TGL18185
FILE NAME	1_G28_Mapbook.mxd
DATE	9/2/2020
SCALE	1:439,410
DESIGNED	KLC
DRAFTED	02588

1.6
FIGURE

Base Map: ESRI World Topographic Map Service

NAD 1983 StatePlane Texas Central FIPS 4203 Feet

ER Measure G28 Bolivar Peninsula and West Bay GIWW Shoreline and Island Protection

Shoreline (2018)

NWI Polygon

2035 Interstitial Benefit Area

NWI Polygon

2035 Benefit Area

NWI Polygon

2065 Benefit Area

NWI Polygon

2085 Benefit Area

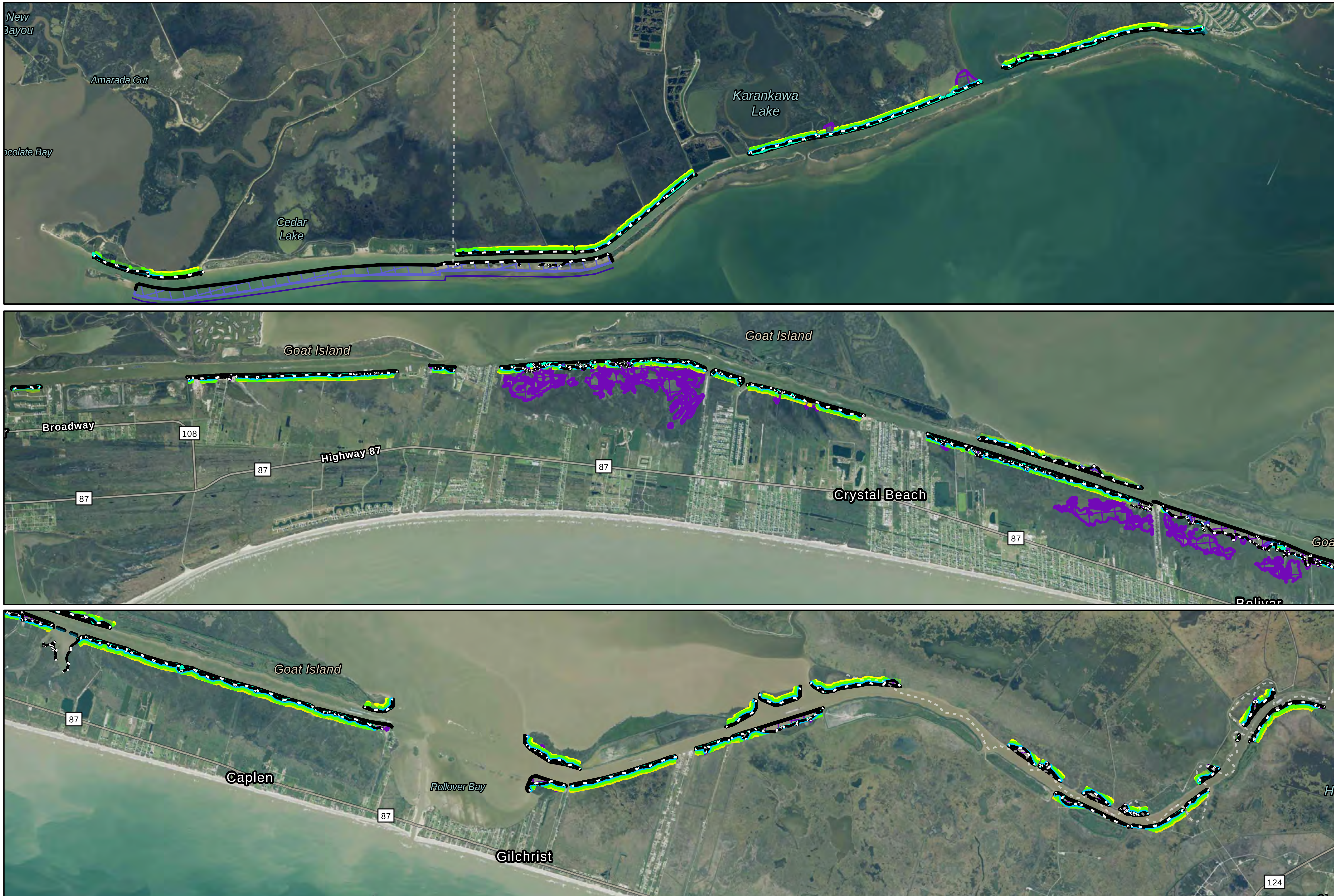
ER Measure

Breakwater

Island Restoration

Oyster Reef Scaling

Wetland / Marsh Restoration



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Coastal Texas Protection and Restoration Feasibility Study

Ecosystem Restoration Passive Benefits

DATUM: NAD 1983
PROJECTION: STATE PLANE
ZONE: TX-SC 4204

Basemap: 2018 NAIP

0 0.5 1 Miles

Date: 30 March 2021

Page: 1

ER Measure G28 Bolivar Peninsula and West Bay GIWW Shoreline and Island Protection

Shoreline (2018)

NWI Polygon

2035 Interstitial Benefit Area

NWI Polygon

2035 Benefit Area

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2065 Benefit Area

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ER Measure

Breakwater

Island Restoration

Oyster Reef Scaling

Wetland / Marsh Restoration

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Ecosystem Restoration Passive Benefits

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0 0.5 1 Miles

Date: 30 March 2021

ER Measure G28 Bolivar Peninsula and West Bay GIWW Shoreline and Island Protection

- Shoreline (2018)
- NWI Polygon
- 2035 Interstitial Benefit Area
- NWI Polygon
- 2035 Benefit Area
- NWI Polygon
- 2065 Benefit Area
- NWI Polygon
- 2085 Benefit Area

ER Measure

- Breakwater
- Island Restoration
- Oyster Reef Scaling
- Wetland / Marsh Restoration

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Texas General Land Office
Established 1836

Coastal Texas Protection and Restoration Feasibility Study

Ecosystem Restoration Passive Benefits

DATUM: NAD 1983
PROJECTION: STATE PLANE
ZONE: TX-SC 4204

Basemap: 2018 NAIP

0 250 500 Feet

Date: 30 March 2021

ER Measure G28 Bolivar Peninsula and West Bay GIWW Shoreline and Island Protection

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- 2065 Benefit Area
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ER Measure

- Breakwater
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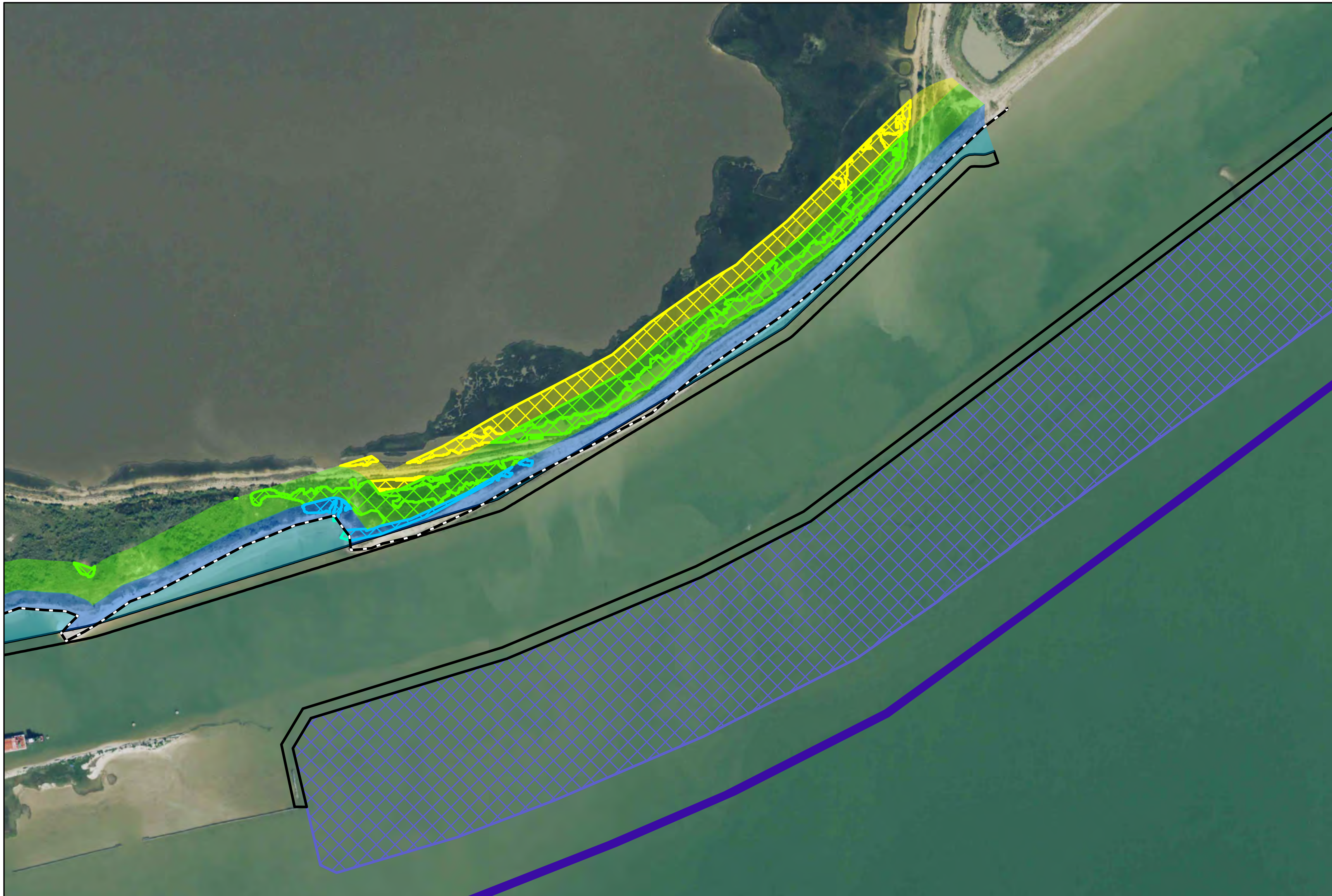
- Oyster Reef Scaling
- Wetland / Marsh Restoration



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Coastal Texas Protection and Restoration Feasibility Study

Ecosystem Restoration Passive Benefits

Basemap: 2018 NAIP

0 250 500 Feet

DATUM: NAD 1983
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ZONE: TX-SC 4204

Date: 30 March 2021

ER Measure G28 Bolivar Peninsula and West Bay GIWW Shoreline and Island Protection

Shoreline (2018)

NWI Polygon

2035 Interstitial Benefit Area

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NWI Polygon

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ER Measure

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Wetland / Marsh Restoration

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Coastal Texas Protection and Restoration Feasibility Study

Ecosystem Restoration Passive Benefits

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Basemap: 2018 NAIP

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ER Measure G28
Bolivar Peninsula
and West Bay GIWW
Shoreline and Island
Protection

Shoreline (2018)

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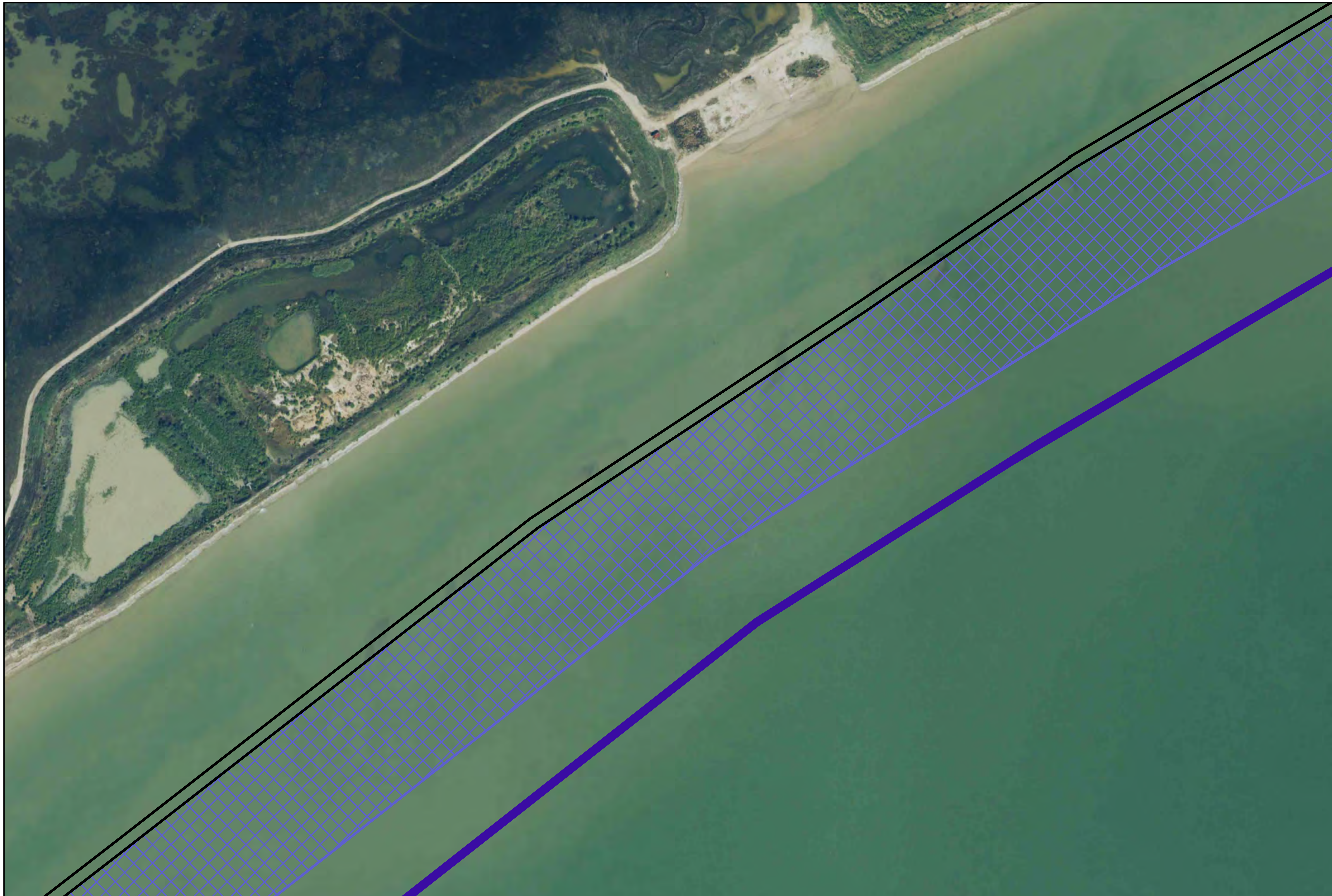

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Coastal Texas Protection and Restoration Feasibility Study

Ecosystem Restoration Passive Benefits

DATUM: NAD 1983
PROJECTION: STATE PLANE
ZONE: TX-SC 4204

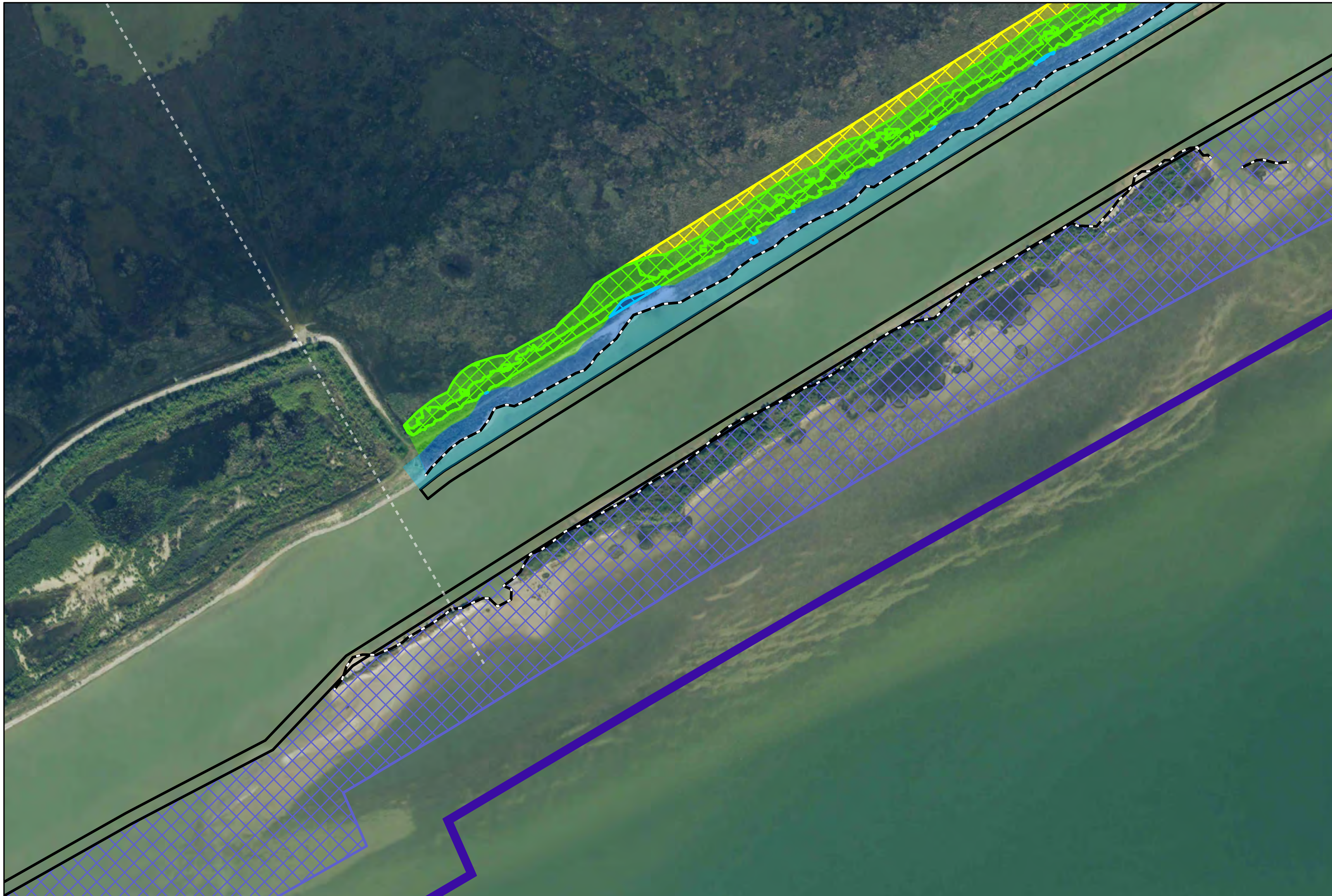
Basemap: 2018 NAIP

0 250 500 Feet

Date: 30 March 2021

Page: 6

ER Measure G28 Bolivar Peninsula and West Bay GIWW Shoreline and Island Protection



Shoreline (2018)

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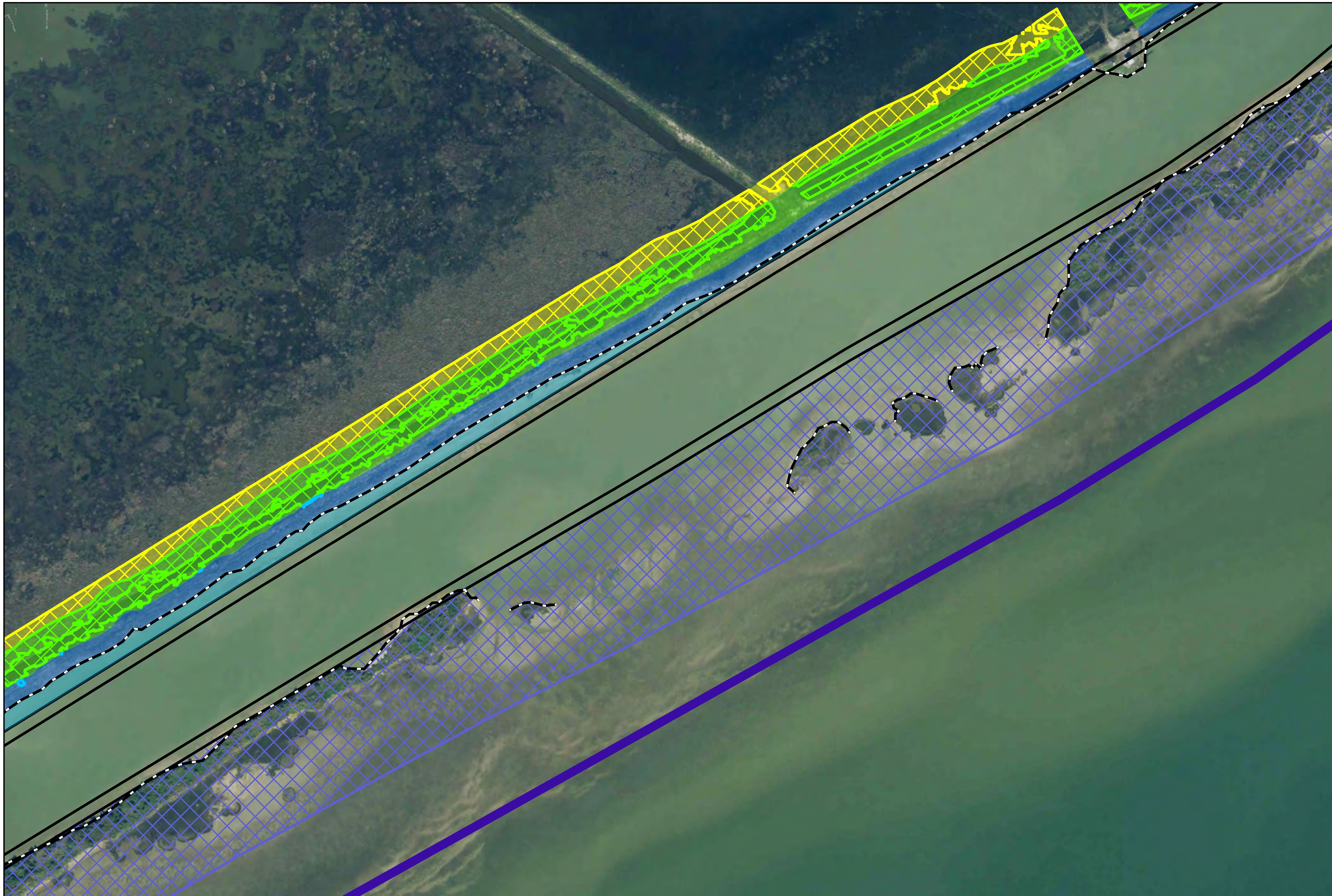

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Coastal Texas Protection and Restoration Feasibility Study

Ecosystem Restoration Passive Benefits

Basemap: 2018 NAIP

0 250 500 Feet

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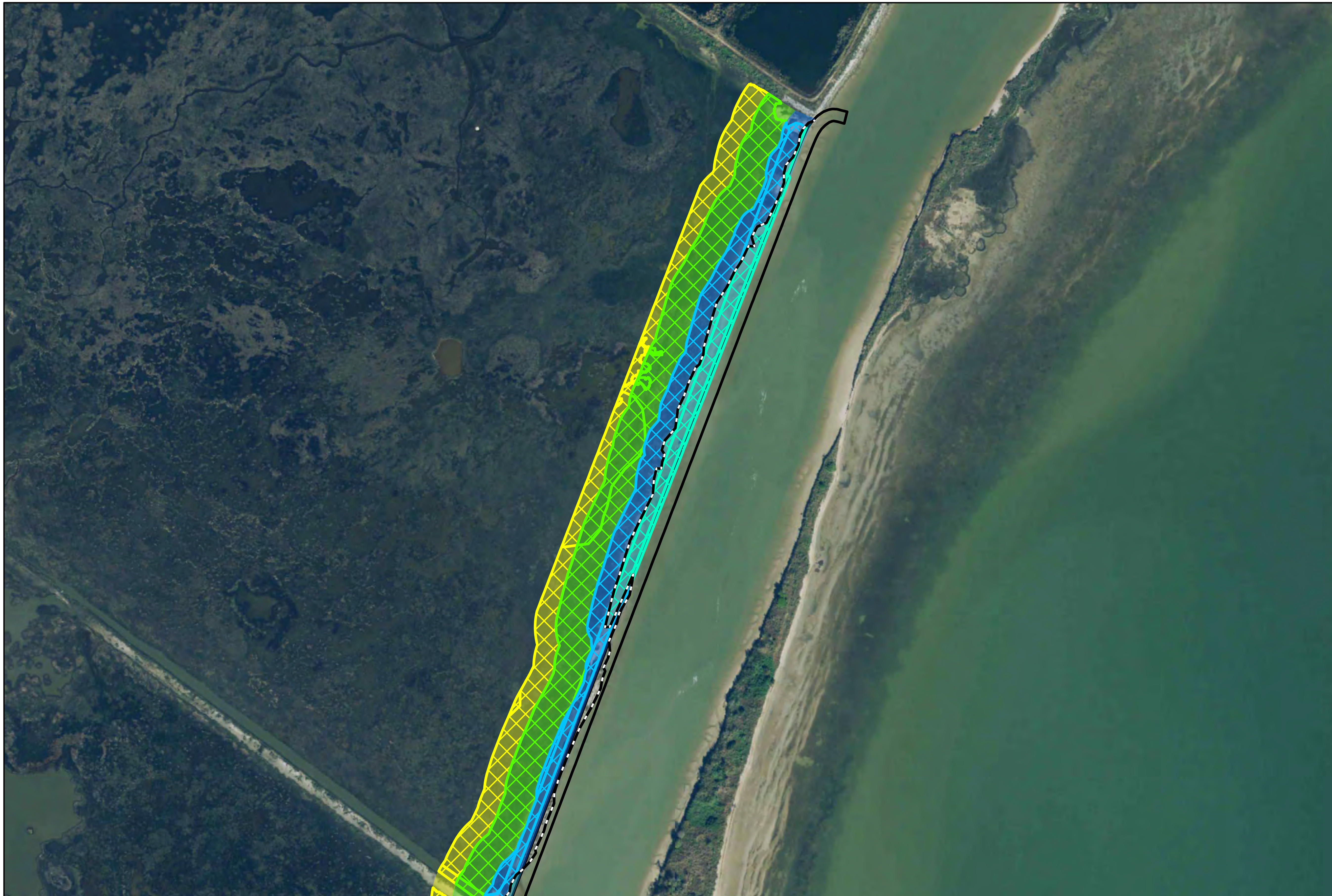

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Coastal Texas Protection and Restoration Feasibility Study

Ecosystem Restoration Passive Benefits

DATUM: NAD 1983
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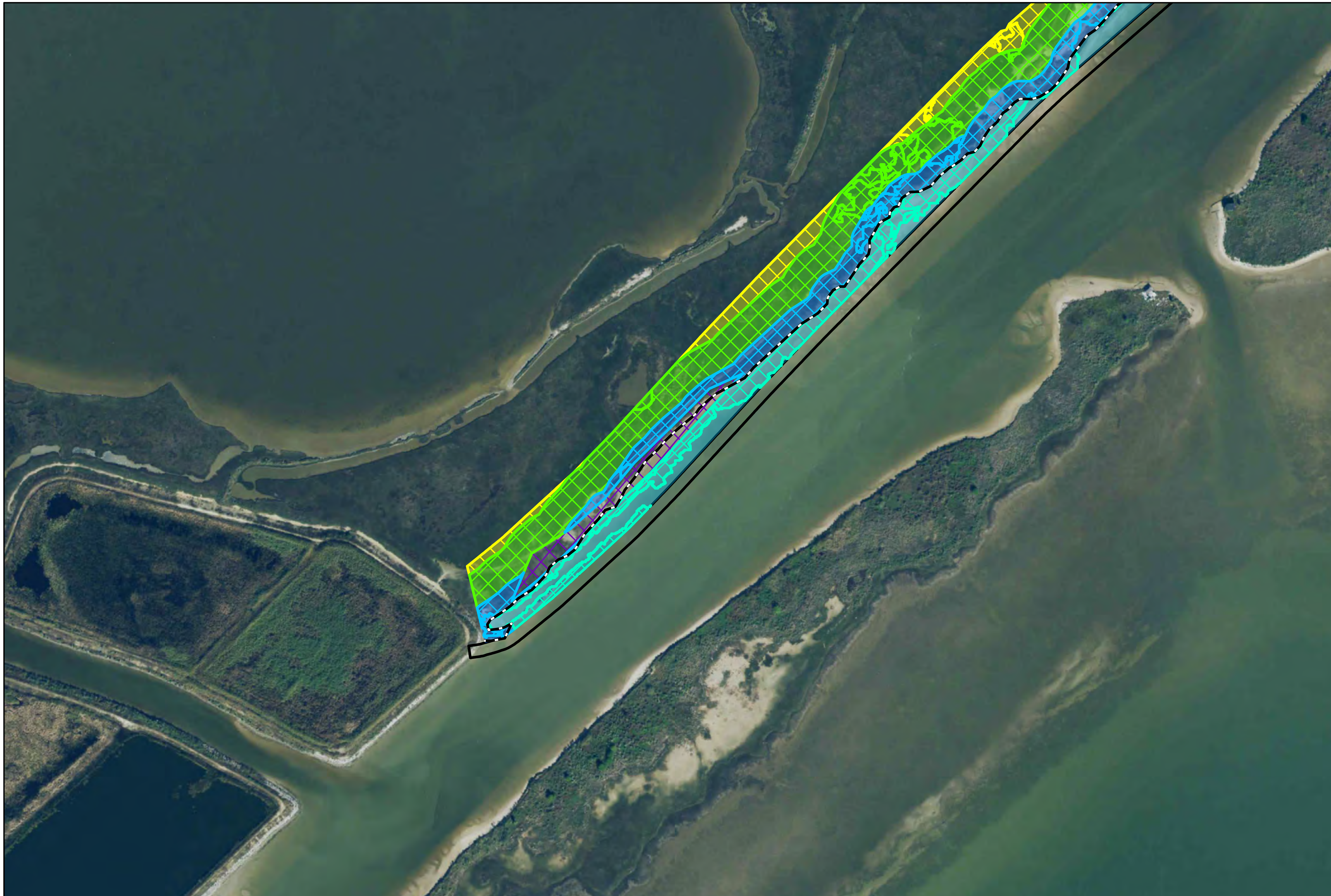

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Coastal Texas Protection and Restoration Feasibility Study

Ecosystem Restoration Passive Benefits

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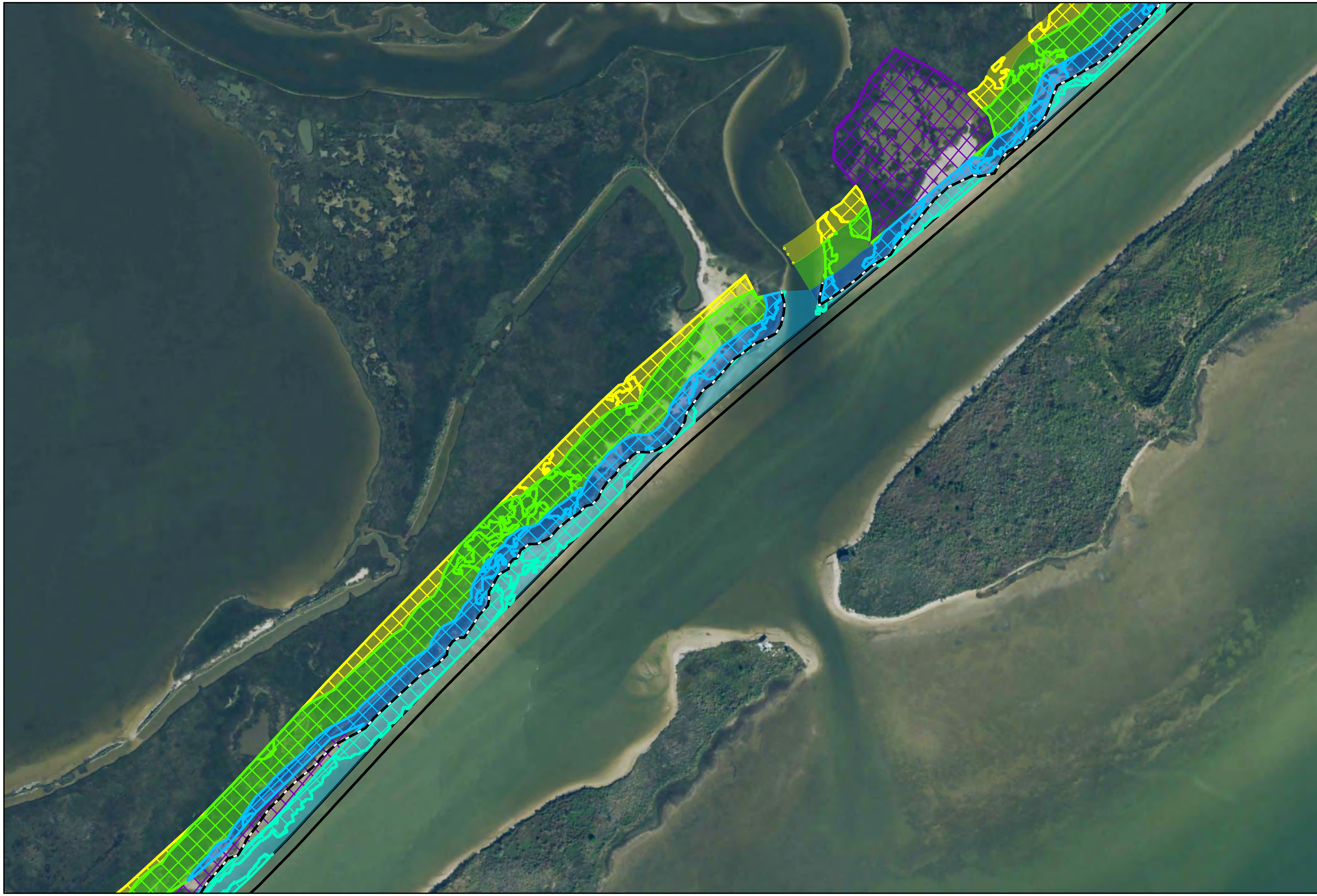

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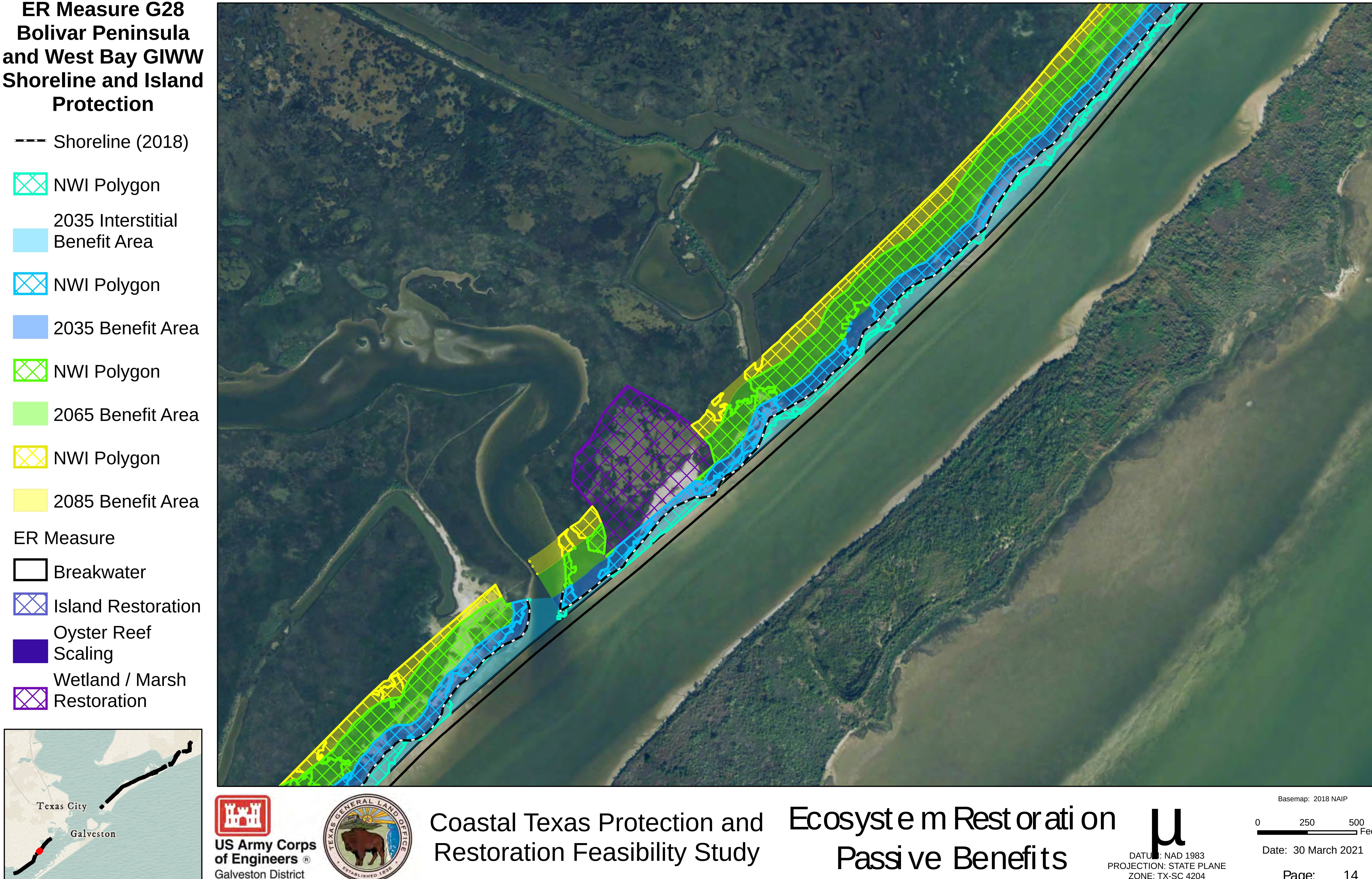

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TEXAS GENERAL LAND OFFICE
ESTABLISHED 1836

Coastal Texas Protection and Restoration Feasibility Study

Ecosystem Restoration Passive Benefits

DATUM: NAD 1983
PROJECTION: STATE PLANE
ZONE: TX-SC 4204

Basemap: 2018 NAIP

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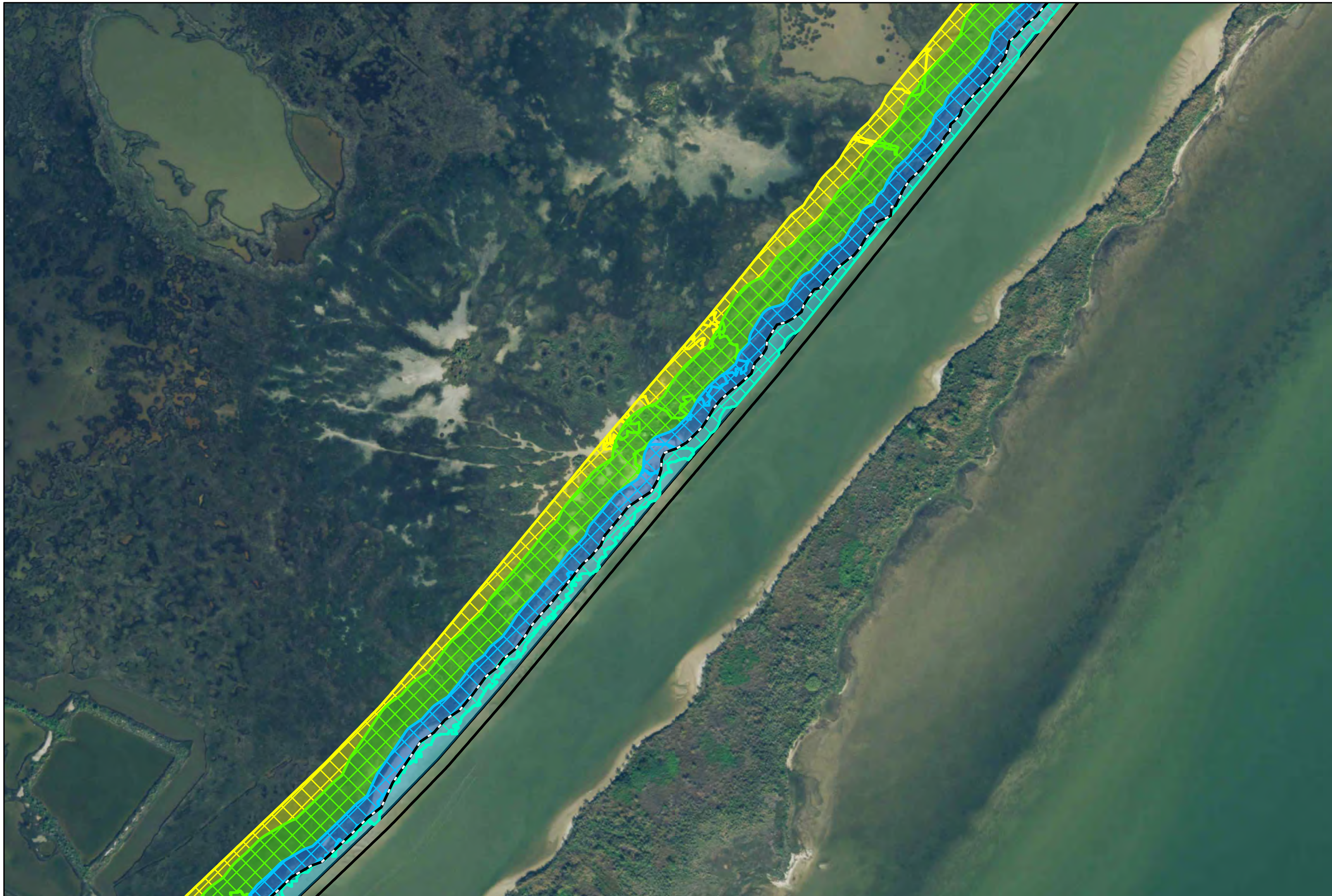

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Ecosystem Restoration Passive Benefits

DATUM: NAD 1983
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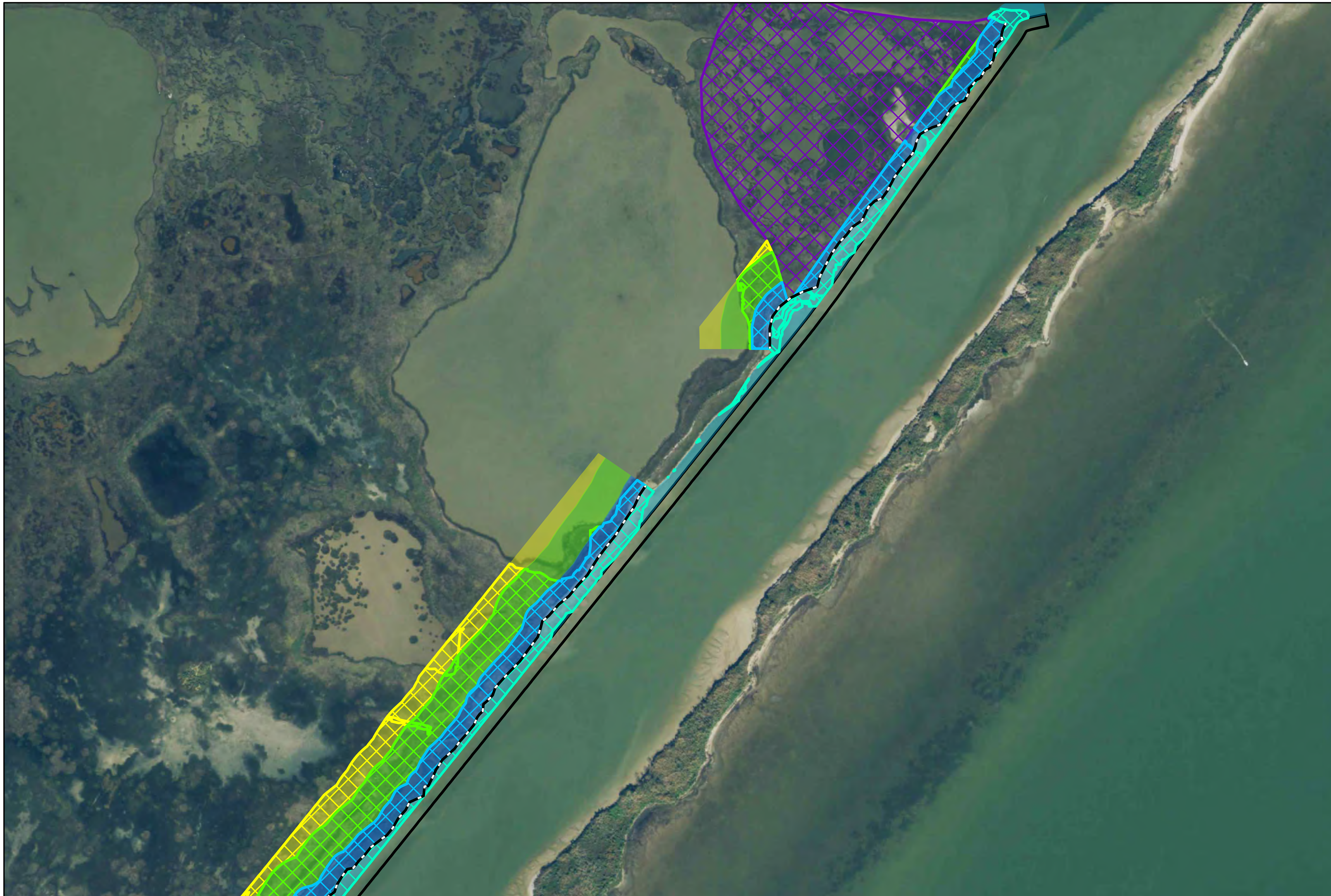

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Galveston District

Coastal Texas Protection and Restoration Feasibility Study

Ecosystem Restoration Passive Benefits

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ER Measure G28 Bolivar Peninsula and West Bay GIWW Shoreline and Island Protection

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ER Measure

Breakwater

Island Restoration

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US Army Corps of Engineers ®
Galveston District

Coastal Texas Protection and Restoration Feasibility Study

Ecosystem Restoration Passive Benefits

DATUM: NAD 1983
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0 250 500 Feet

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ER Measure G28 Bolivar Peninsula and West Bay GIWW Shoreline and Island Protection

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Coastal Texas Protection and Restoration Feasibility Study

Ecosystem Restoration Passive Benefits

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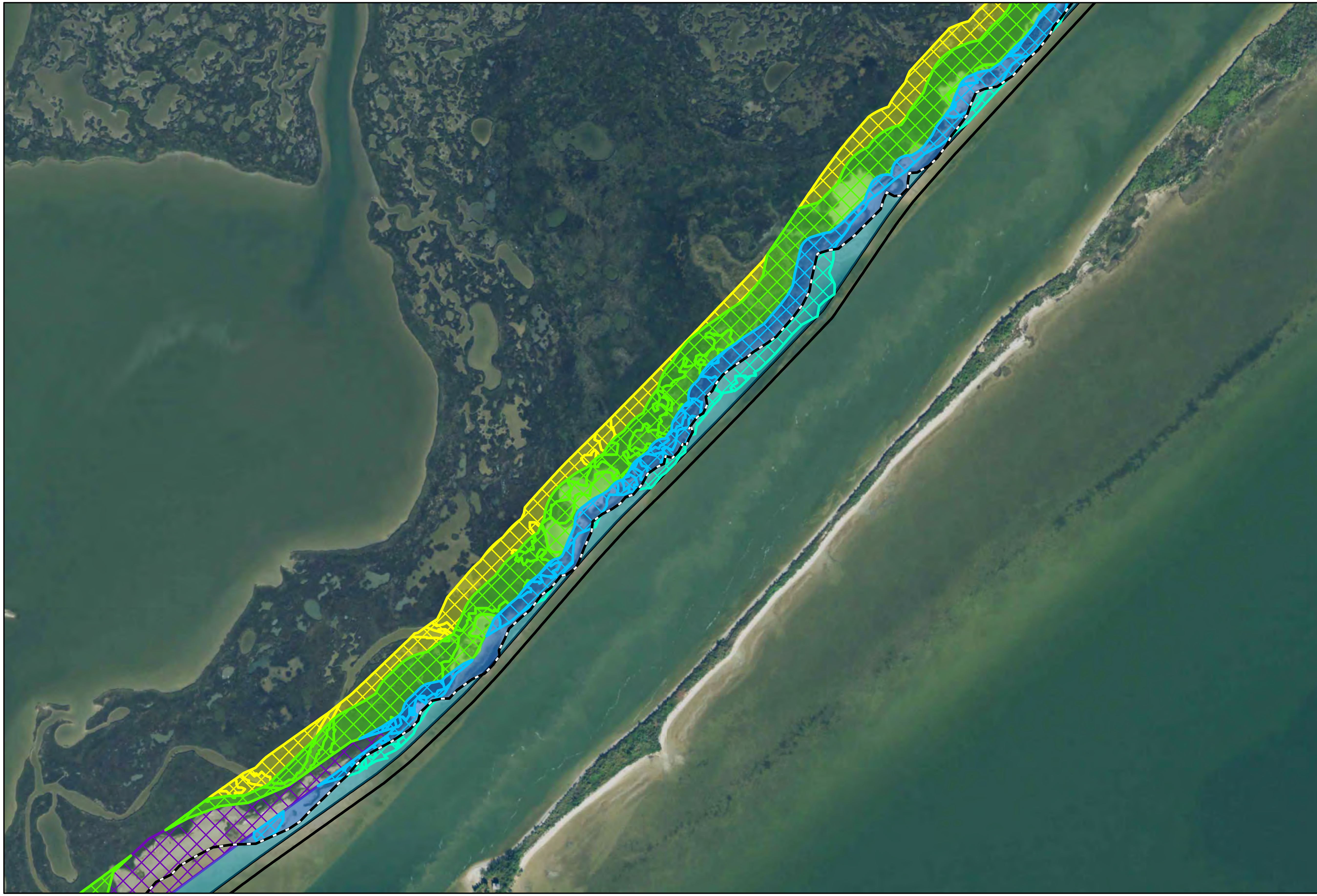

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Coastal Texas Protection and Restoration Feasibility Study

Ecosystem Restoration Passive Benefits

Basemap: 2018 NAIP

0 250 500 Feet

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Wetland / Marsh Restoration

US Army Corps of Engineers ®
Galveston District

Coastal Texas Protection and Restoration Feasibility Study

Ecosystem Restoration Passive Benefits

DATUM: NAD 1983
PROJECTION: STATE PLANE
ZONE: TX-SC 4204

Basemap: 2018 NAIP

0 250 500 Feet

Date: 30 March 2021

ER Measure G28 Bolivar Peninsula and West Bay GIWW Shoreline and Island Protection

Shoreline (2018)

NWI Polygon

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Texas General Land Office Established 1836

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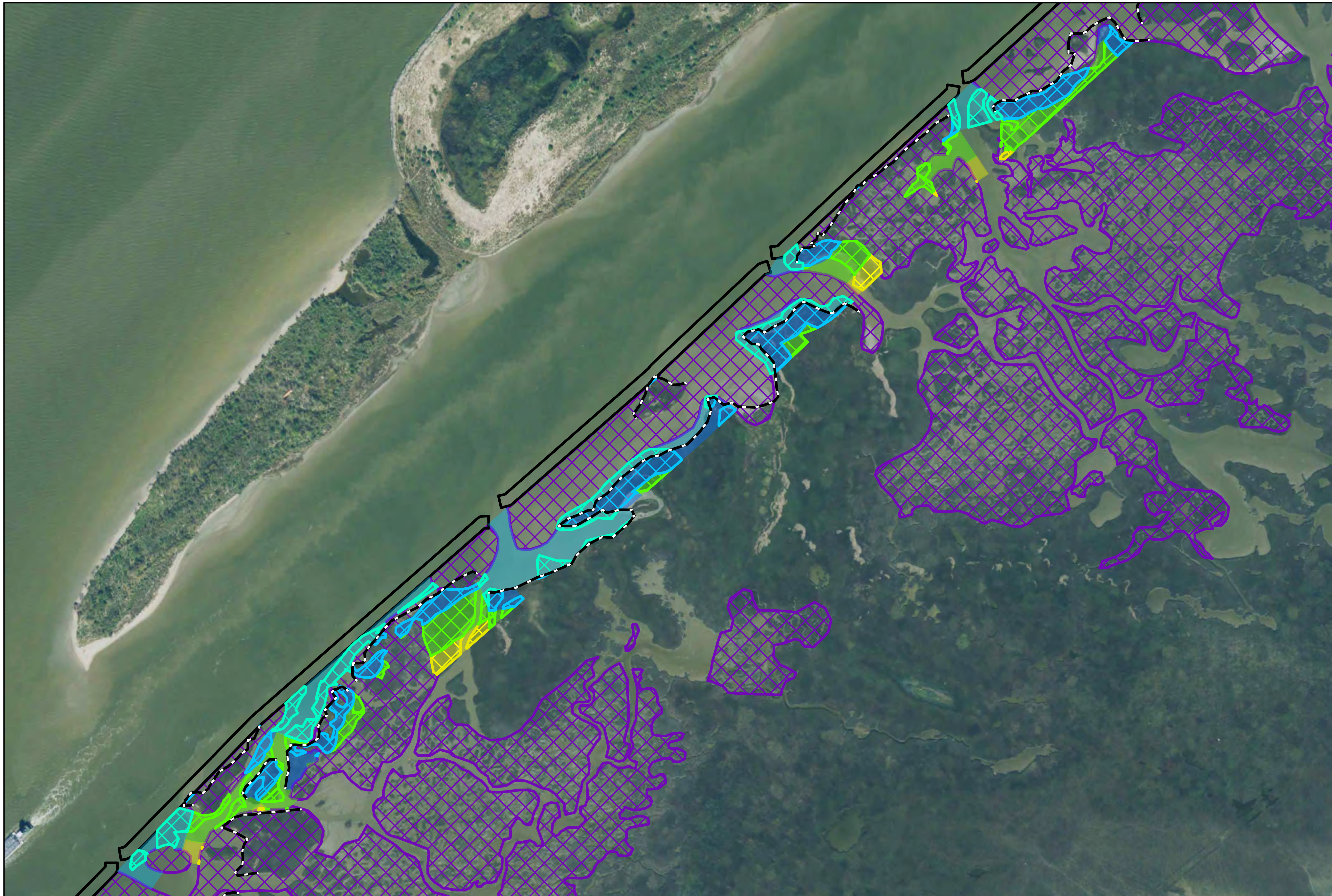

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Galveston District

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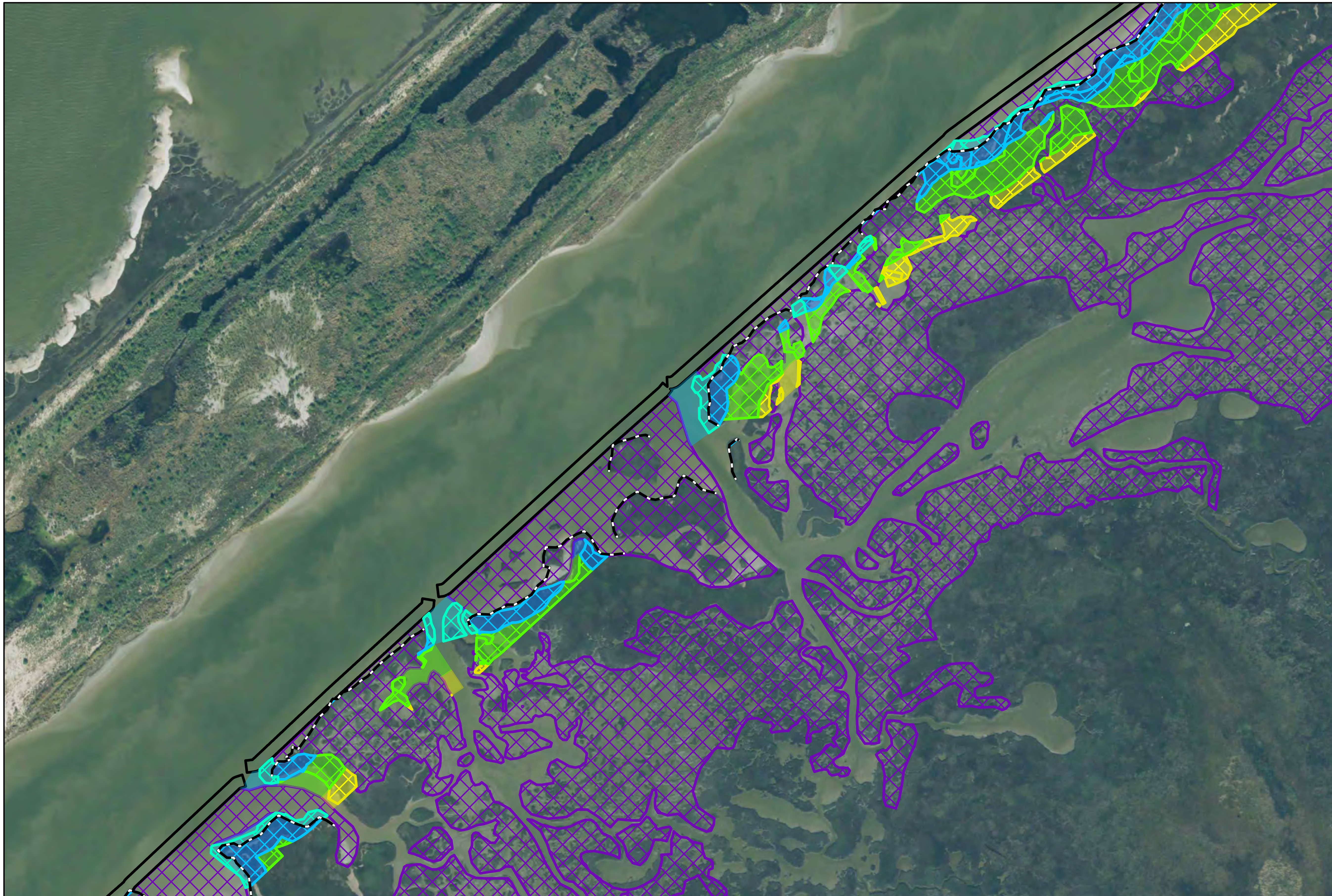

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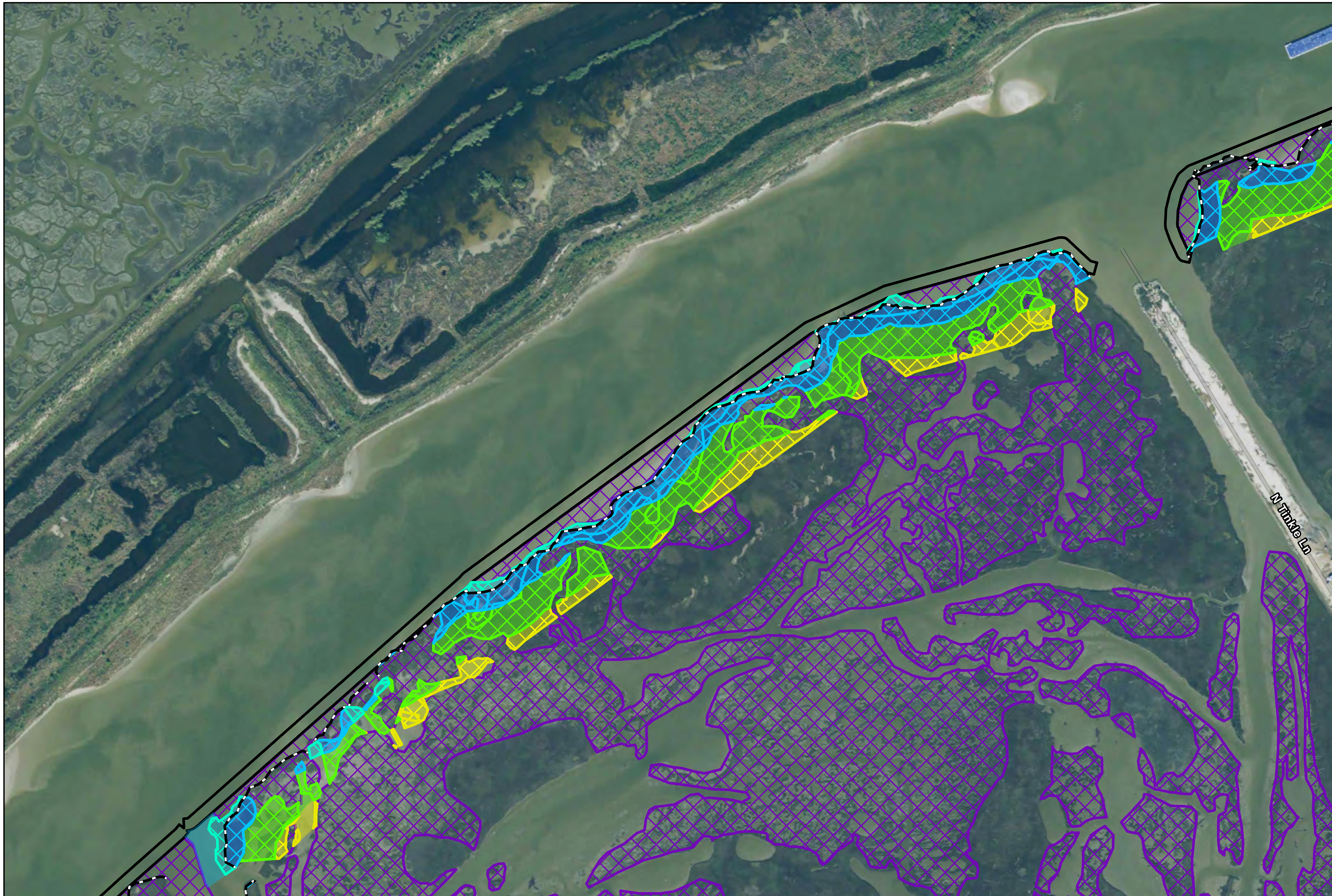

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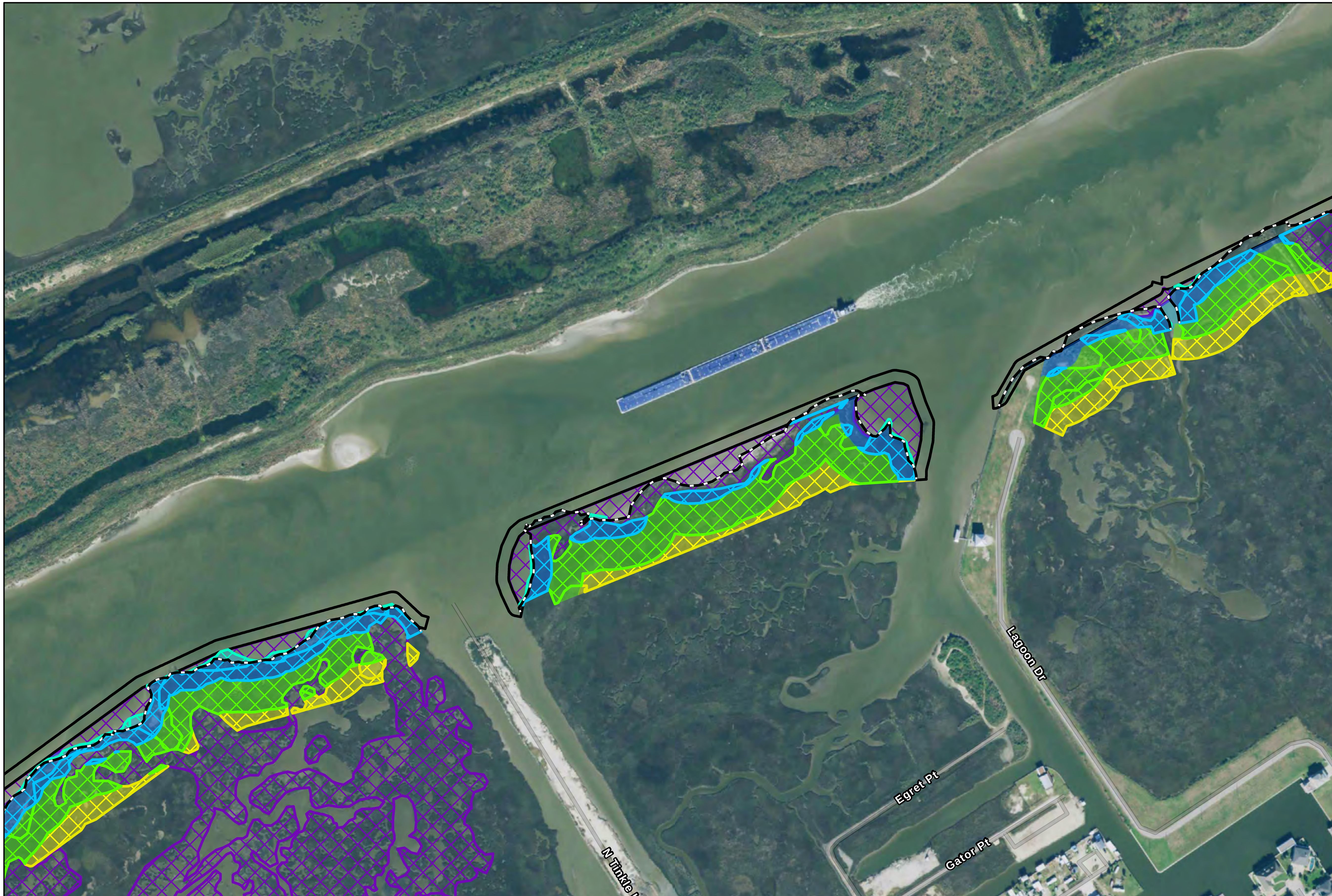

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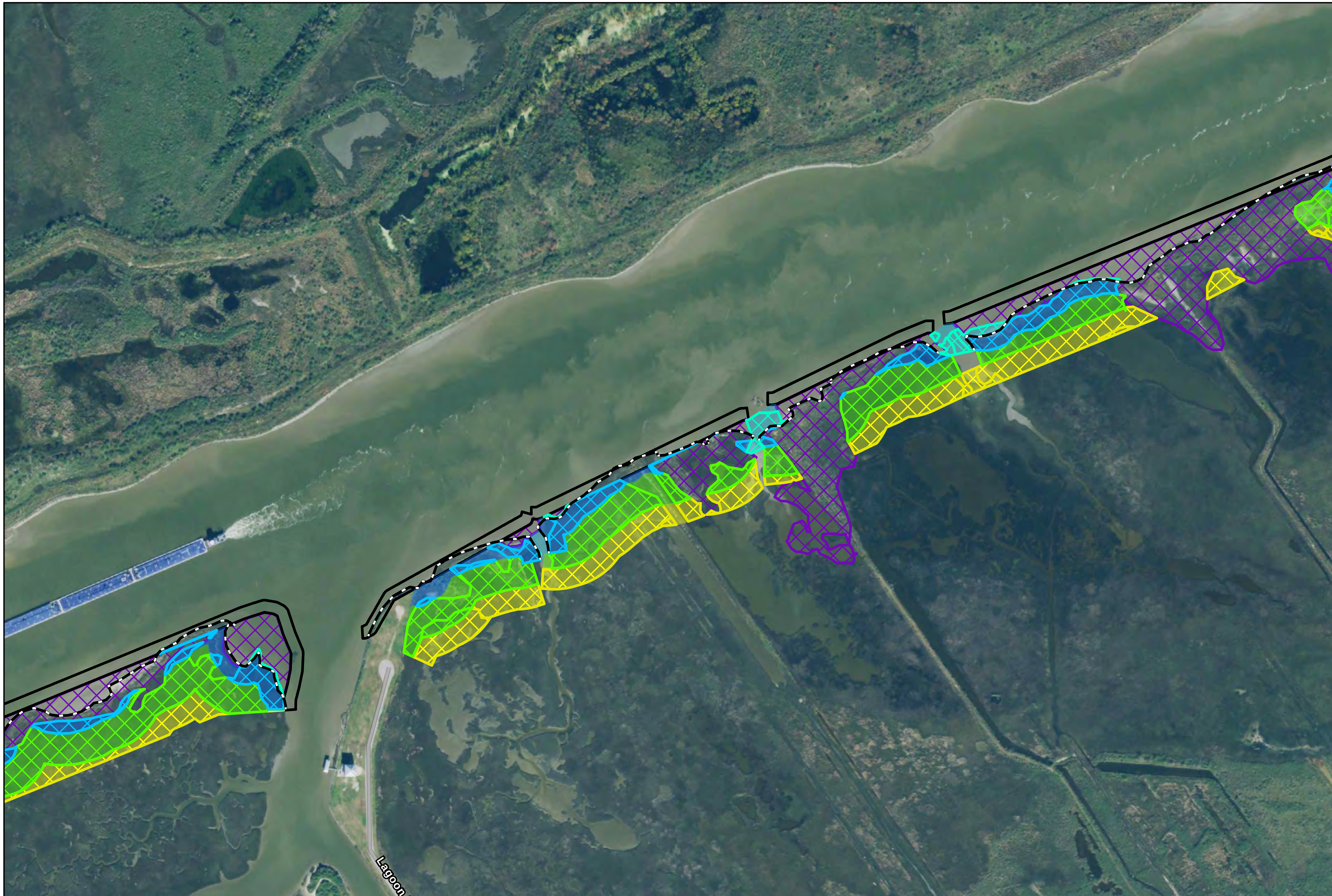

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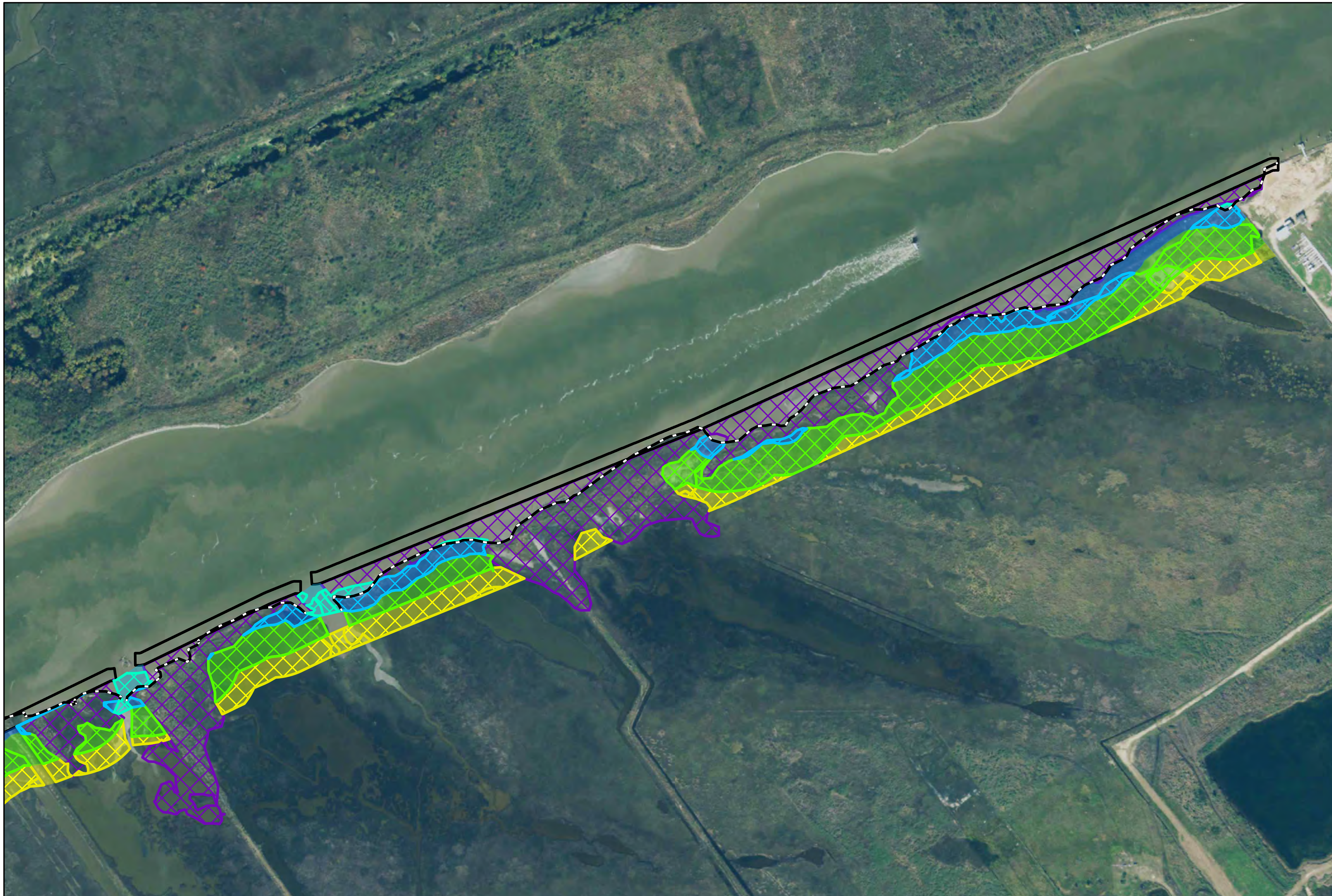

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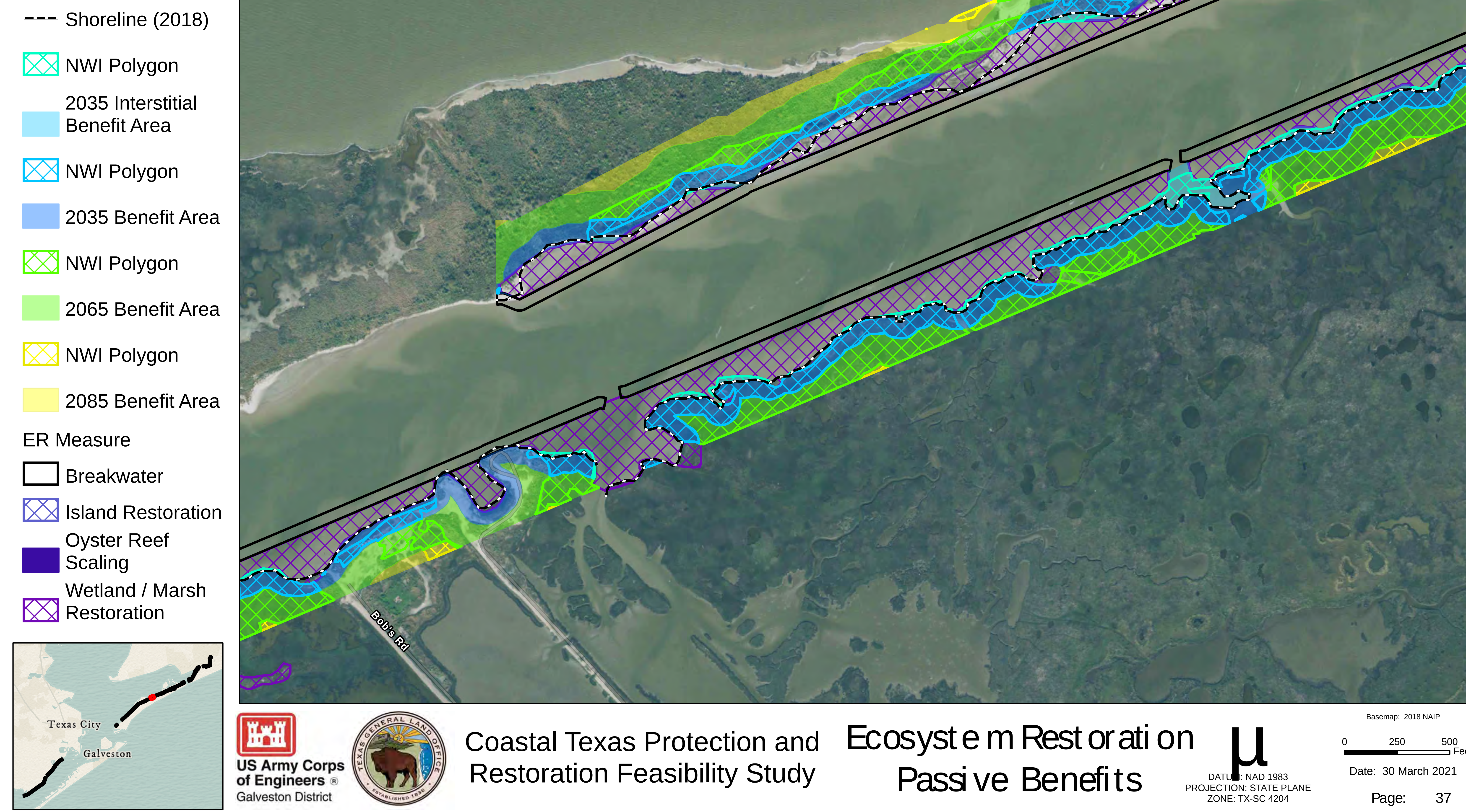

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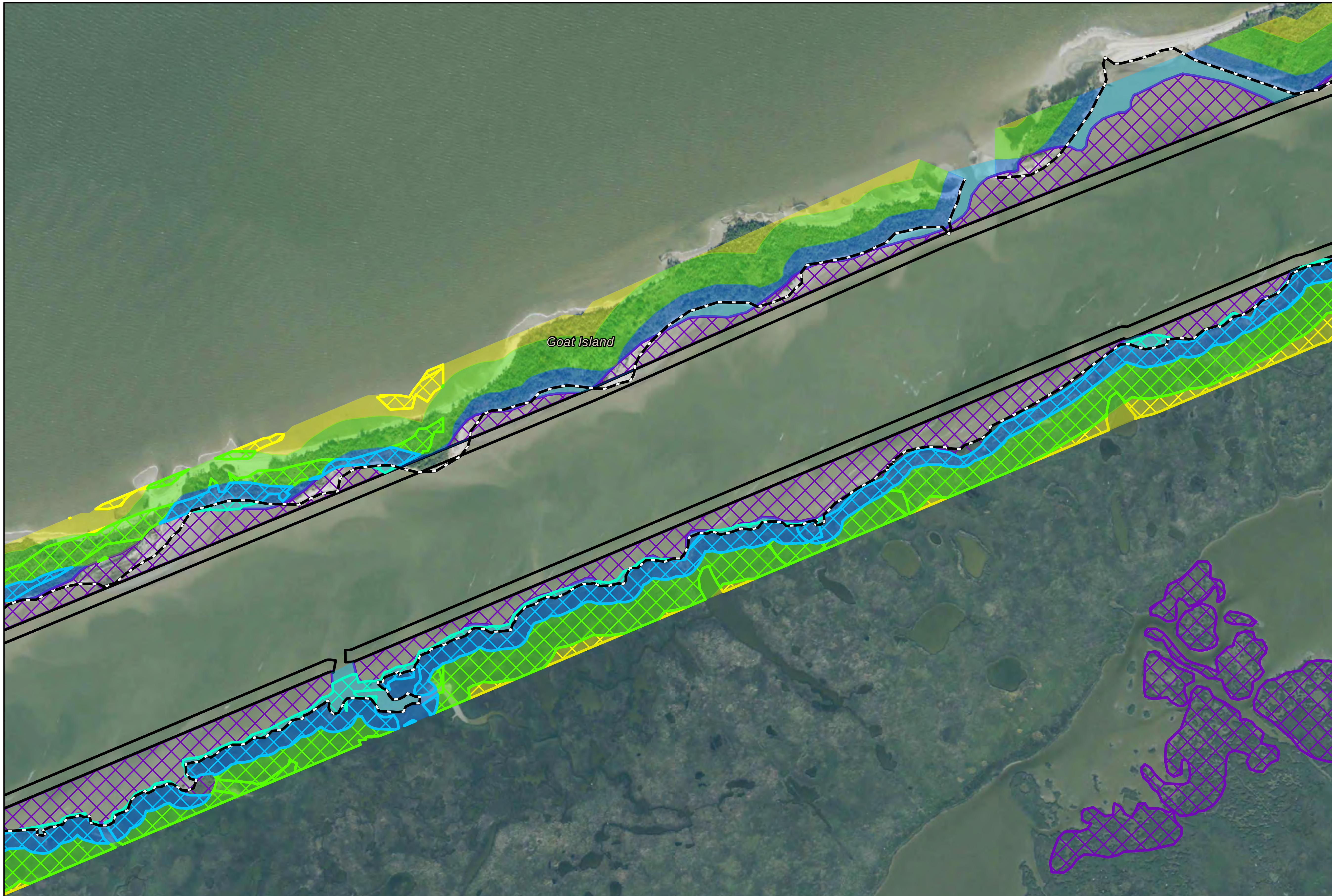

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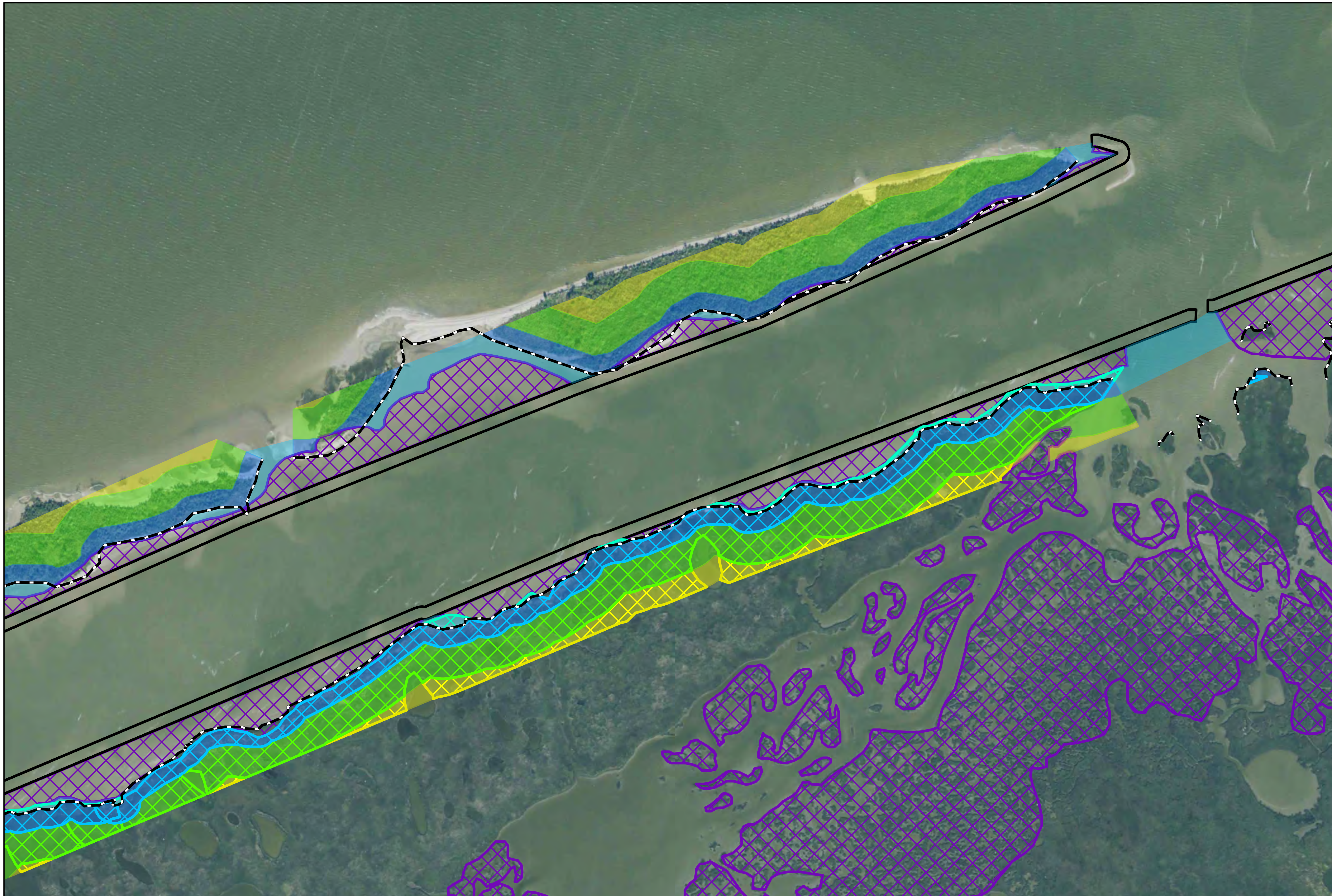

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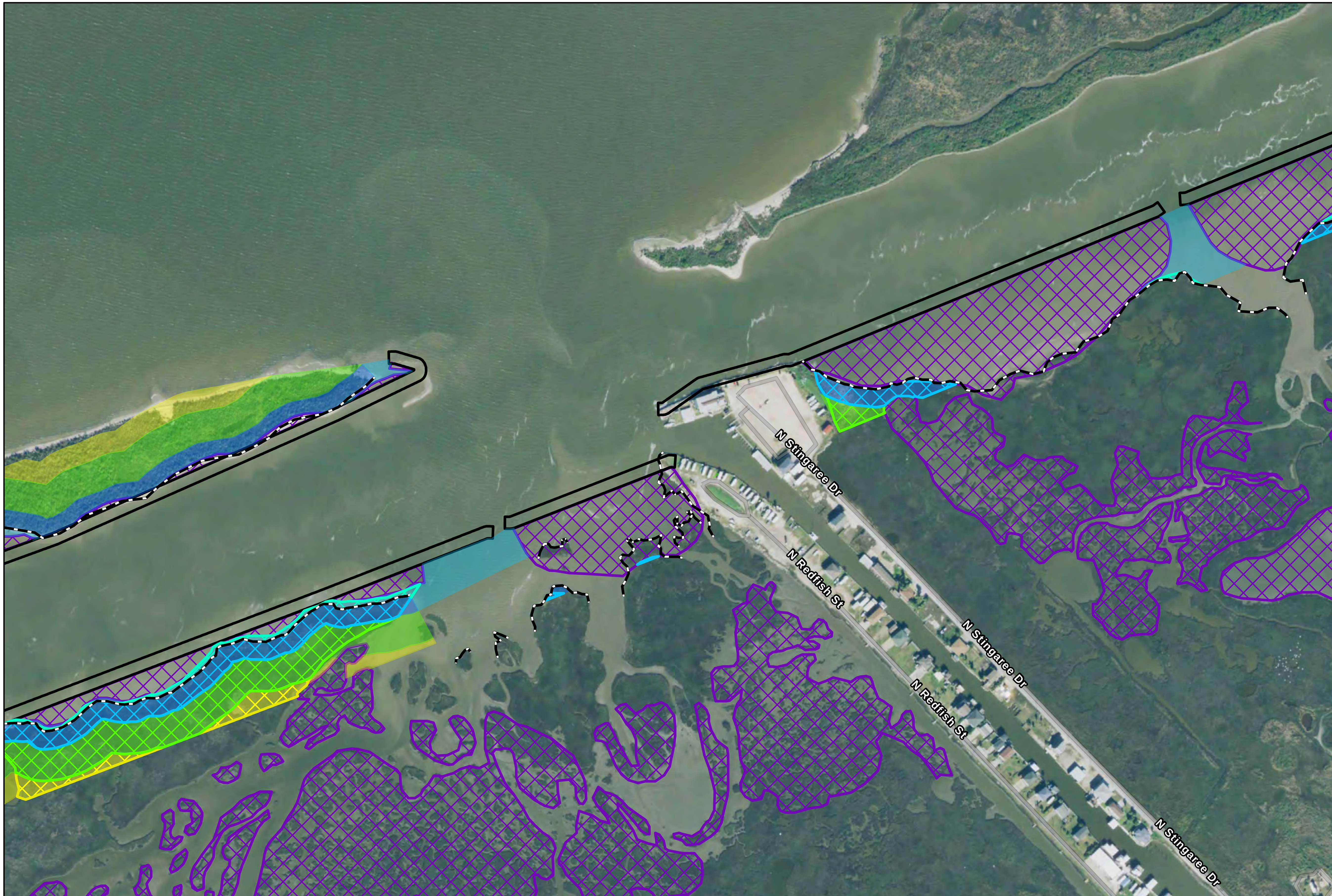

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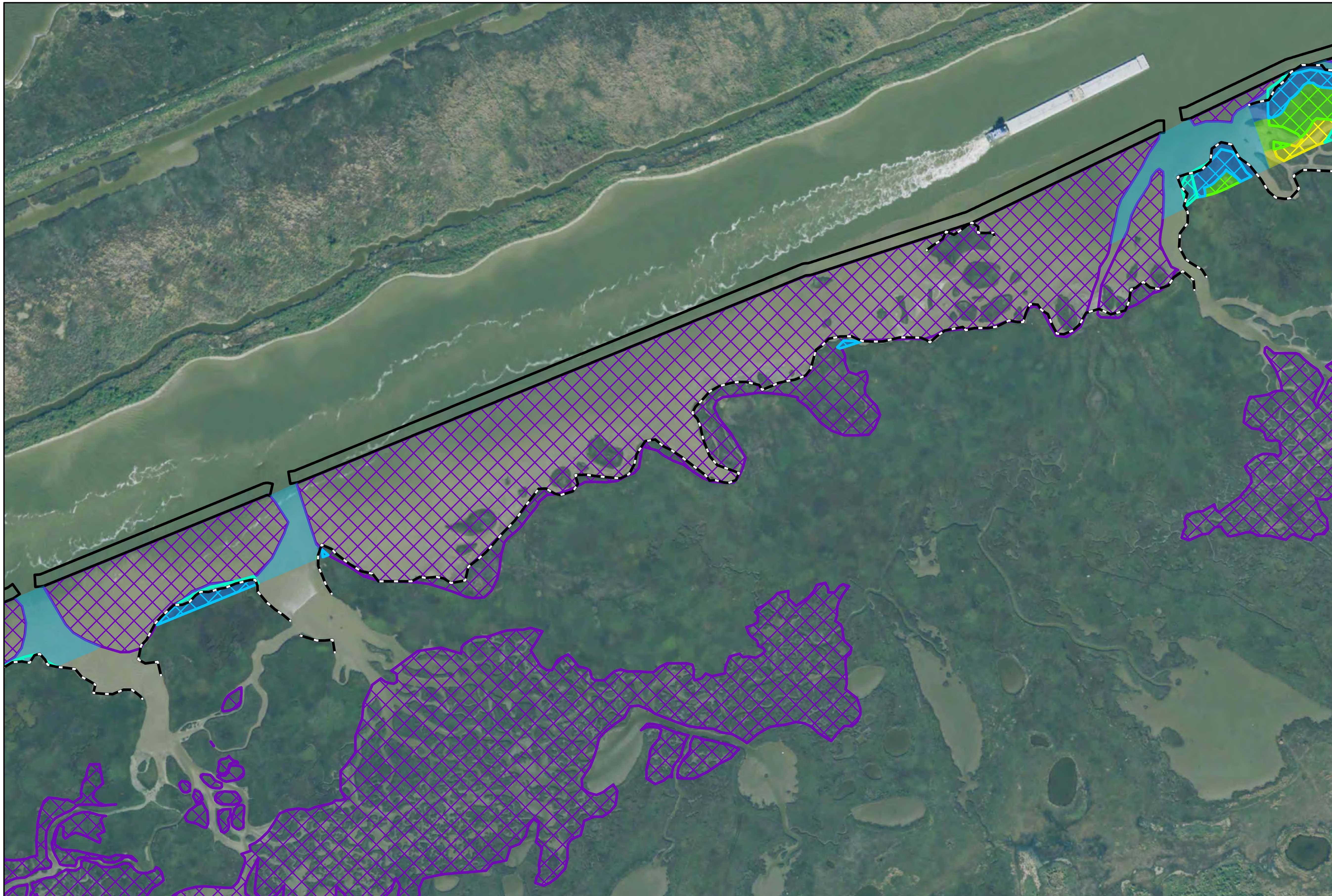

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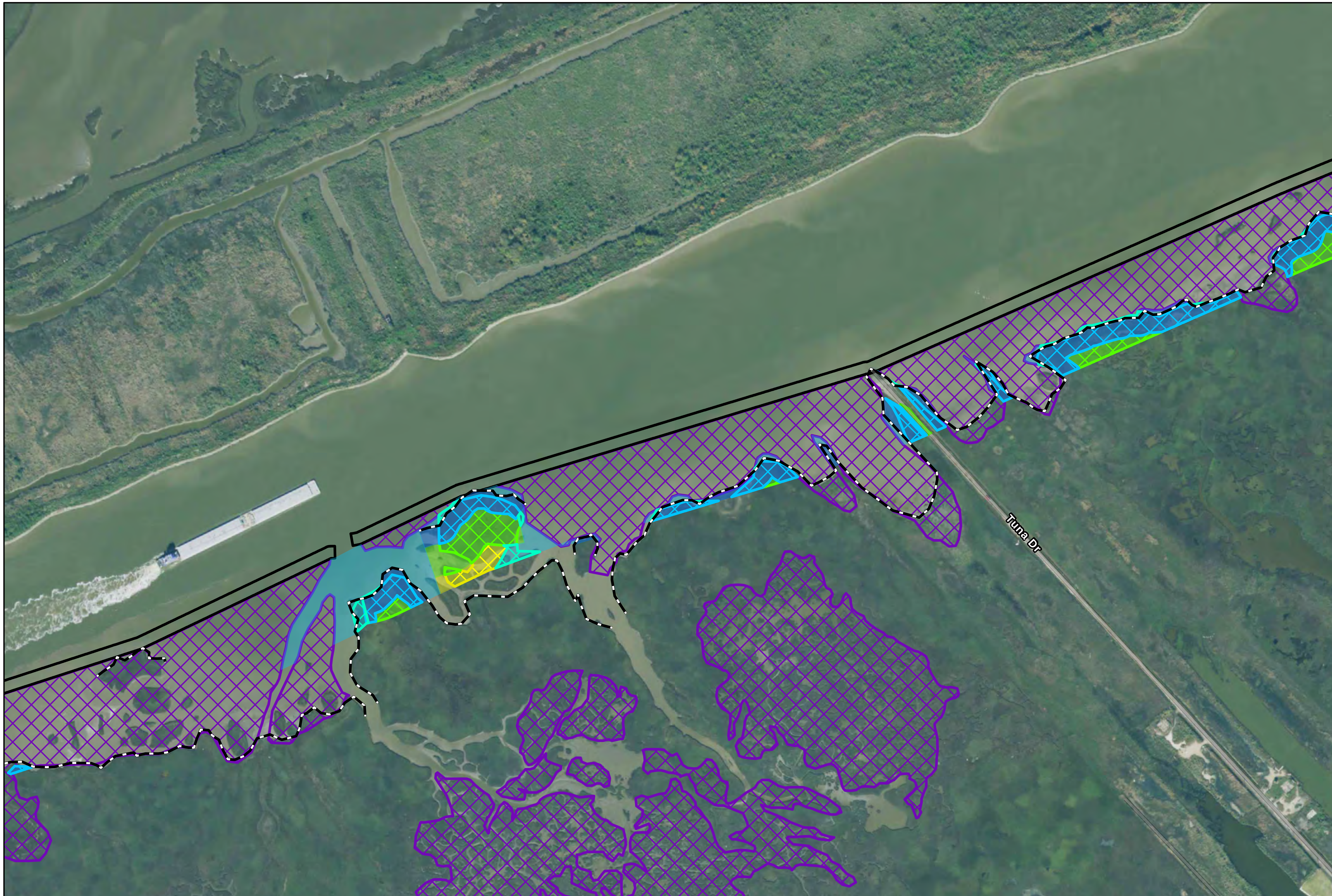

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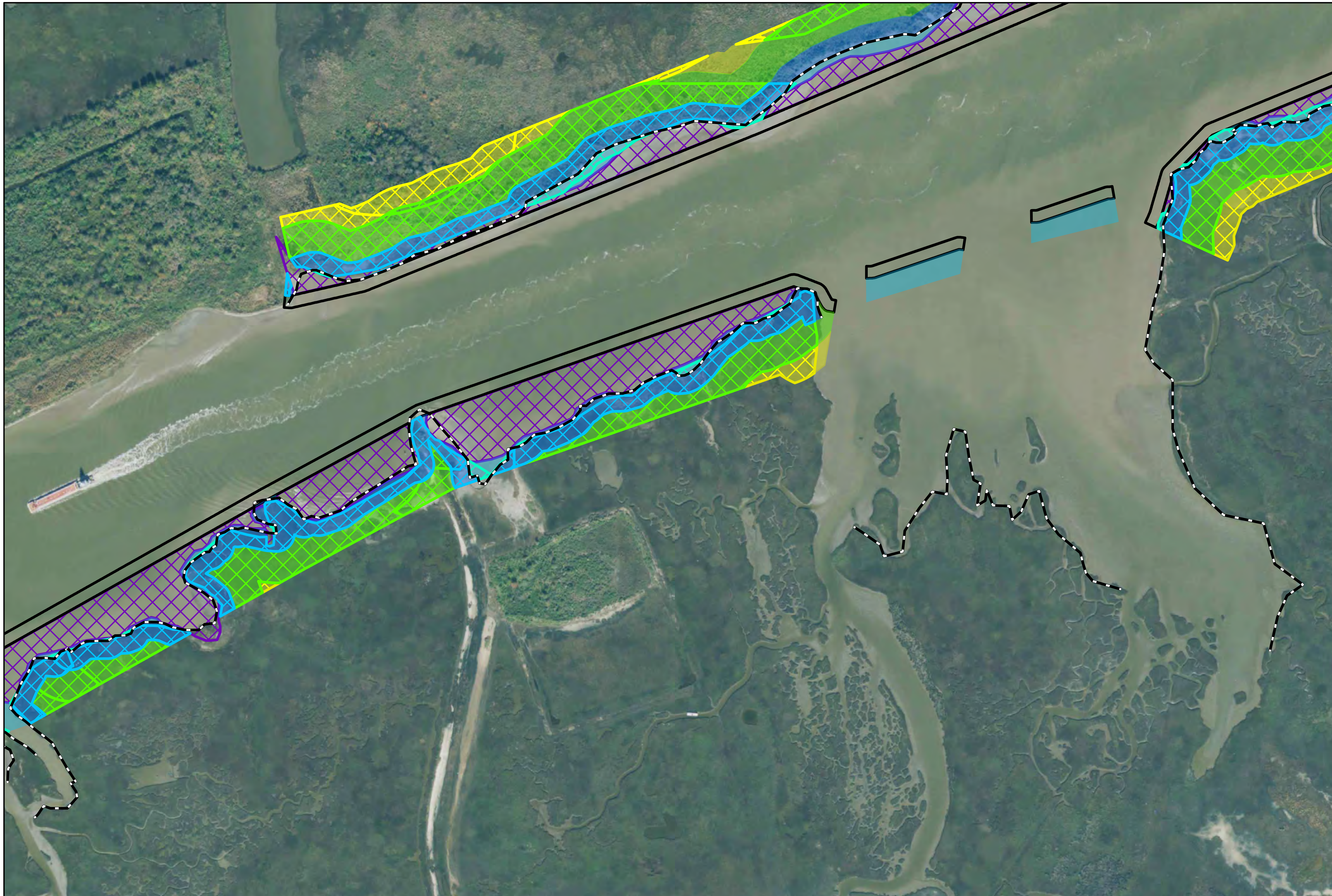

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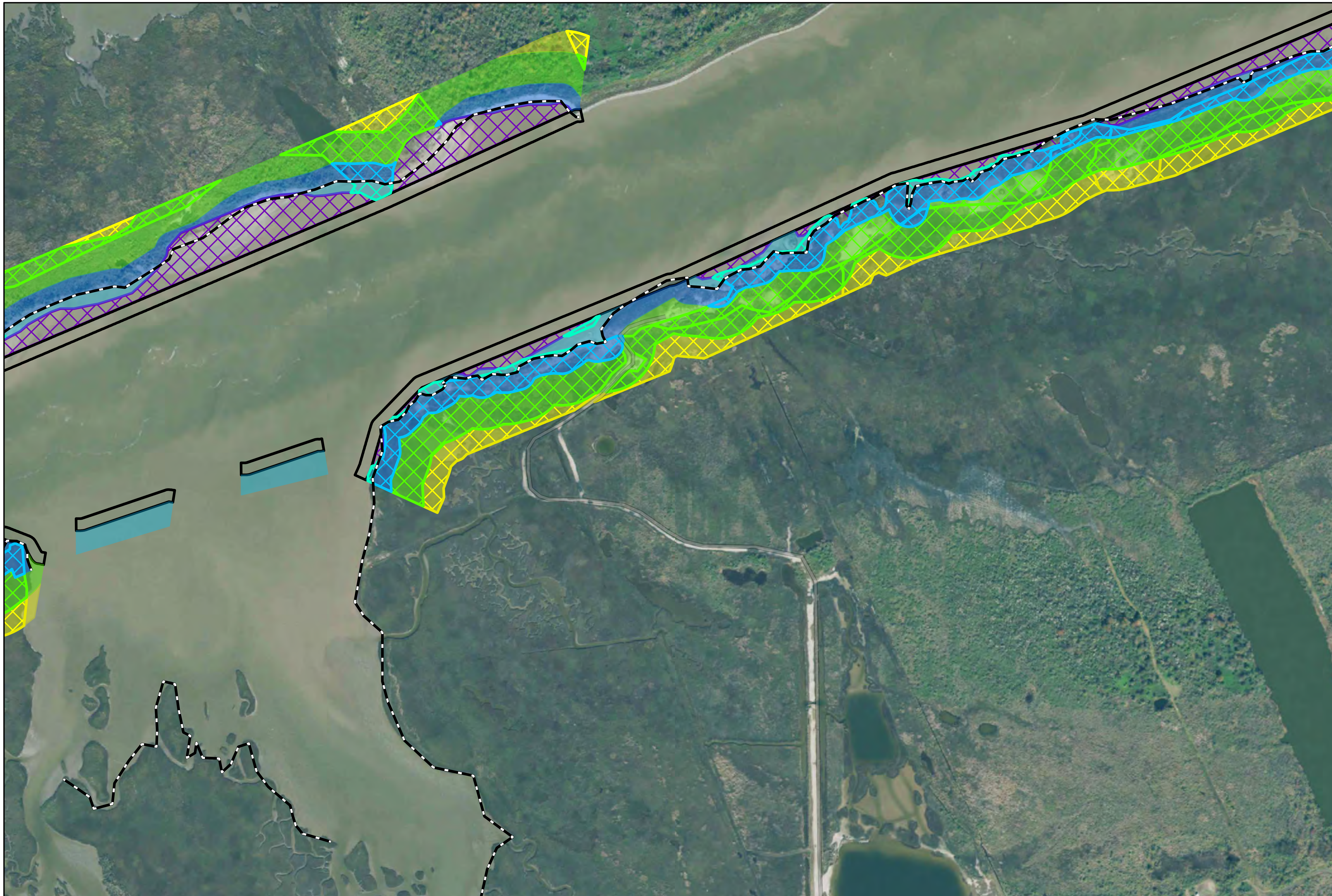

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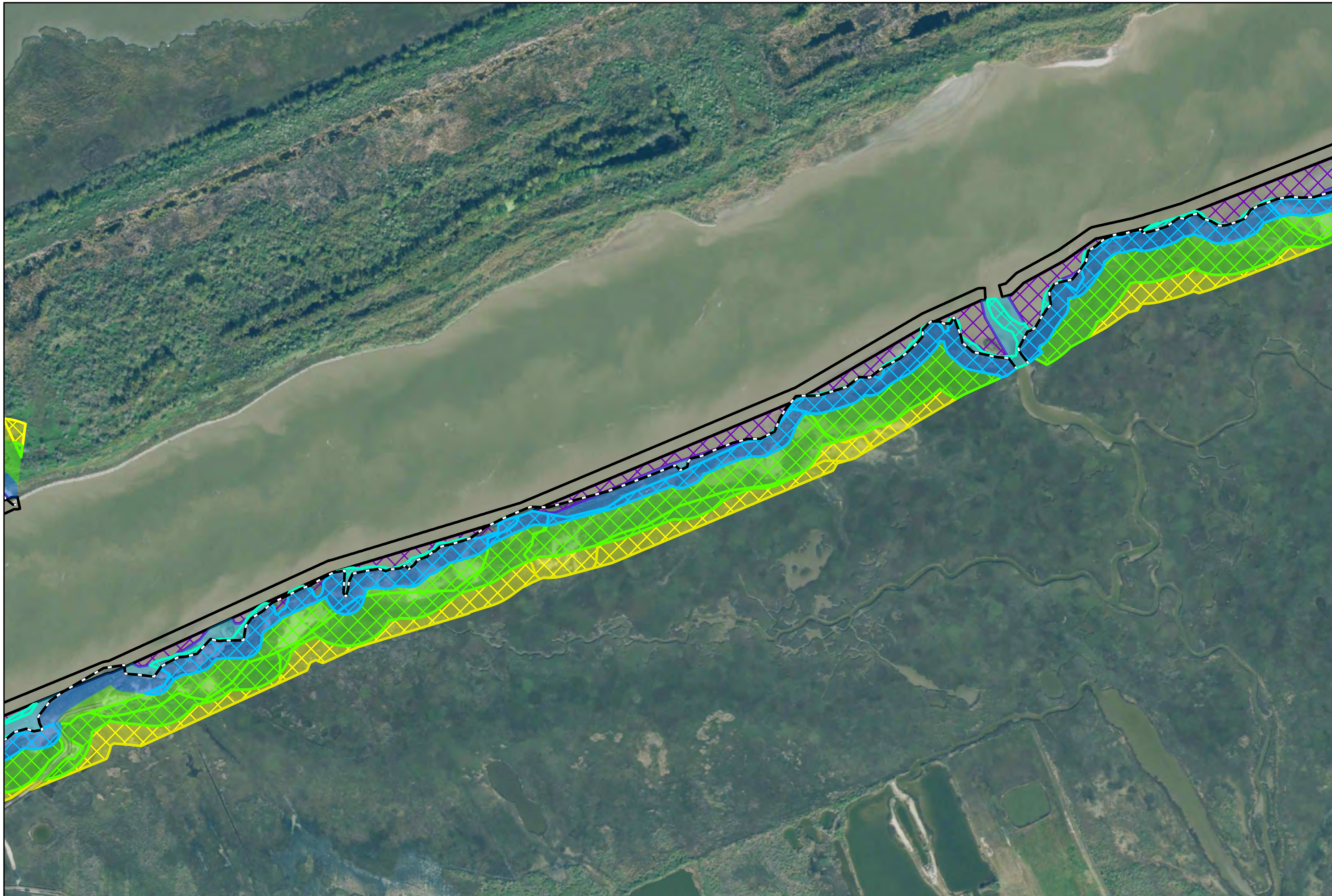

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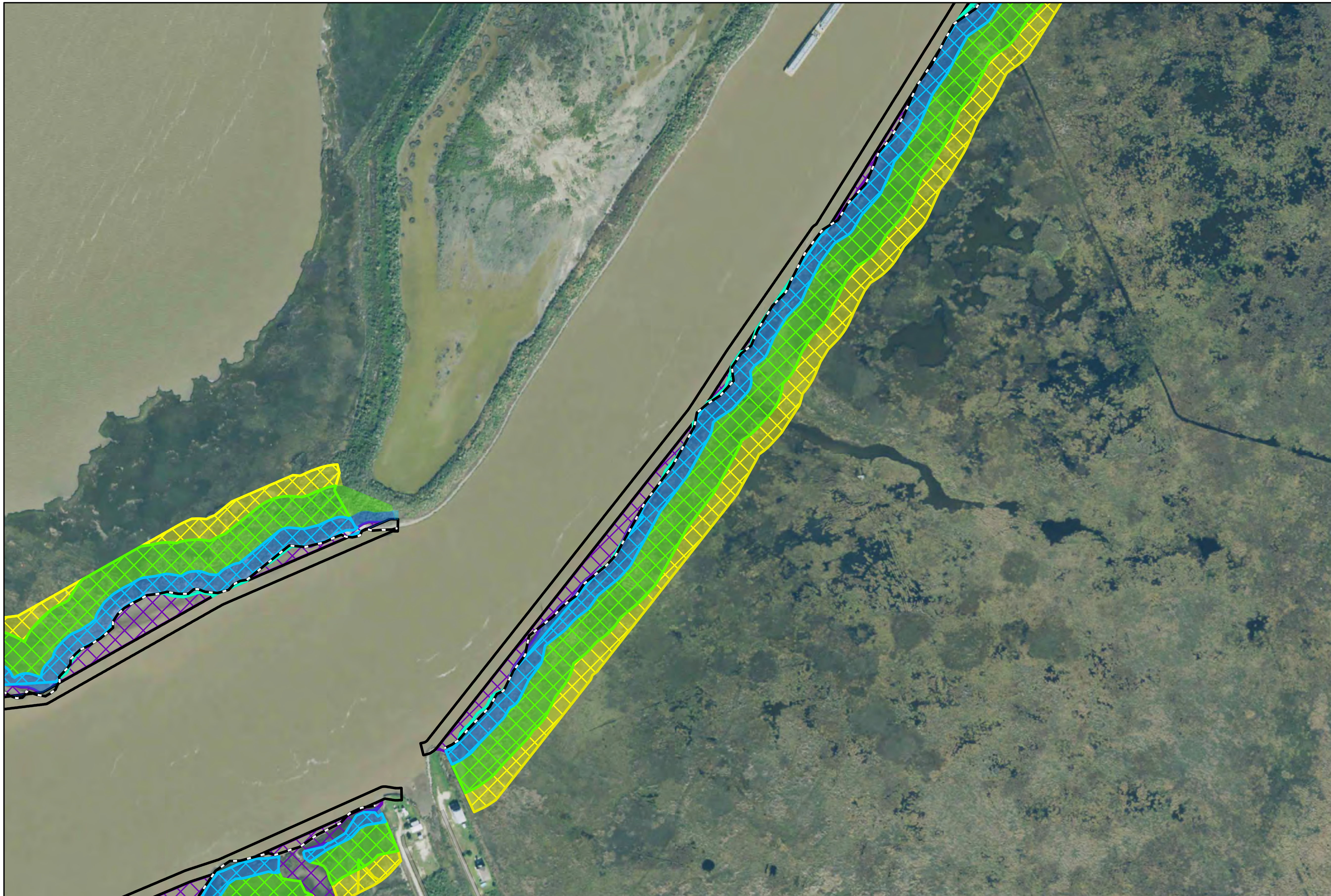

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Island Restoration

Oyster Reef Scaling

Wetland / Marsh Restoration

US Army Corps of Engineers®
Galveston District

Coastal Texas Protection and Restoration Feasibility Study

Ecosystem Restoration Passive Benefits

DATUM: NAD 1983
PROJECTION: STATE PLANE
ZONE: TX-SC 4204

Basemap: 2018 NAIP

0 250 500 Feet

Date: 30 March 2021

ER Measure G28 Bolivar Peninsula and West Bay GIWW Shoreline and Island Protection

Shoreline (2018)

NWI Polygon

2035 Interstitial Benefit Area

NWI Polygon

2035 Benefit Area

NWI Polygon

2065 Benefit Area

NWI Polygon

2085 Benefit Area

ER Measure

Breakwater

Island Restoration

Oyster Reef Scaling

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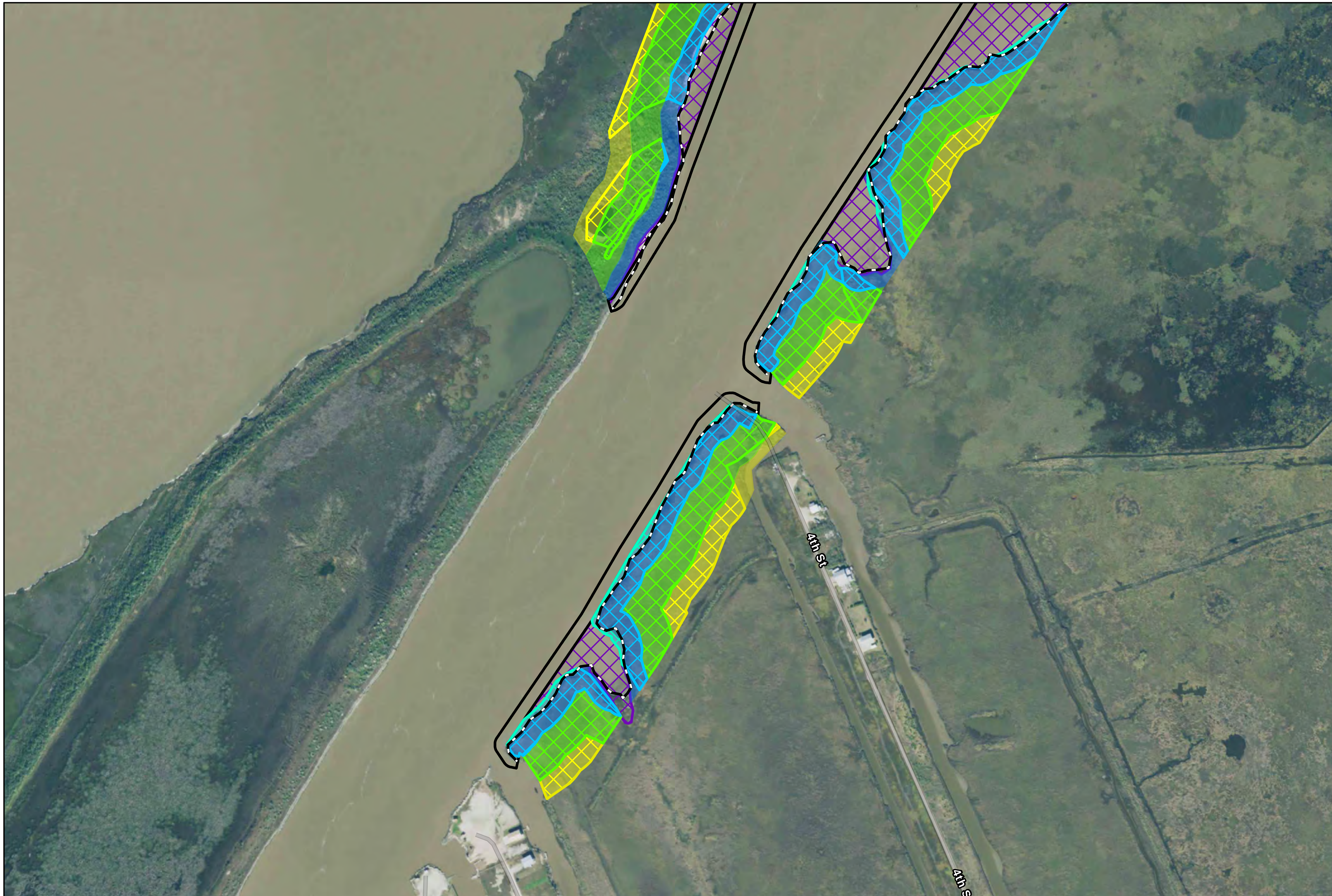

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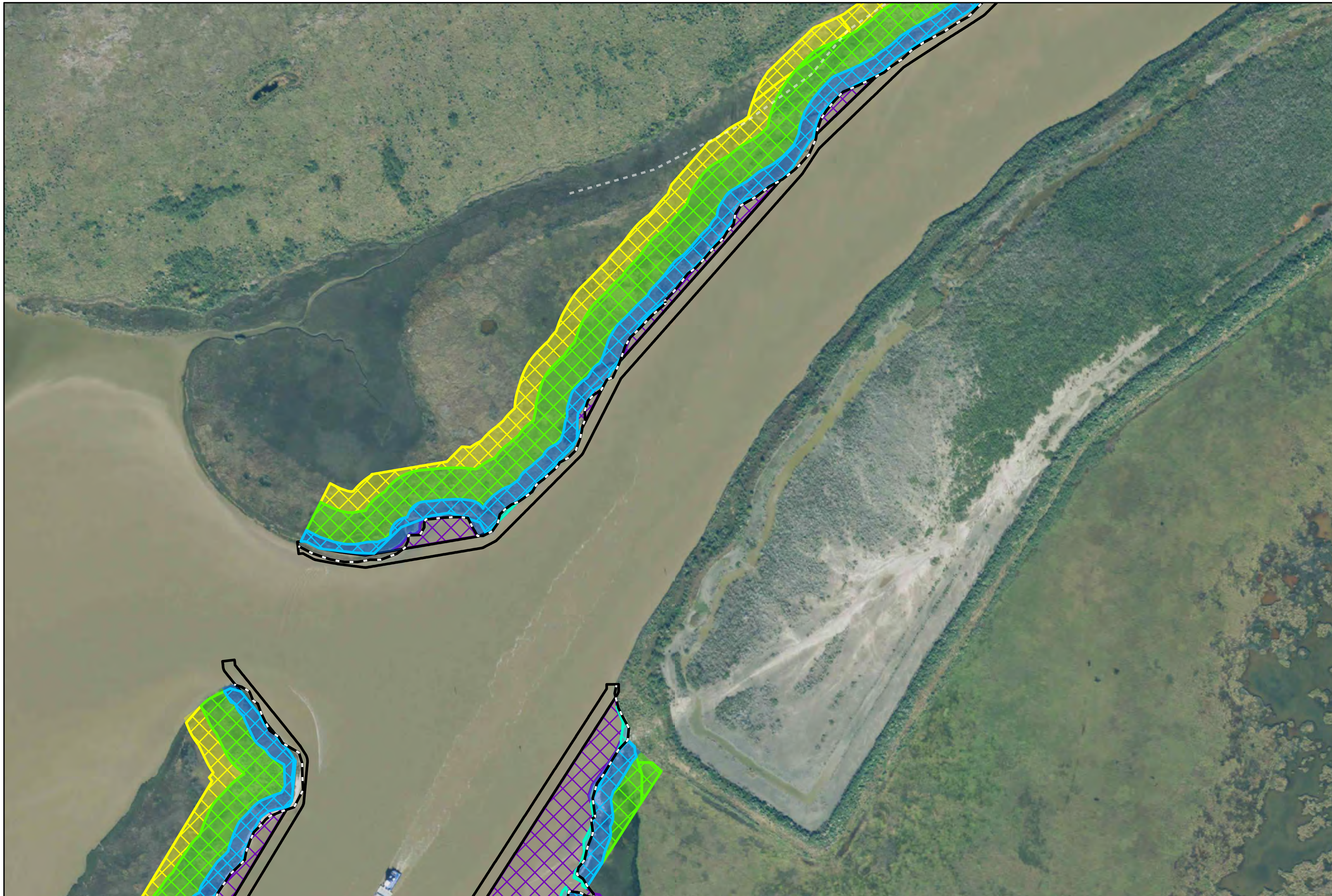

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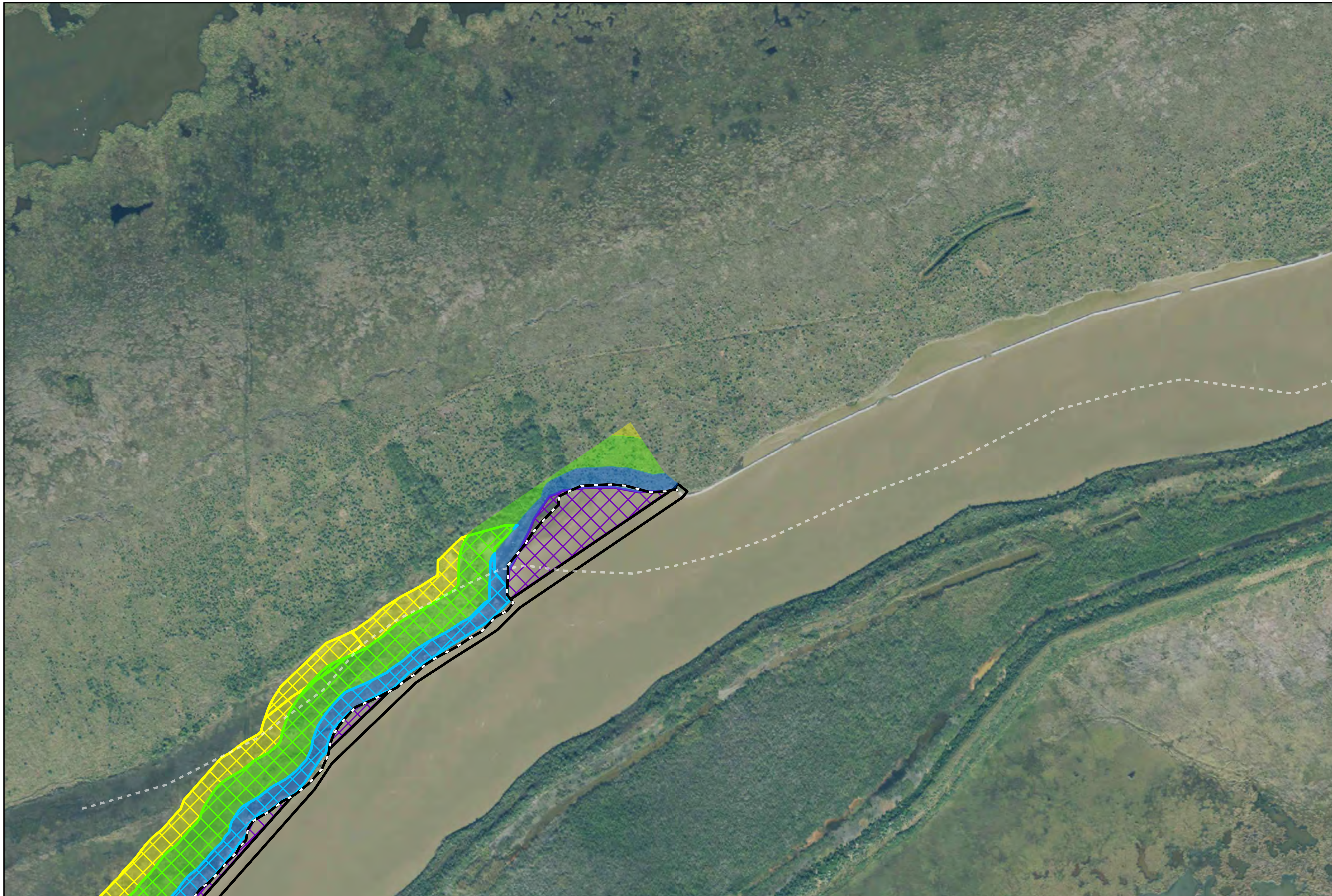

US Army Corps of Engineers
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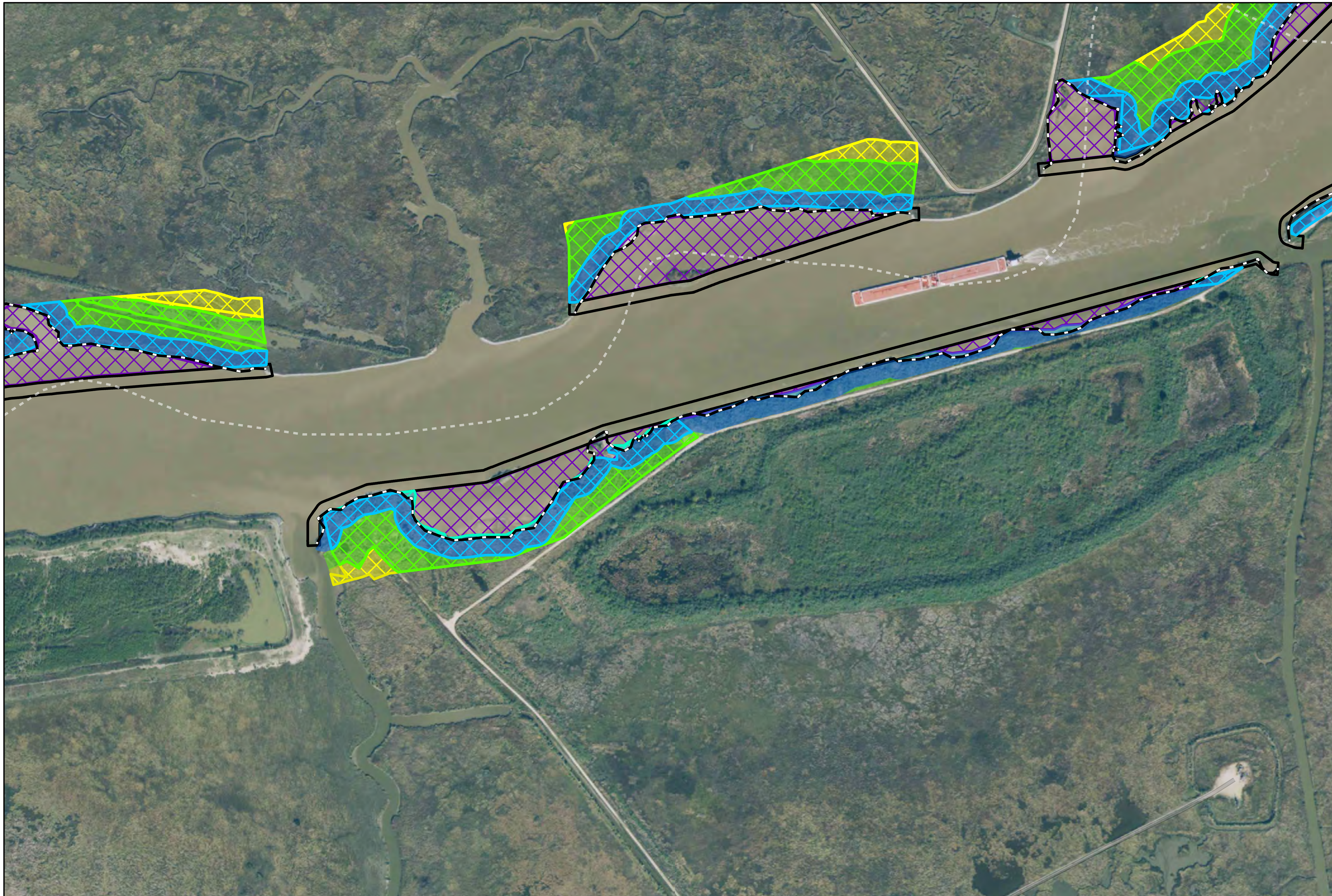

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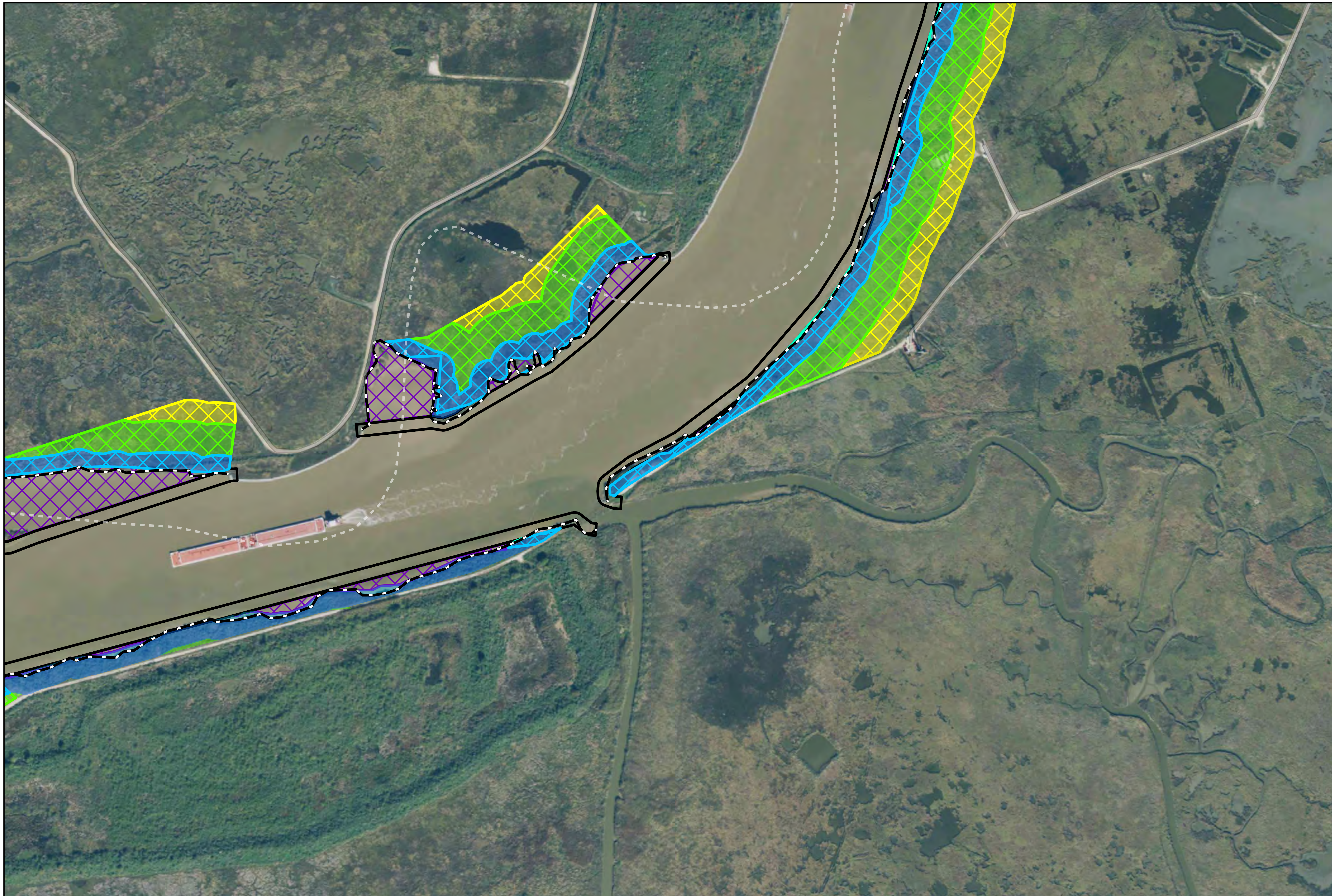

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Ecosystem Restoration Passive Benefits

Basemap: 2018 NAIP

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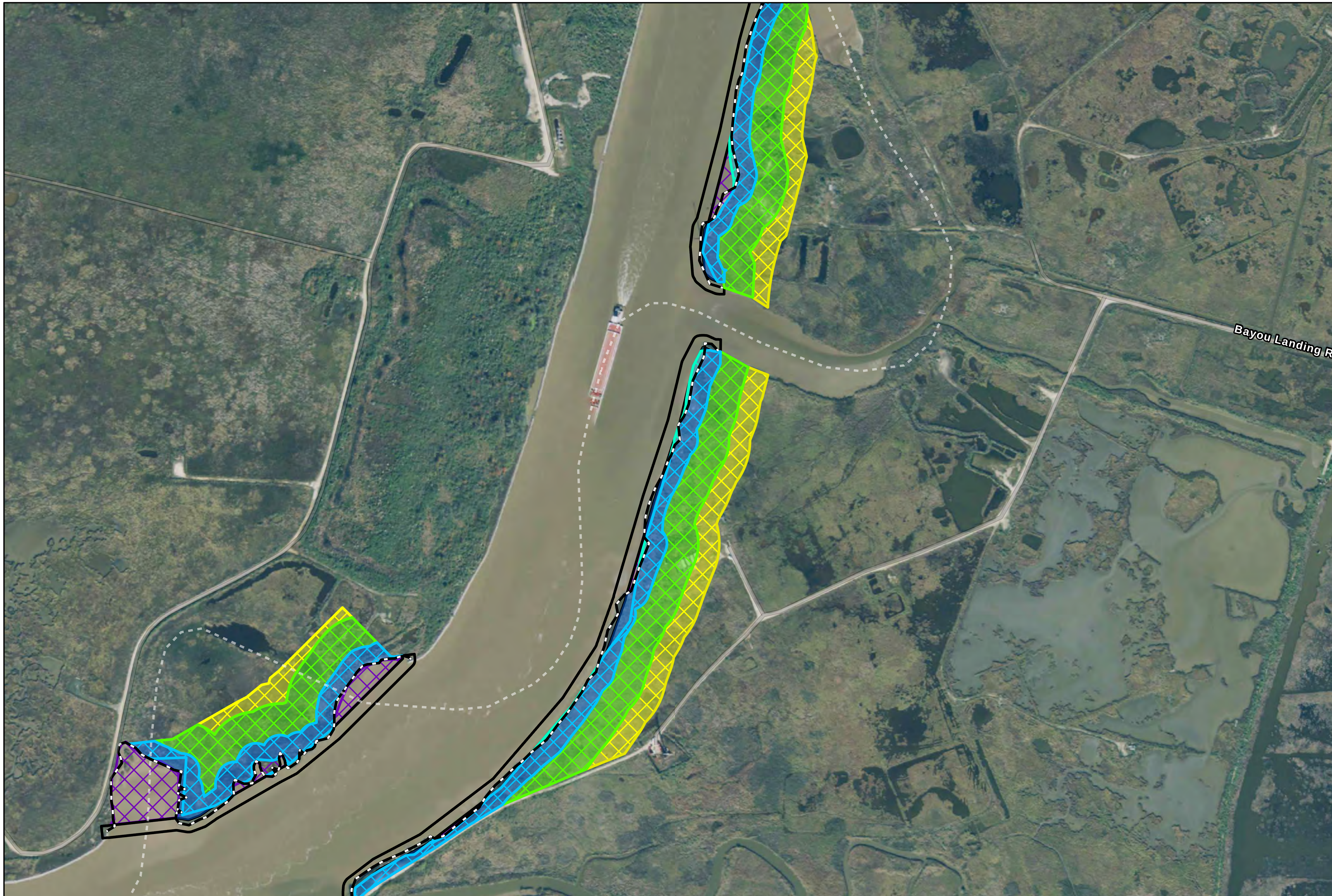

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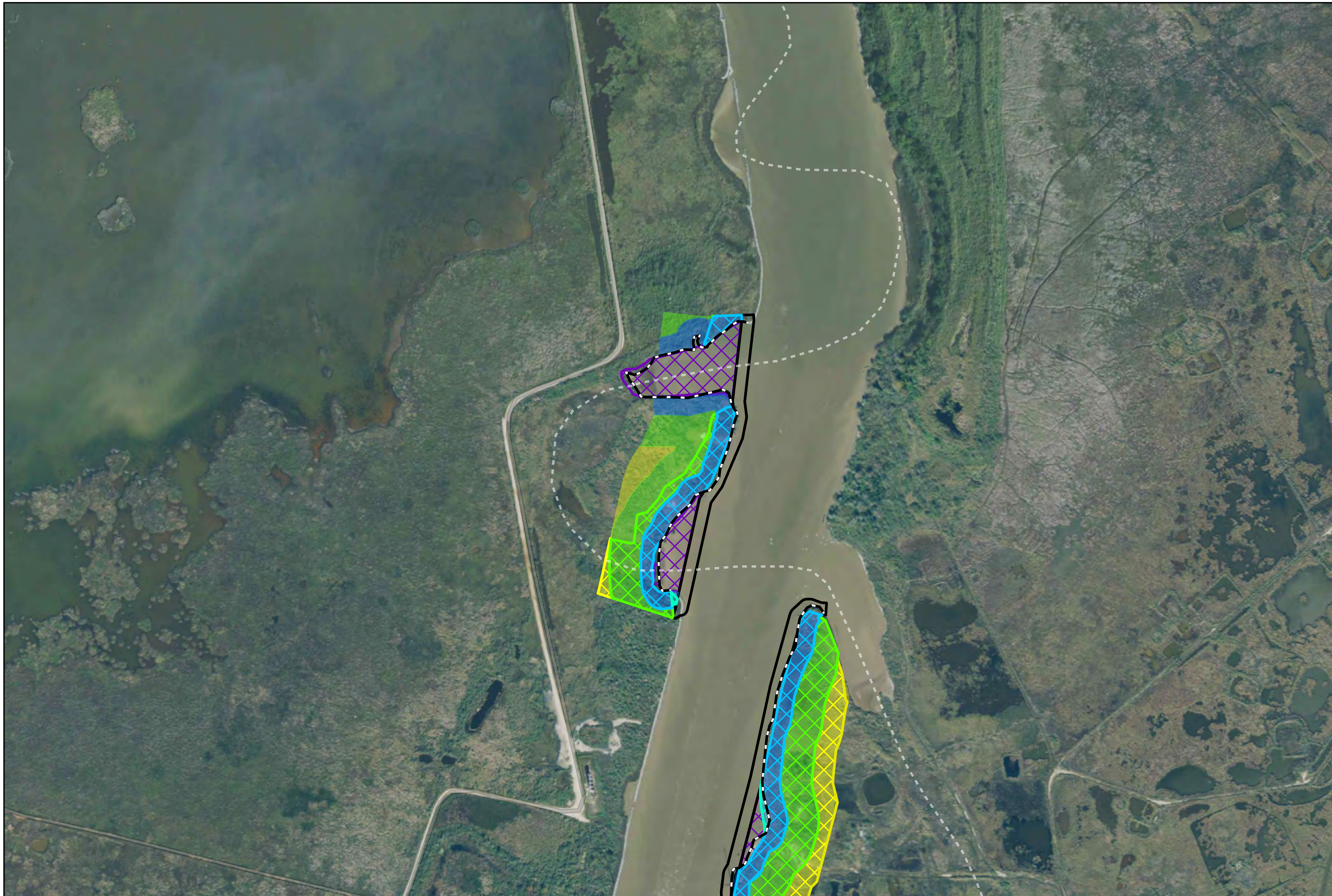

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Coastal Texas Protection and Restoration Feasibility Study

Ecosystem Restoration Passive Benefits

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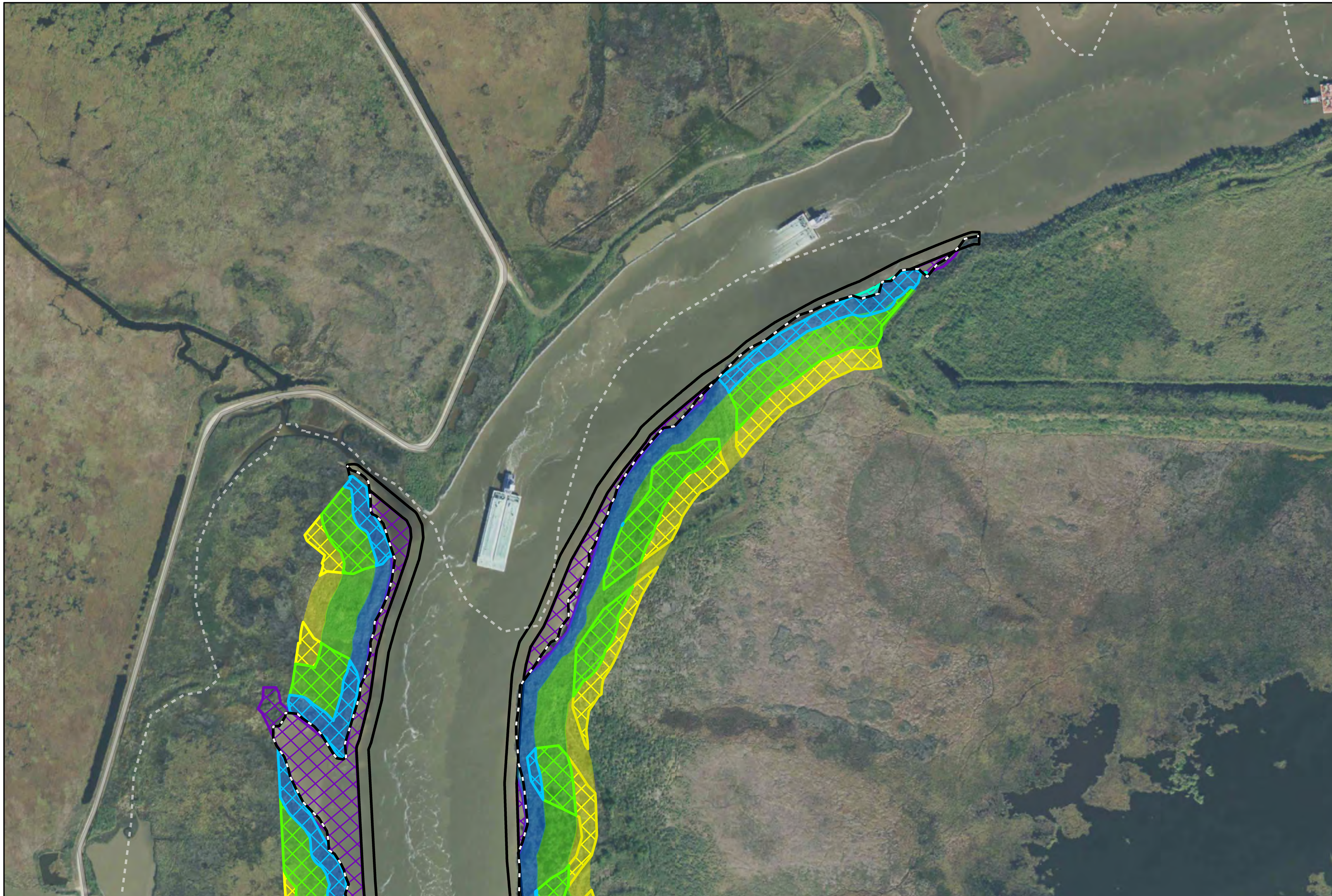

US Army Corps of Engineers ®
Galveston District

Coastal Texas Protection and Restoration Feasibility Study

Ecosystem Restoration Passive Benefits

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PROJECTION: STATE PLANE
ZONE: TX-SC 4204

Basemap: 2018 NAIP

0 250 500 Feet

Date: 30 March 2021

B-12

Habitat Modeling

American Oyster HSI Model Spreadsheet

Project: B-12 American Oyster

Acres 0.46

Condition: Future Without Project

Variable		TY 0	SI	TY 1	SI	TY 31	SI
V1	Percent cultch cover	0	0.00	0	0.00	0	0.00
V2	Mean salinity during spawning season	22	1.00	23	0.91	25	0.74
V3	Minimum annual salinity	13	1	14	1	15	1
V4	Annual mean salinity	23	0.39	25	0.25	27	0.19
		HSI=	**0.00**	HSI=	**0.00**	HSI=	**0.00**

Condition: Future Without Project

Variable		TY 51	SI	TY	SI	TY	SI
V1	Percent cultch cover	0	0.00				
V2	Mean salinity during spawning season	26	0.65				
V3	Minimum annual salinity	16	1				
V4	Annual mean salinity	28	0.16				
		HSI=	**0.00**	HSI=		HSI=	

Condition: Future Without Project

Variable		TY	SI	TY	SI	TY	SI
V1	Percent cultch cover						
V2	Mean salinity during spawning season						
V3	Minimum annual salinity						
V4	Annual mean salinity						
		HSI=		HSI=		HSI=	

Acres 2

Condition: Future With Project

Variable		TY 0	SI	TY 1	SI	TY 31	SI
V1	Percent cultch cover	0	0.00	100	1.00	100	1.00
V2	Mean salinity during spawning season	22	1.00	23	0.91	25	0.74
V3	Minimum annual salinity	13	1	14	1	15	1
V4	Annual mean salinity	23	0.39	25	0.25	27	0.19
		HSI=	**0.00**	HSI=	**0.69**	HSI=	**0.61**

Condition: Future With Project

Variable		TY 51	SI	TY	SI	TY	SI
V1	Percent cultch cover	100	1.00				
V2	Mean salinity during spawning season	26	0.65				
V3	Minimum annual salinity	16	1				
V4	Annual mean salinity	28	0.16				
		HSI=	**0.57**	HSI=		HSI=	

Condition: Future With Project

Variable		TY	SI	TY	SI	TY	SI
V1	Percent cultch cover						
V2	Mean salinity during spawning season						
V3	Minimum annual salinity						
V4	Annual mean salinity						
		HSI=		HSI=		HSI=	

American Oyster HSI Model Spreadsheet

Condition: Future Without Project

TY	Acres	HSI	Total HUs	Cumulative HUs
0	0.46	0.00	0.00	
1	0	0.00	0.00	0.00
31	0	0.00	0.00	0.00
51	0	0.00	0.00	0.00
Max TY=	51		AAHUs=	0.00

Condition: Future With Project

TY	Acres	HSI	Total HUs	Cumulative HUs
0	0.46	0.00	0.00	
1	2	0.69	1.38	0.51
31	2	0.61	1.22	39.09
51	2	0.57	1.14	23.59
Max TY=	51		AAHUs=	1.24

Net Change in AAHUs due to Project

Future With Project AAHUs	1.24
Future Without Project AAHUs	0.00
Net Change	**1.24**

B-12 -- Estuarine Marsh (Direct Benefits of Marsh Nourishment)

Project: B-12 Bastrop Bay, Oyster Lake, West Bay, and GIWW Shoreline Protection (BU)

Brown Shrimp HSI Model Spreadsheet

Condition: Future Without Project

		TY	0	TY	1	TY	31
	Acreage by TY		551		551		1303
Variable			SI		SI		SI
V1	% of estuary covered by vegetation (marsh and seagrass).	0	0.00	0	0.00	0	0.00
V2	Substrate Composition	soft bo	1.00	soft bo	1.00	soft bo	1.00
V3	Mean salinity - spring	26	0.88	27	0.86	29	0.82
V4	Mean water temperature - spring	24	1	24	1	24	1
		HSI=	**0.00**	HSI=	**0.00**	HSI=	**0.00**
		vba fn	0.00		0.00		0.00

Condition: Future With Project

		TY	0	TY	1	TY	31
	Acreage by TY		551		551		1303
Variable			SI		SI		SI
V1	% of estuary covered by vegetation (marsh and seagrass).	0	0.00	50	0.50	90	0.90
V2	Substrate Composition	soft bo	1.00	soft bo	1.00	soft bo	1.00
V3	Mean salinity - spring	26	0.88	27	0.86	29	0.82
V4	Mean water temperature - spring	24	1	24	1	24	1
		HSI=	**0.00**	HSI=	**0.63**	HSI=	**0.91**
		vba fn	0.00		0.37		0.91

Condition: Future Without Project

		TY	51	TY		TY	
			1756				
Variable			SI		SI		SI
V1	% of estuary covered by vegetation (marsh and seagrass).	0	0.00				
V2	Substrate Composition	soft bo	1.00				
V3	Mean salinity - spring	31	0.75				
V4	Mean water temperature - spring	24	1				
		HSI=	**0.00**	HSI=		HSI=	
		vba fn	0.00		V1_ENTRY		V1_ENTRY

Condition: Future With Project

		TY	51	TY		TY	
			1756				
Variable			SI		SI		SI
V1	% of estuary covered by vegetation (marsh and seagrass).	90	0.90				
V2	Substrate Composition	soft bo	1.00				
V3	Mean salinity - spring	31	0.75				
V4	Mean water temperature - spring	24	1				
		HSI=	**0.86**	HSI=		HSI=	
		vba fn	0.86		V1_ENTRY		V1_ENTRY

Condition: Future Without Project

		TY		TY		TY	
Variable			SI		SI		SI
V1	% of estuary covered by vegetation (marsh and seagrass).						
V2	Substrate Composition						
V3	Mean salinity - spring						
V4	Mean water temperature - spring						
		HSI=		HSI=		HSI=	
		vba fn	V1_ENTRY		V1_ENTRY		V1_ENTRY

Condition: Future With Project

		TY		TY		TY	
Variable			SI		SI		SI
V1	% of estuary covered by vegetation (marsh and seagrass).						
V2	Substrate Composition						
V3	Mean salinity - spring						
V4	Mean water temperature - spring						
		HSI=		HSI=		HSI=	
		vba fn	V1_ENTRY		V1_ENTRY		V1_ENTRY

B-12 -- Estuarine Marsh (Direct Benefits of Marsh Nourishment)

Brown Shrimp HSI Model Spreadsheet

Condition: Future Without Project

TY	Acres	HSI	Total HUs	Cumulative HUs
0	551	0.00	0.00	
1	551	0.00	0.00	0.00
31	1303	0.00	0.00	0.00
51	1756	0.00	0.00	0.00
Max TY=	**51**		**AAHUs=**	**0.0**

Condition: Future With Project

TY	Acres	HSI	Total HUs	Cumulative HUs
0	551	0.00	0.00	
1	551	0.63	347.11	173.55
31	1303	0.91	1179.92	21869.20
51	1756	0.86	1517.36	27035.35
Max TY=	**51**		**AAHUs=**	**962.3**

Net Change in AAHUs due to Project

Future With Project AAHUs	962.3
Future Without Project AAHUs	0.0
Net Change	962.3

B-12 -- Estuarine Marsh (Passive Benefits of Breakwater Accretion)

Brown Shrimp HSI Model Spreadsheet

Project: B-12 - Bastrop Bay, Oyster Lake, West Bay, and GIWW Protection (Breakwaters-Accretion)

Condition: Future Without Project

		TY	0	TY	1	TY	31
	Acreage by TY		130		130		130
Variable			SI		SI		SI
V1	% of estuary covered by vegetation (marsh and seagrass).	0	0.00	0	0.00	0	0.00
V2	Substrate Composition	soft bc	1.00	soft bc	1.00	soft bc	1.00
V3	Mean salinity - spring	18	1.00	19	1.00	21	0.98
V4	Mean water temperature - spring	24	1	24	1	24	1
		HSI=	0.00	HSI=	0.00	HSI=	0.00
		vba fn	0.00		0.00		0.00

Condition: Future With Project

		TY	0	TY	1	TY	31
	Acreage by TY		130		130		130
Variable			SI		SI		SI
V1	% of estuary covered by vegetation (marsh and seagrass).	0	0.00	90	0.90	90	0.90
V2	Substrate Composition	soft bc	1.00	soft bc	1.00	soft bc	1.00
V3	Mean salinity - spring	18	1.00	18	1.00	18	1.00
V4	Mean water temperature - spring	24	1	24	1	24	1
		HSI=	0.00	HSI=	0.93	HSI=	0.93
		vba fn	0.00		0.55		0.93

Condition: Future Without Project

		TY	51	TY		TY	
			130				
Variable			SI		SI		SI
V1	% of estuary covered by vegetation (marsh and seagrass).	0	0.00				
V2	Substrate Composition	soft bc	1.00				
V3	Mean salinity - spring	22	0.96				
V4	Mean water temperature - spring	24	1				
		HSI=	0.00	HSI=		HSI=	
		vba fn	0.00		V1_ENTRY		V1_ENTRY

Condition: Future With Project

		TY	51	TY		TY	
			130				
Variable			SI		SI		SI
V1	% of estuary covered by vegetation (marsh and seagrass).	90	0.90				
V2	Substrate Composition	soft bc	1.00				
V3	Mean salinity - spring	18	1.00				
V4	Mean water temperature - spring	24	1				
		HSI=	0.93	HSI=		HSI=	
		vba fn	0.87		V1_ENTRY		V1_ENTRY

Condition: Future Without Project

		TY		TY		TY	
Variable			SI		SI		SI
V1	% of estuary covered by vegetation (marsh and seagrass).						
V2	Substrate Composition						
V3	Mean salinity - spring						
V4	Mean water temperature - spring						
		HSI=		HSI=		HSI=	
		vba fn	V1_ENTRY		V1_ENTRY		V1_ENTRY

Condition: Future With Project

		TY		TY		TY	
Variable			SI		SI		SI
V1	% of estuary covered by vegetation (marsh and seagrass).						
V2	Substrate Composition						
V3	Mean salinity - spring						
V4	Mean water temperature - spring						
		HSI=		HSI=		HSI=	
		vba fn	V1_ENTRY		V1_ENTRY		V1_ENTRY

B-12 -- Estuarine Marsh (Passive Benefits of Breakwater Accretion)

Brown Shrimp HSI Model Spreadsheet

Condition: Future Without Project

TY	Acres	HSI	Total HUs	Cumulative HUs
0	130	0.00	0.00	
1	130	0.00	0.00	0.00
31	130	0.00	0.00	0.00
51	130	0.00	0.00	0.00
Max TY=	**51**		**AAHUs=**	**0.0**

Condition: Future With Project

TY	Acres	HSI	Total HUs	Cumulative HUs
0	130	0.00	0.00	
1	130	0.93	121.18	60.59
31	130	0.93	121.18	3635.46
51	130	0.93	121.18	2423.64
Max TY=	**51**		**AAHUs=**	**120.0**

Net Change in AAHUs due to Project

Future With Project AAHUs	120.0
Future Without Project AAHUs	0.0
Net Change	120.0

B-12 -- Estuarine Marsh (Passive Benefits of Breakwater Prevention of Erosion)

Project: B-12 Bastrop Bay, Oyster Lake, West Bay, and GIWW Shoreline Protection (Breakwater -- Erosion)

Brown Shrimp HSI Model Spreadsheet

Condition: Future Without Project

Variable		TY	0	TY	1	TY	31
	Acreage by TY		414		414		144
			SI		**SI**		**SI**
V1	% of estuary covered by vegetation (marsh and seagrass).	90	0.90	92	0.92	92	0.92
V2	Substrate Composition	soft bo	1.00	soft bo	1.00	soft bo	1.00
V3	Mean salinity - spring	18	1.00	19	1.00	21	0.98
V4	Mean water temperature - spring	24	1	24	1	24	1
		HSI=	0.93	HSI=	0.95	HSI=	0.95
		vba fn	0.93		0.95		0.88

Condition: Future With Project

Variable		TY	0	TY	1	TY	31
	Acreage by TY		414		414		414
			SI		**SI**		**SI**
V1	% of estuary covered by vegetation (marsh and seagrass).	90	0.90	94	0.94	92	0.92
V2	Substrate Composition	soft bo	1.00	soft bo	1.00	soft bo	1.00
V3	Mean salinity - spring	18	1.00	19	1.00	21	0.98
V4	Mean water temperature - spring	24	1	24	1	24	1
		HSI=	0.93	HSI=	0.96	HSI=	0.95
		vba fn	0.93		0.56		0.95

Condition: Future Without Project

Variable		TY	51	TY		TY	
			0				
			SI		**SI**		**SI**
V1	% of estuary covered by vegetation (marsh and seagrass).	92	0.92				
V2	Substrate Composition	soft bo	1.00				
V3	Mean salinity - spring	22	0.96				
V4	Mean water temperature - spring	24	1				
		HSI=	0.95	HSI=		HSI=	
		vba fn	0.95		V1_ENTRY		V1_ENTRY

Condition: Future With Project

Variable		TY	51	TY		TY	
			414				
			SI		**SI**		**SI**
V1	% of estuary covered by vegetation (marsh and seagrass).	92	0.92				
V2	Substrate Composition	soft bo	1.00				
V3	Mean salinity - spring	22	0.96				
V4	Mean water temperature - spring	24	1				
		HSI=	0.95	HSI=		HSI=	
		vba fn	0.88		V1_ENTRY		V1_ENTRY

Condition: Future Without Project

Variable		TY		TY		TY	
			SI		**SI**		**SI**
V1	% of estuary covered by vegetation (marsh and seagrass).						
V2	Substrate Composition						
V3	Mean salinity - spring						
V4	Mean water temperature - spring						
		HSI=		HSI=		HSI=	
		vba fn	V1_ENTRY		V1_ENTRY		V1_ENTRY

Condition: Future With Project

Variable		TY		TY		TY	
			SI		**SI**		**SI**
V1	% of estuary covered by vegetation (marsh and seagrass).						
V2	Substrate Composition						
V3	Mean salinity - spring						
V4	Mean water temperature - spring						
		HSI=		HSI=		HSI=	
		vba fn	V1_ENTRY		V1_ENTRY		V1_ENTRY

B-12 -- Estuarine Marsh (Passive Benefits of Breakwater Prevention of Erosion)

Brown Shrimp HSI Model Spreadsheet

Condition: Future Without Project

TY	Acres	HSI	Total HUs	Cumulative HUs
0	414	0.93	385.92	
1	414	0.95	391.61	388.77
31	144	0.95	136.21	7917.43
51	0	0.95	0.00	1362.14
Max TY=	51		AAHUs=	189.6

Net Change in AAHUs due to Project

Future With Project AAHUs	393.3
Future Without Project AAHUs	189.6
Net Change	203.7

Condition: Future With Project

TY	Acres	HSI	Total HUs	Cumulative HUs
0	414	0.93	385.92	
1	414	0.96	397.27	391.59
31	414	0.95	391.61	11833.27
51	414	0.95	391.61	7832.29
Max TY=	51		AAHUs=	393.3

B-12 -- Palustrine Marsh (Passive Benefits of Breakwater Prevention of Erosion)

Project: B-12- West Bay and Brazoria GIWW Shoreline Protection (Erosion)

American alligator HSI Model Spreadsheet

Acres 24

Condition: Future Without Project

		TY	0	TY	1	TY	31
Variable			**SI**		**SI**		**SI**
V1	% wetland that is open water (ponds, bayous, canals).	30	1.00	30	1.00	30	1.00
V2	% open water in bayous, canals or > 1.2m deep	10	1.00	10	1.00	10	1.00
V3	Interspersion Class	Medium	0.50	Mediu	0.50	Mediu	0.50
V4	% ponded area >=15 cm deep (May - September)	60	0.6	60	0.6	60	0.6
V5	% substrate exposed at MLT (May - Sep) - Tidal only						
	CI (tidal) | CI (non-tidal)		0.6694		0.6694		0.6694
		HSI=	0.8182	HSI=	0.8182	HSI=	0.8182

Acres 24

Condition: Future With Project

		TY	0	TY	1	TY	31
Variable			**SI**		**SI**		**SI**
V1	% wetland that is open water (ponds, bayous, canals).	30	1.00	30	1.00	30	1.00
V2	% open water in bayous, canals or > 1.2m deep	10	1.00	10	1.00	10	1.00
V3	Interspersion Class	Medium	0.50	Mediu	0.50	Mediu	0.50
V4	% ponded area >=15 cm deep (May - September)	60	0.6	60	0.6	60	0.6
V5	% substrate exposed at MLT (May - Sep) - Tidal only						
	CI (tidal) | CI (non-tidal)		0.6694		0.6694		0.6694
		HSI=	0.8182	HSI=	0.8182	HSI=	0.8182

Condition: Future Without Project

		TY	51	TY		TY	
Variable			**SI**		**SI**		**SI**
V1	% wetland that is open water (ponds, bayous, canals).	30	1.00				
V2	% open water in bayous, canals or > 1.2m deep	10	1.00				
V3	Interspersion Class	Medium	0.50				
V4	% ponded area >=15 cm deep (May - September)	60	0.6				
V5	% substrate exposed at MLT (May - Sep) - Tidal only						
	CI (tidal) | CI (non-tidal)		0.6694				
		HSI=	0.8182	HSI=		HSI=	

Condition: Future With Project

		TY	51	TY		TY	
Variable			**SI**		**SI**		**SI**
V1	% wetland that is open water (ponds, bayous, canals).	30	1.00				
V2	% open water in bayous, canals or > 1.2m deep	10	1.00				
V3	Interspersion Class	Medium	0.50				
V4	% ponded area >=15 cm deep (May - September)	60	0.6				
V5	% substrate exposed at MLT (May - Sep) - Tidal only						
	CI (tidal) | CI (non-tidal)		0.6694				
		HSI=	0.8182	HSI=		HSI=	

Condition: Future Without Project

		TY		TY		TY	
Variable			**SI**		**SI**		**SI**
V1	% wetland that is open water (ponds, bayous, canals).						
V2	% open water in bayous, canals or > 1.2m deep						
V3	Interspersion Class						
V4	% ponded area >=15 cm deep (May - September)						
V5	% substrate exposed at MLT (May - Sep) - Tidal only						
	CI (tidal) | CI (non-tidal)						
		HSI=		HSI=		HSI=	

Condition: Future With Project

		TY		TY		TY	
Variable			**SI**		**SI**		**SI**
V1	% wetland that is open water (ponds, bayous, canals).						
V2	% open water in bayous, canals or > 1.2m deep						
V3	Interspersion Class						
V4	% ponded area >=15 cm deep (May - September)						
V5	% substrate exposed at MLT (May - Sep) - Tidal only						
	CI (tidal) | CI (non-tidal)						
		HSI=		HSI=		HSI=	

B-12 -- Palustrine Marsh (Passive Benefits of Breakwater Prevention of Erosion)

American alligator HSI Model Spreadsheet

Condition: Future Without Project

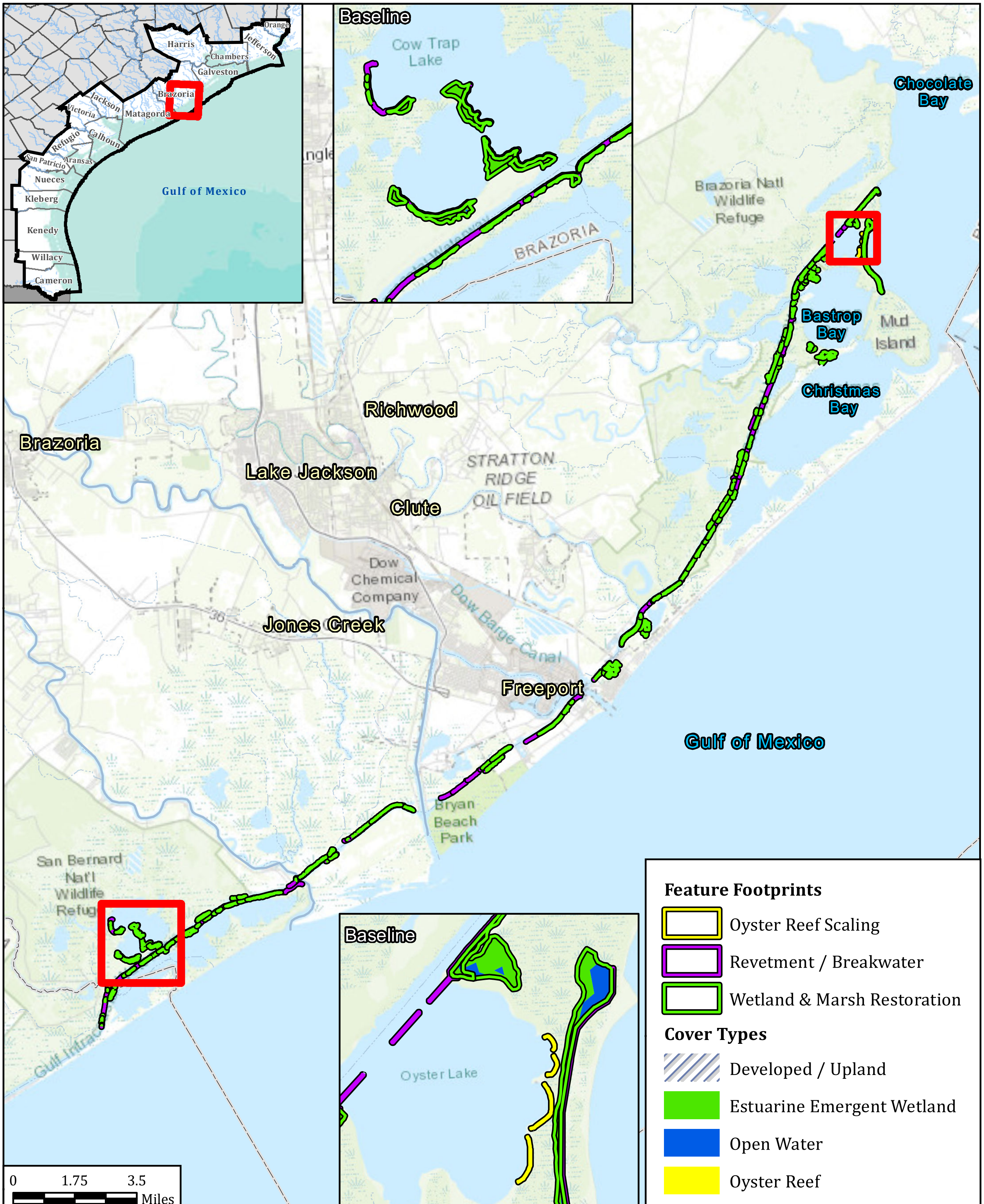
TY	Acres	HSI	Total HUs	Cumulative HUs
0	24	0.82	19.64	
1	24	0.82	19.64	19.64
31	8	0.82	6.55	392.73
51	0	0.82	0.00	65.46
Max TY=	**51**		**AAHUs=**	**9.4**

Condition: Future With Project

TY	Acres	HSI	Total HUs	Cumulative HUs
0	24	0.82	19.64	
1	24	0.82	19.64	19.64
31	24	0.82	19.64	589.10
51	24	0.82	19.64	392.73
Max TY=	**51**		**AAHUs=**	**19.6**

Net Change in AAHUs due to Project

Future With Project AAHUs	19.6
Future Without Project AAHUs	9.4
Net Change	10.3



N
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S

USACE COASTAL TEXAS
PROTECTION AND RESTORATION STUDY

B-12 - West Bay and Brazoria GIWW Shoreline Protection Baseline Cover Types

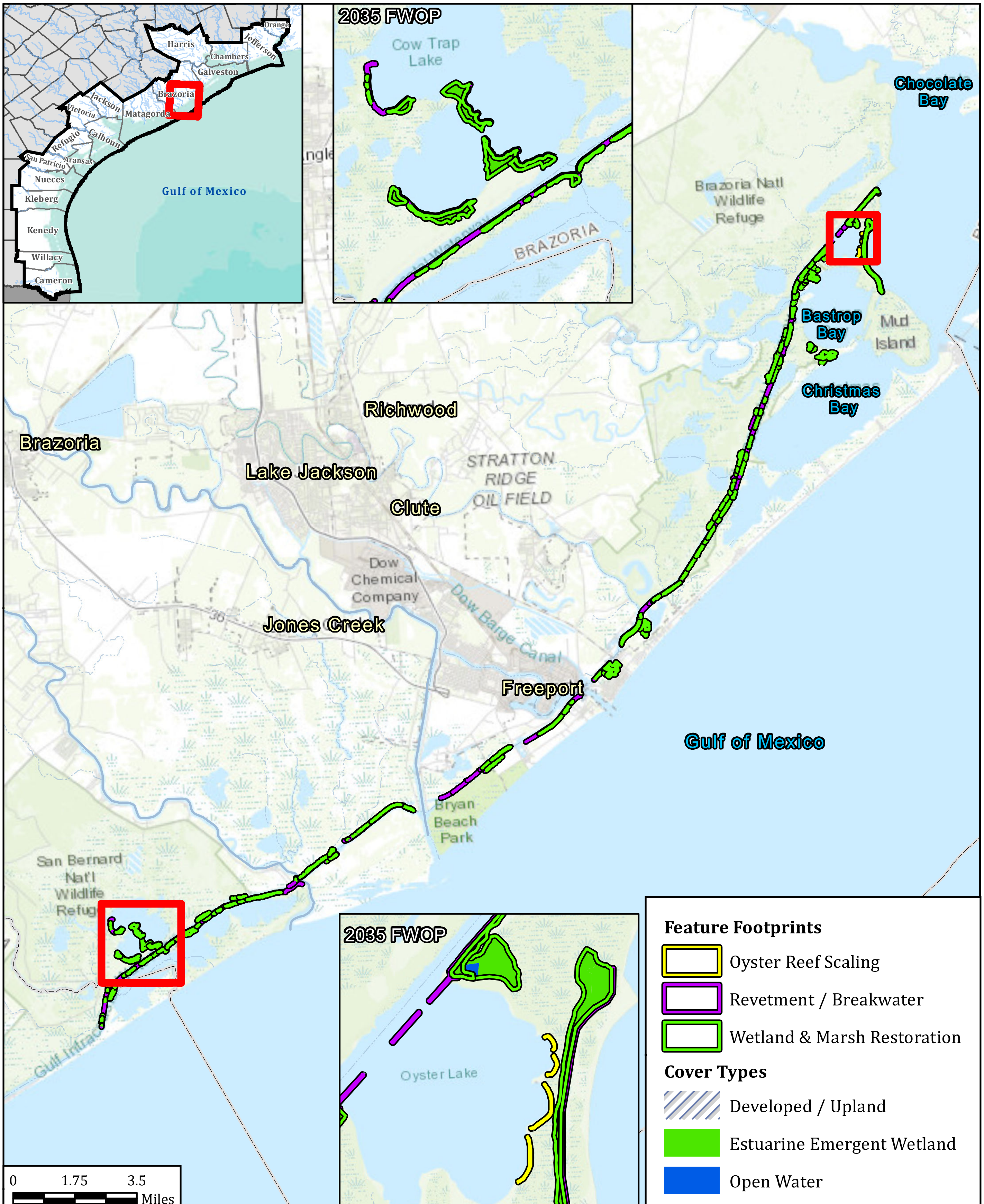
FN JOB NO	TGL18185
FILE NAME	2_B12_Mapbook.mxd
DATE	9/2/2020
SCALE	1:238,310
DESIGNED	KLC
DRAFTED	02588

2.0

FIGURE

Base Map: ESRI World Topographic Map Service

NAD 1983 StatePlane Texas Central FIPS 4203 Feet



USACE COASTAL TEXAS
PROTECTION AND RESTORATION STUDY

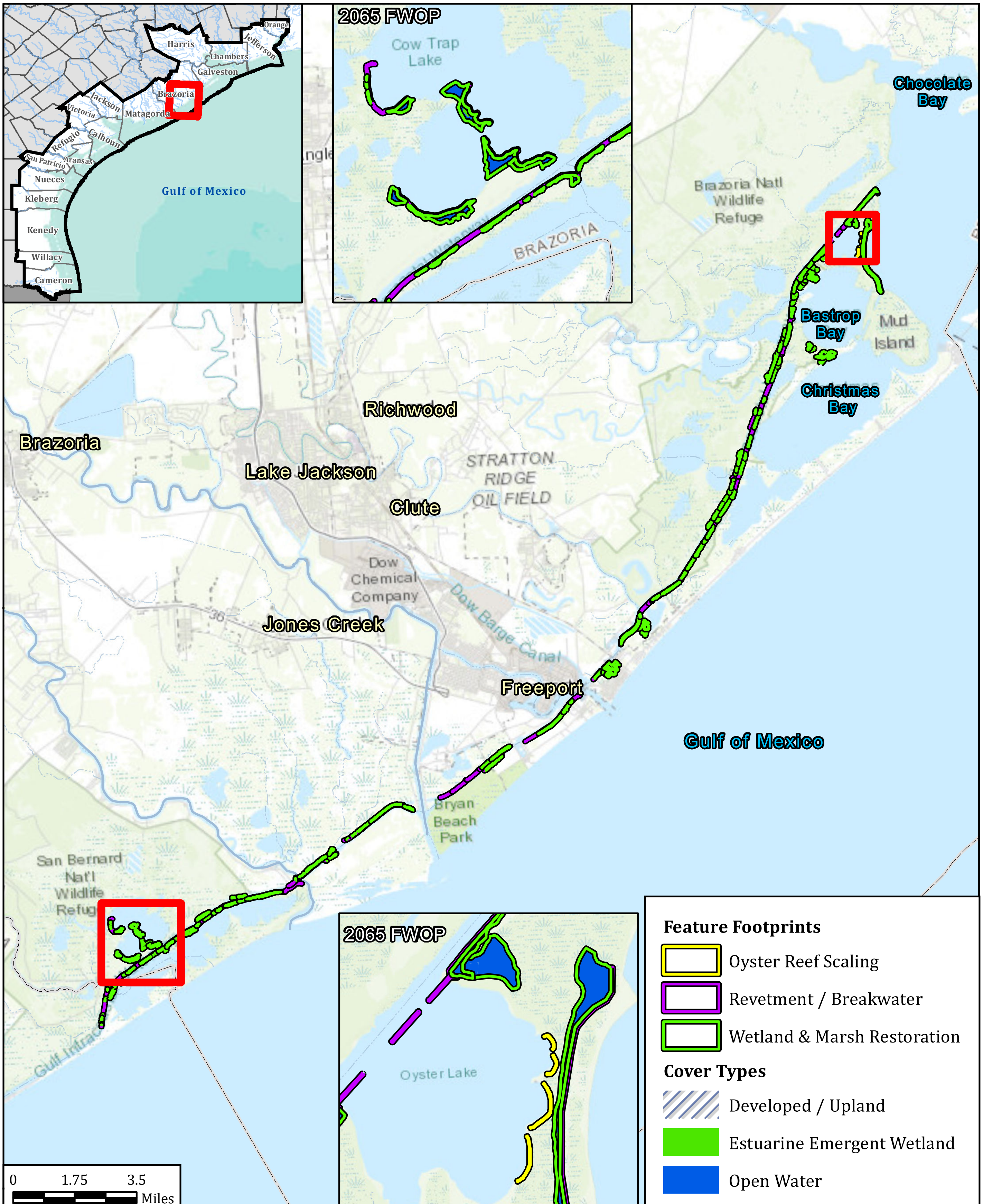
B-12 - West Bay and Brazoria GIWW Shoreline Protection 2035 FWOP Cover Types

FN JOB NO	TGL18185
FILE NAME	2_B12_Mapbook.mxd
DATE	9/2/2020
SCALE	1:238,310
DESIGNED	KLC
DRAFTED	02588

2.1
FIGURE

Base Map: ESRI World Topographic Map Service

NAD 1983 StatePlane Texas Central FIPS 4203 Feet



USACE COASTAL TEXAS
PROTECTION AND RESTORATION STUDY

B-12 - West Bay and Brazoria GIWW Shoreline Protection 2065 FWOP Cover Types

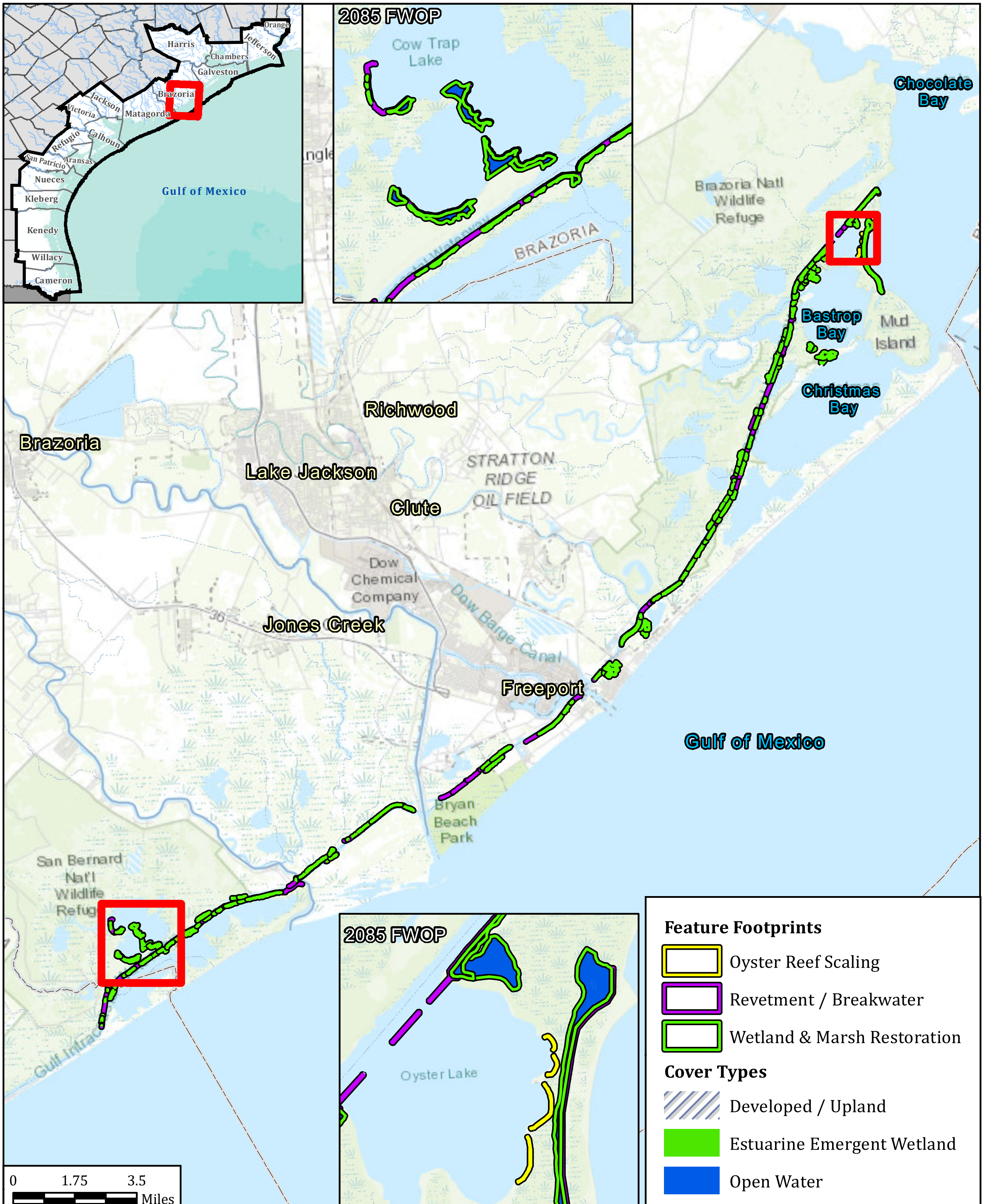
FN JOB NO	TGL18185
FILE NAME	2_B12_Mapbook.mxd
DATE	9/2/2020
SCALE	1:238,310
DESIGNED	KLC
DRAFTED	02588

2.2

FIGURE

Base Map: ESRI World Topographic Map Service

NAD 1983 StatePlane Texas Central FIPS 4203 Feet



USACE COASTAL TEXAS
PROTECTION AND RESTORATION STUDY

B-12 - West Bay and Brazoria GIWW Shoreline Protection 2085 FWOP Cover Types

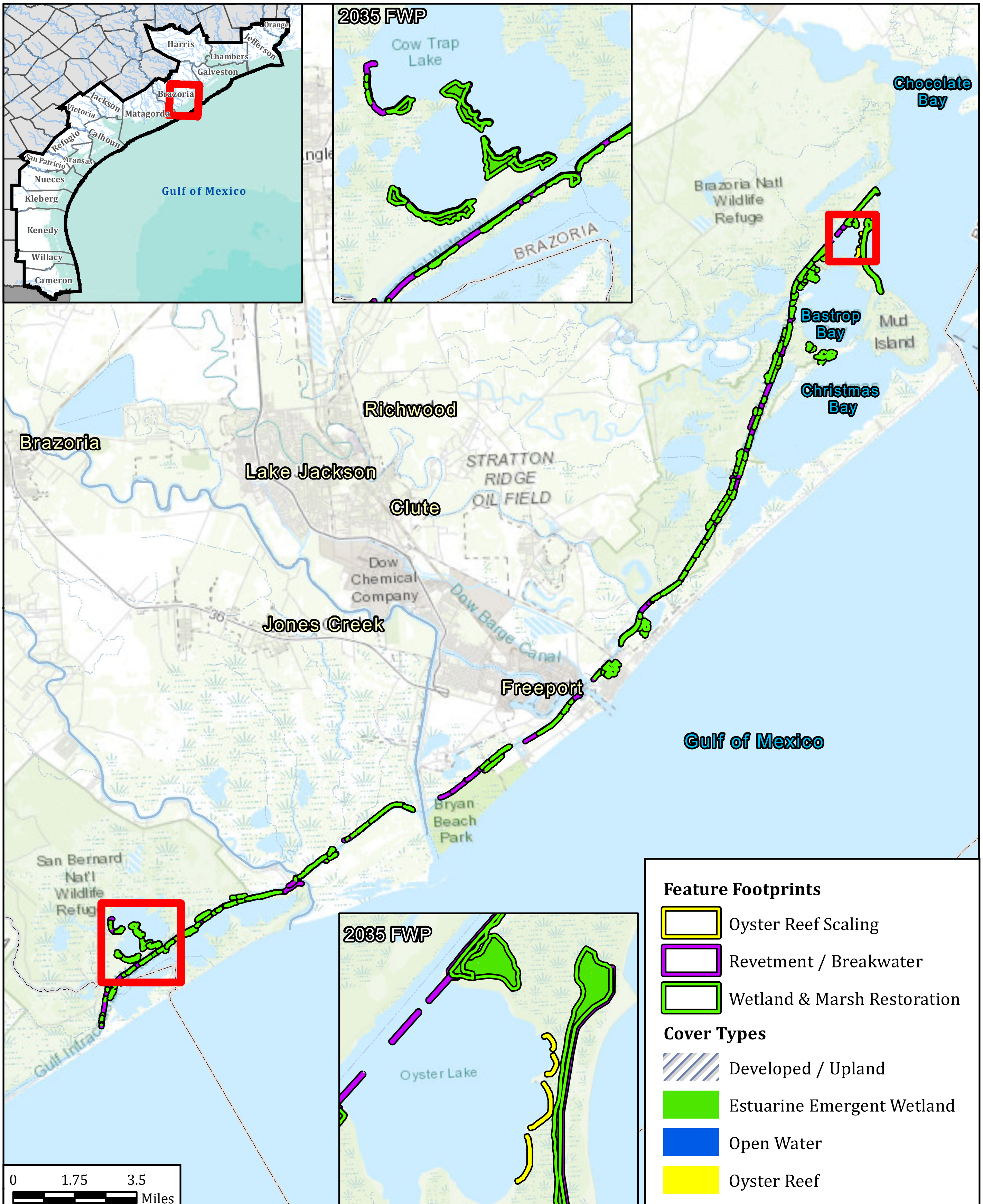
FN JOB NO	TGL18185
FILE NAME	2_B12_Mapbook.mxd
DATE	9/2/2020
SCALE	1:238,310
DESIGNED	KLC
DRAFTED	02588

2.3

FIGURE

Base Map: ESRI World Topographic Map Service

NAD 1983 StatePlane Texas Central FIPS 4203 Feet



USACE COASTAL TEXAS
PROTECTION AND RESTORATION STUDY

B-12 - West Bay and Brazoria GIWW Shoreline Protection 2035 FWP Cover Types

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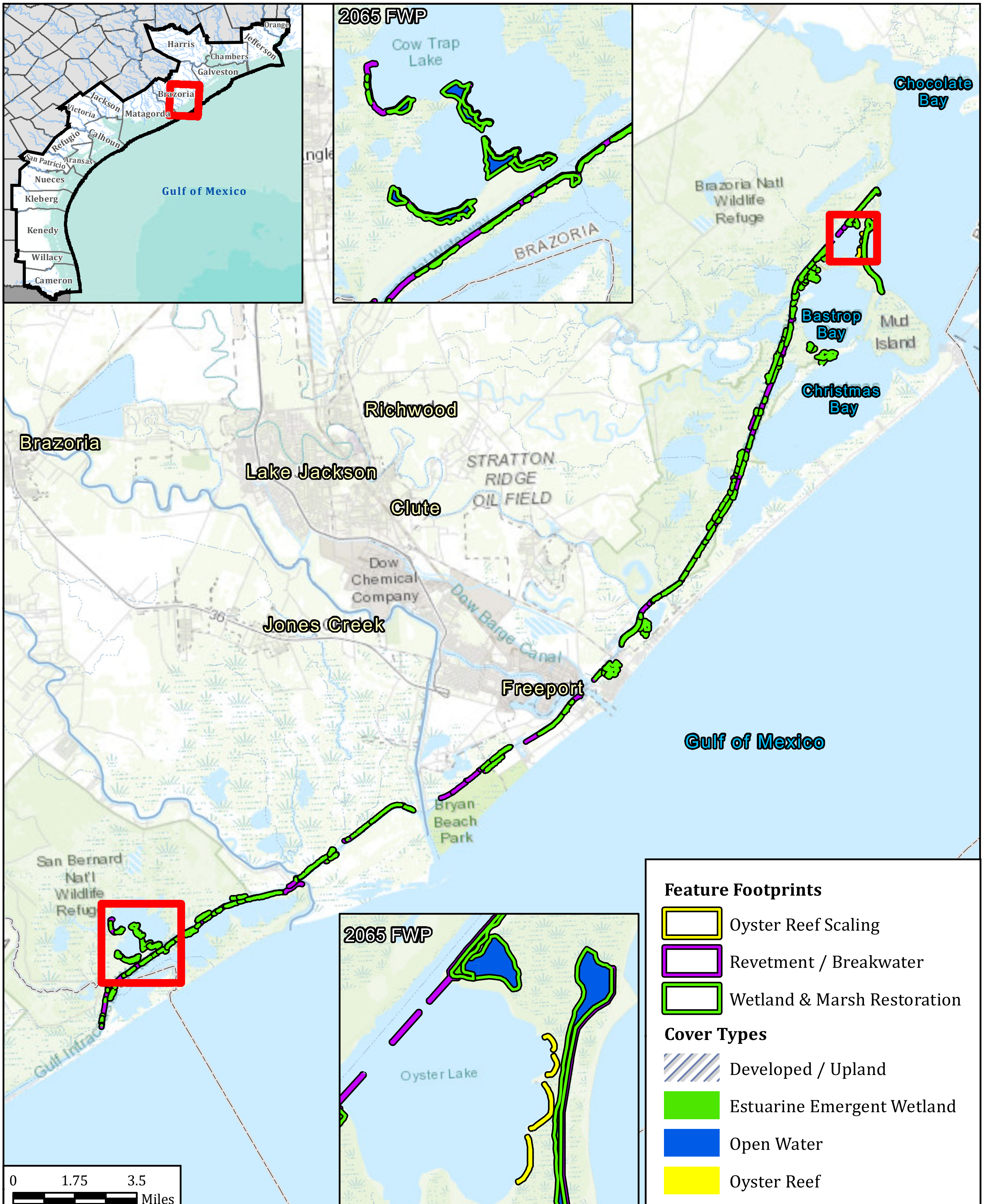
FILE NAME	2_B12_Mapbook.mxd
DATE	9/2/2020
SCALE	1:238,310
DESIGNED	KLC
DRAFTED	02588

2.4

FIGURE

Base Map: ESRI World Topographic Map Service

NAD 1983 StatePlane Texas Central FIPS 4203 Feet



N W E S

USACE COASTAL TEXAS PROTECTION AND RESTORATION STUDY

B-12 - West Bay and Brazoria GIWW Shoreline Protection 2065 FWP Cover Types

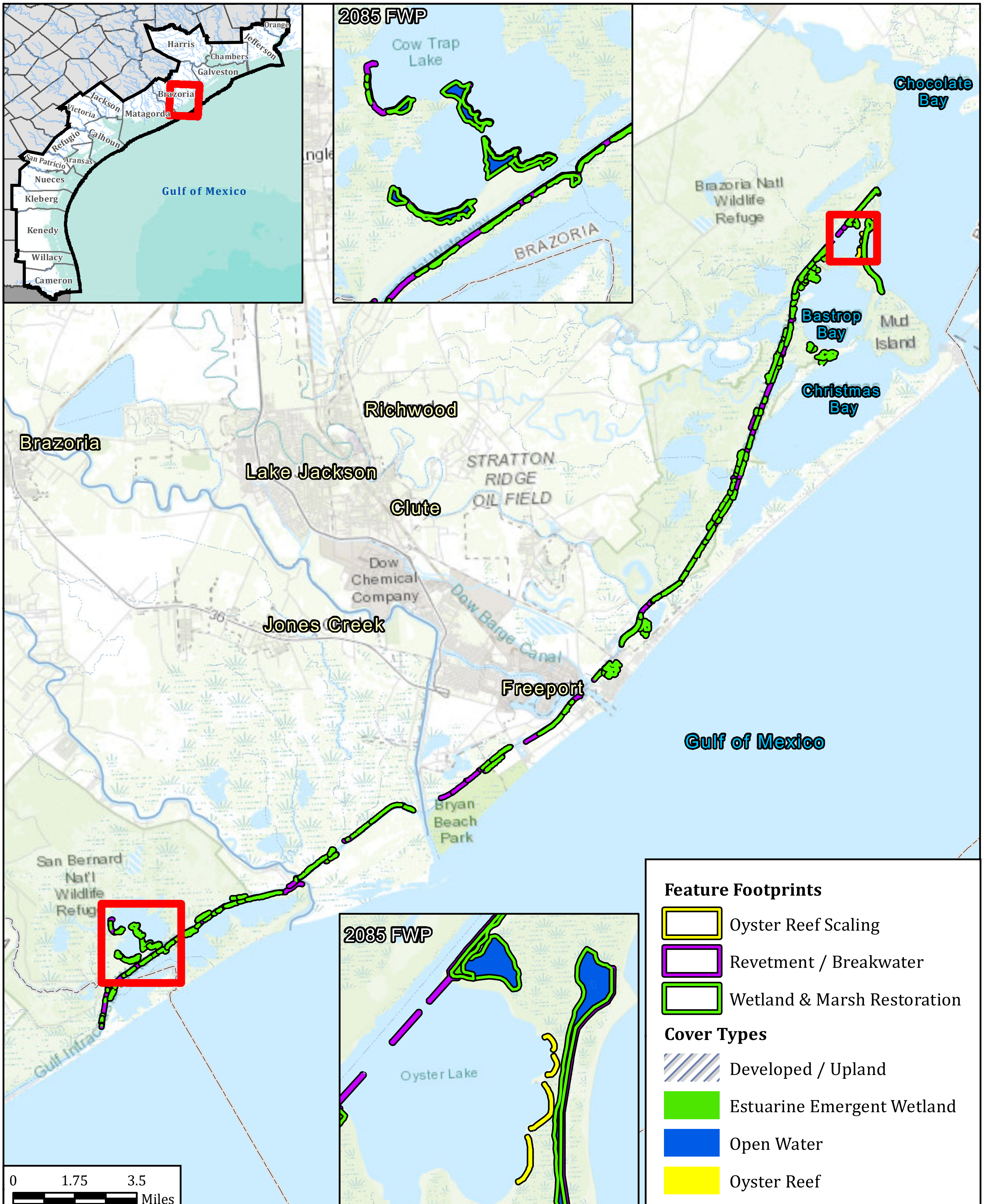
FN JOB NO	TGL18185
FILE NAME	2_B12_Mapbook.mxd
DATE	9/2/2020
SCALE	1:238,310
DESIGNED	KLC
DRAFTED	02588

2.5

FIGURE

Base Map: ESRI World Topographic Map Service

NAD 1983 StatePlane Texas Central FIPS 4203 Feet



N W E S

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PROTECTION AND RESTORATION STUDY

B-12 - West Bay and Brazoria GIWW Shoreline Protection 2085 FWP Cover Types

FN JOB NO	TGL18185
FILE NAME	2_B12_Mapbook.mxd
DATE	9/2/2020
SCALE	1:238,310
DESIGNED	KLC
DRAFTED	02588

2.6

FIGURE

Base Map: ESRI World Topographic Map Service

NAD 1983 StatePlane Texas Central FIPS 4203 Feet

ER Measure B12 Bastrop Bay, West Bay, and GIWW Shoreline Protection

Shoreline (2018)

NWI Polygon

2035 Interstitial Benefit Area

NWI Polygon

2035 Benefit Area

NWI Polygon

2065 Benefit Area

NWI Polygon

2085 Benefit Area

ER Measure

Breakwater

Island Restoration

Oyster Reef Scaling

Wetland / Marsh Restoration

US Army Corps of Engineers ®
Galveston District

Coastal Texas Protection and Restoration Feasibility Study

Ecosystem Restoration Passive Benefits

DATUM: NAD 1983
PROJECTION: STATE PLANE
ZONE: TX-SC 4204

Basemap: 2018 NAIP

0 0.5 1 Miles

Date: 30 March 2021

Page: 1

ER Measure B12 Bastrop Bay, West Bay, and GIWW Shoreline Protection

Shoreline (2018)

NWI Polygon

2035 Interstitial Benefit Area

NWI Polygon

2035 Benefit Area

NWI Polygon

2065 Benefit Area

NWI Polygon

2085 Benefit Area

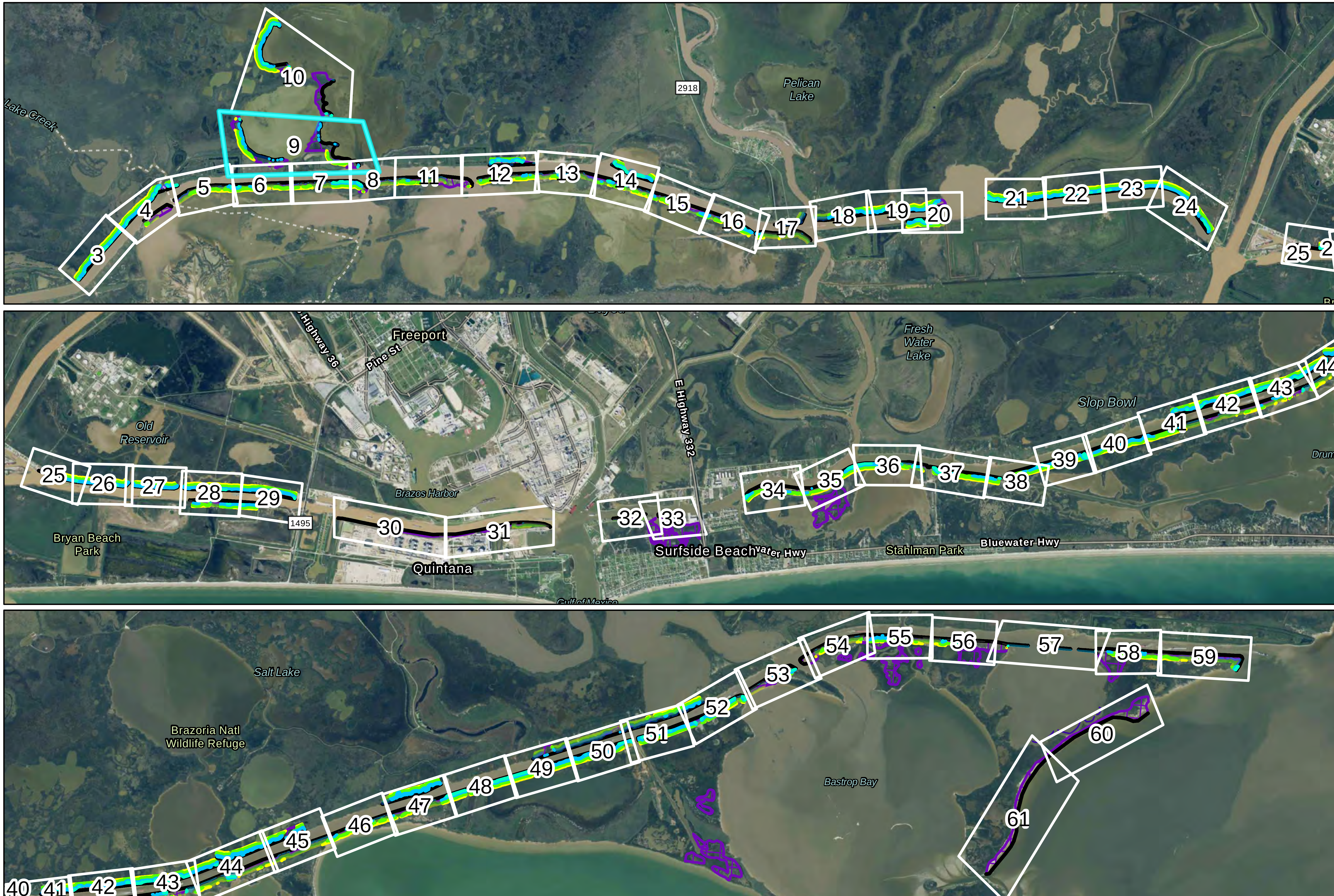
ER Measure

Breakwater

Island Restoration

Oyster Reef Scaling

Wetland / Marsh Restoration



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Coastal Texas Protection and Restoration Feasibility Study

Ecosystem Restoration Passive Benefits

DATUM: NAD 1983
PROJECTION: STATE PLANE
ZONE: TX-SC 4204

Basemap: 2018 NAIP

0 0.5 1 Miles

Date: 30 March 2021

Page: 2

ER Measure B12 Bastrop Bay, West Bay, and GIWW Shoreline Protection

Shoreline (2018)

NWI Polygon

2035 Interstitial Benefit Area

NWI Polygon

2035 Benefit Area

NWI Polygon

2065 Benefit Area

NWI Polygon

2085 Benefit Area

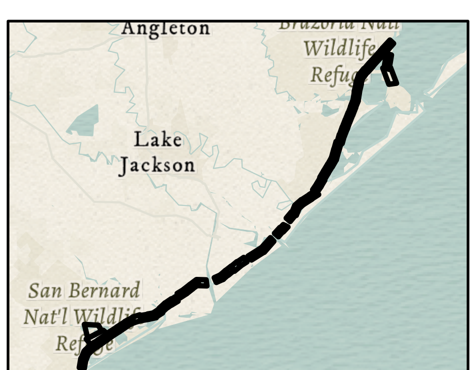
ER Measure

Breakwater

Island Restoration

Oyster Reef Scaling

Wetland / Marsh Restoration



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Coastal Texas Protection and Restoration Feasibility Study

Ecosystem Restoration Passive Benefits

DATUM: NAD 1983
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ZONE: TX-SC 4204

Basemap: 2018 NAIP

0 0.5 1 Miles

Date: 30 March 2021

ER Measure B12 Bastrop Bay, West Bay, and GIWW Shoreline Protection

- - - Shoreline (2018)

NWI Polygon

2035 Interstitial Benefit Area

NWI Polygon

2035 Benefit Area

NWI Polygon

2065 Benefit Area

NWI Polygon

2085 Benefit Area

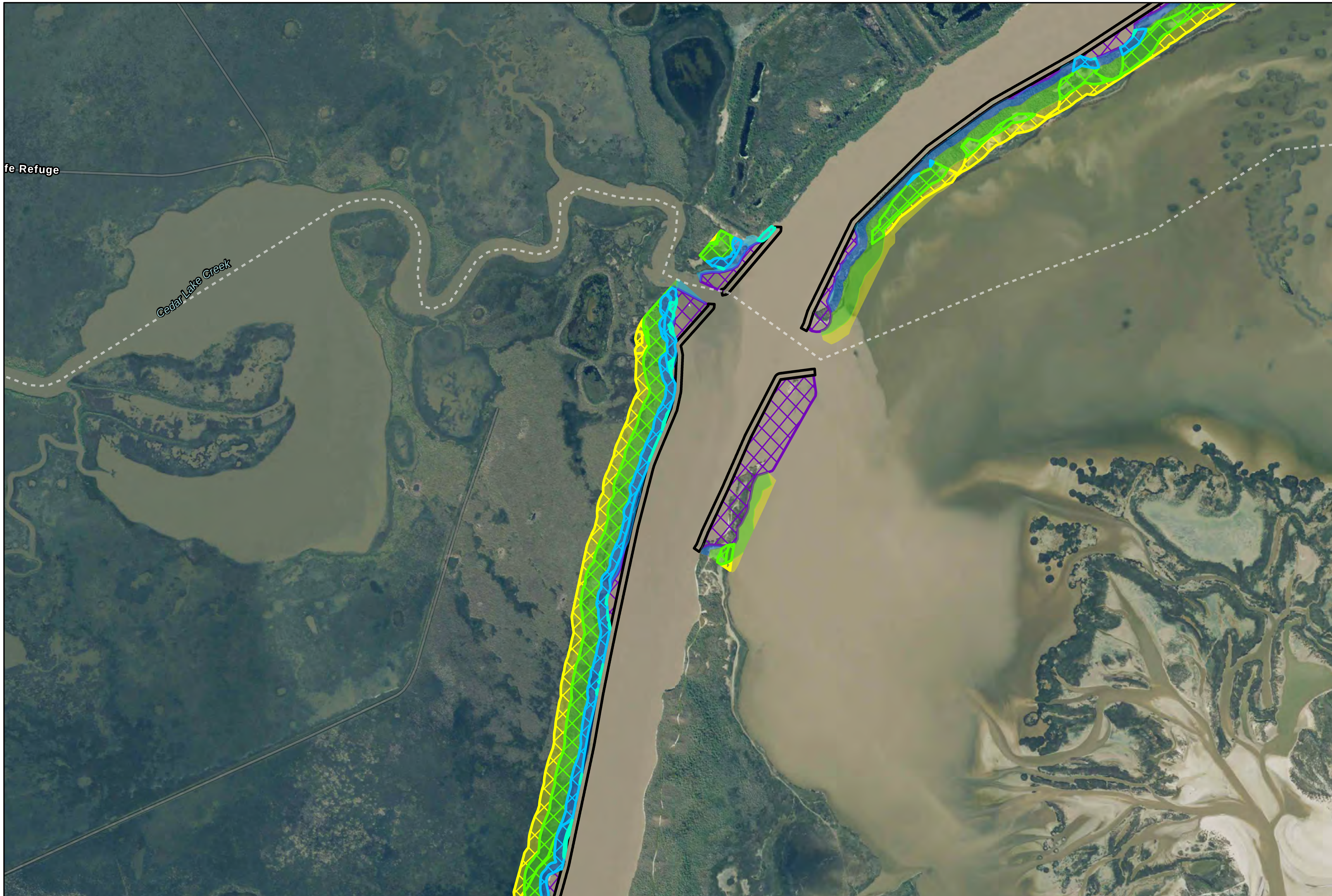
ER Measure

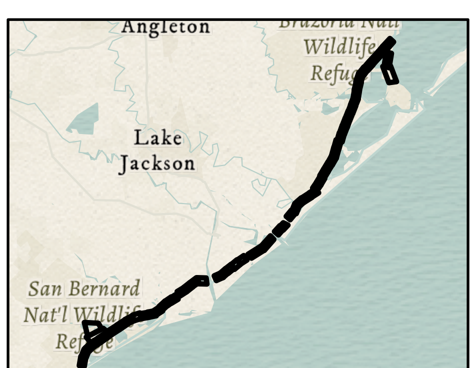
Breakwater

Island Restoration

Oyster Reef Scaling

Wetland / Marsh Restoration





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Coastal Texas Protection and Restoration Feasibility Study

Ecosystem Restoration Passive Benefits

DATUM: NAD 1983
PROJECTION: STATE PLANE
ZONE: TX-SC 4204

Basemap: 2018 NAIP

0 0.5 1 Miles

Date: 30 March 2021

ER Measure B12 Bastrop Bay, West Bay, and GIWW Shoreline Protection

Shoreline (2018)

NWI Polygon

2035 Interstitial Benefit Area

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2035 Benefit Area

NWI Polygon

2065 Benefit Area

NWI Polygon

2085 Benefit Area

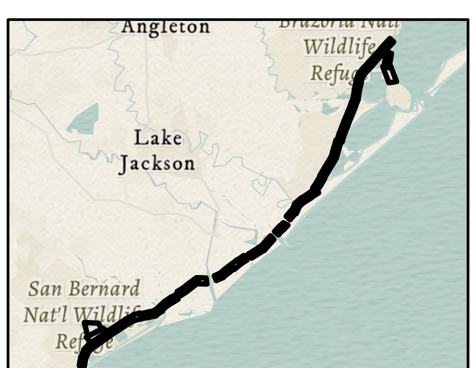
ER Measure

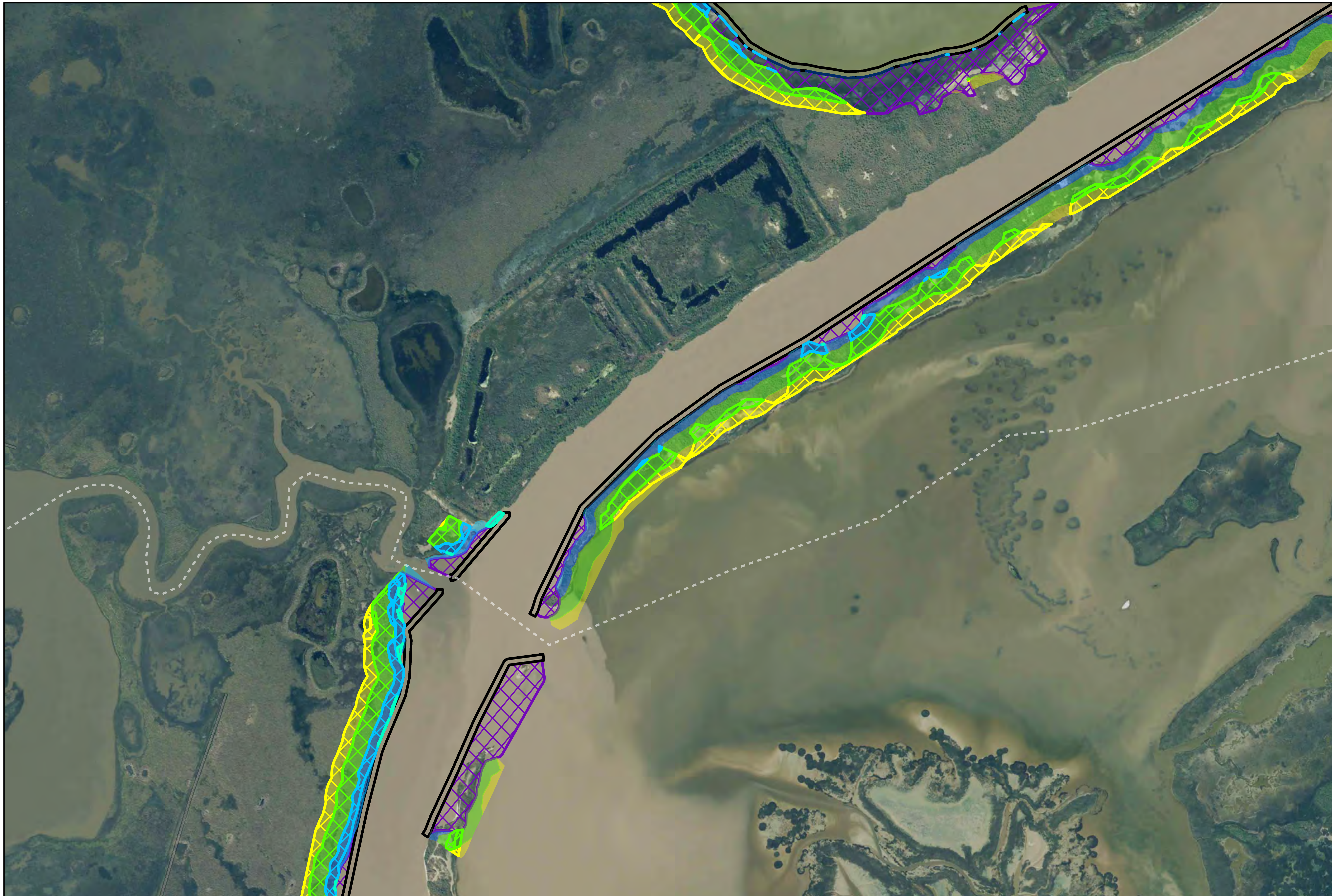
Breakwater

Island Restoration

Oyster Reef Scaling

Wetland / Marsh Restoration





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Galveston District

Coastal Texas Protection and Restoration Feasibility Study

Ecosystem Restoration Passive Benefits

DATUM: NAD 1983
PROJECTION: STATE PLANE
ZONE: TX-SC 4204

Basemap: 2018 NAIP

0 0.5 1 Miles

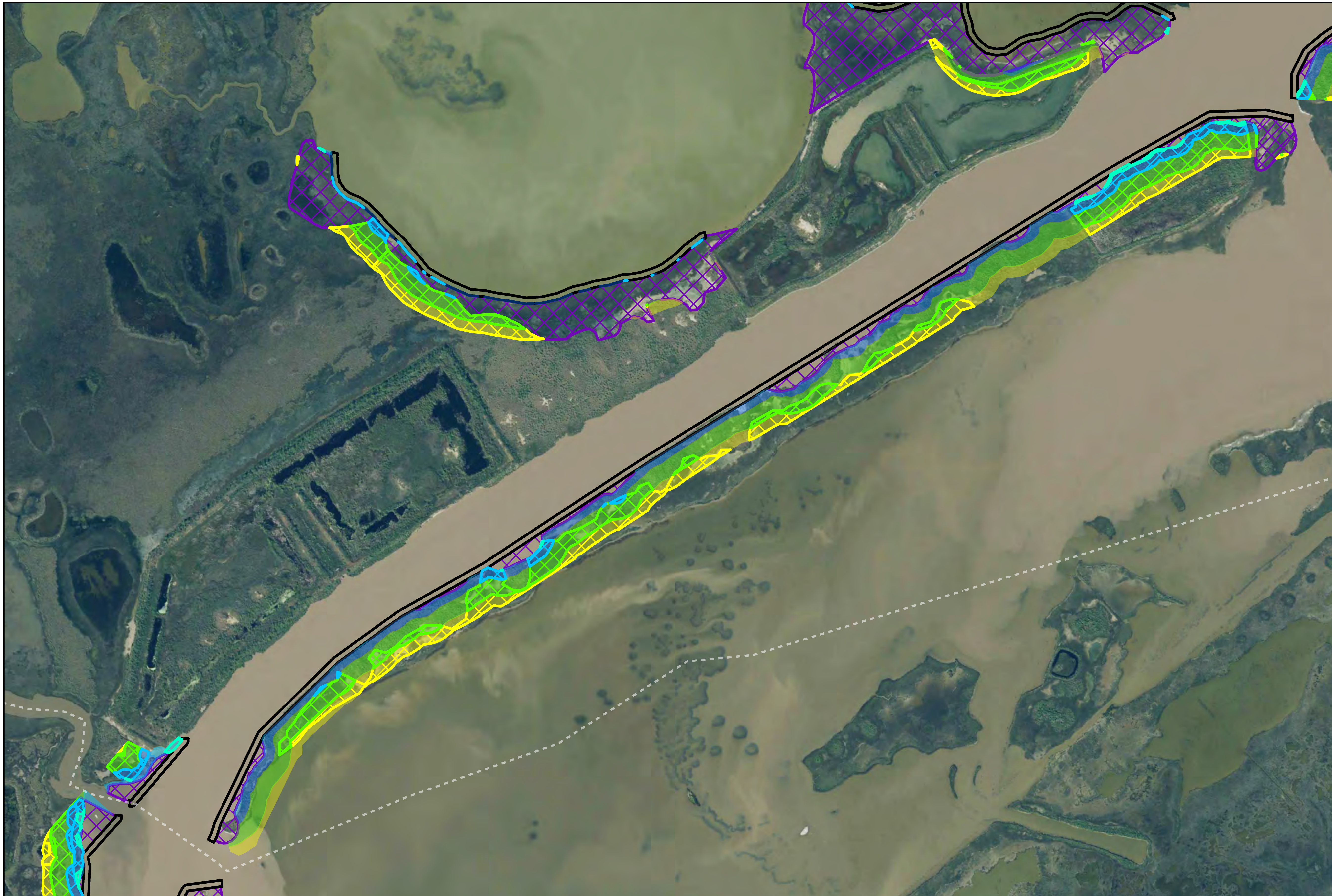
Date: 30 March 2021

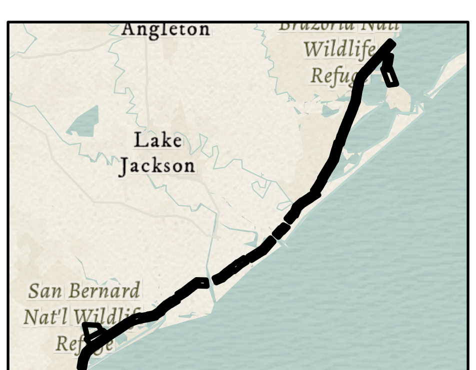
ER Measure B12 Bastrop Bay, West Bay, and GIWW Shoreline Protection

- Shoreline (2018)
- NWI Polygon
- 2035 Interstitial Benefit Area
- NWI Polygon
- 2035 Benefit Area
- NWI Polygon
- 2065 Benefit Area
- NWI Polygon
- 2085 Benefit Area

ER Measure

- Breakwater
- Island Restoration
- Oyster Reef Scaling
- Wetland / Marsh Restoration





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Coastal Texas Protection and Restoration Feasibility Study

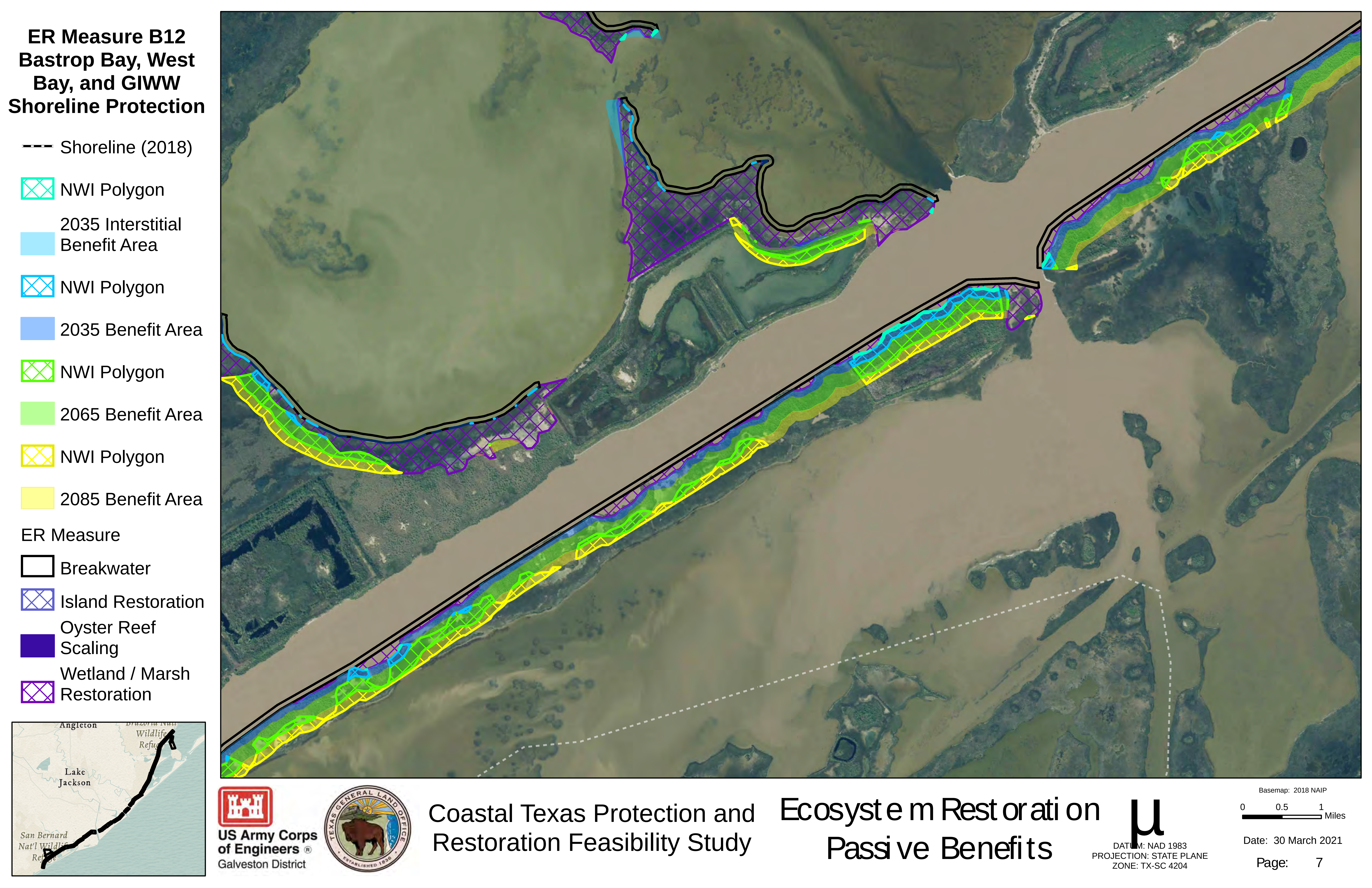
Ecosystem Restoration Passive Benefits

DATUM: NAD 1983
PROJECTION: STATE PLANE
ZONE: TX-SC 4204

Basemap: 2018 NAIP

0 0.5 1 Miles

Date: 30 March 2021



ER Measure B12
Bastrop Bay, West Bay, and GIWW Shoreline Protection
Shoreline (2018)
NWI Polygon
2035 Interstitial Benefit Area
NWI Polygon
2035 Benefit Area
NWI Polygon
2065 Benefit Area
NWI Polygon
2085 Benefit Area
ER Measure
Breakwater
Island Restoration
Oyster Reef Scaling
Wetland / Marsh Restoration
Angleton
Lake Jackson
San Bernard Nat'l Wildlife Refuge
US Army Corps of Engineers
Galveston District
Coastal Texas Protection and Restoration Feasibility Study
Ecosystem Restoration Passive Benefits
DATUM: NAD 1983
PROJECTION: STATE PLANE
ZONE: TX-SC 4204
Basemap: 2018 NAIP
0
0.5
1
Miles
Date: 30 March 2021
Page: 7

ER Measure B12 Bastrop Bay, West Bay, and GIWW Shoreline Protection

Shoreline (2018)

NWI Polygon

2035 Interstitial Benefit Area

NWI Polygon

2035 Benefit Area

NWI Polygon

2065 Benefit Area

NWI Polygon

2085 Benefit Area

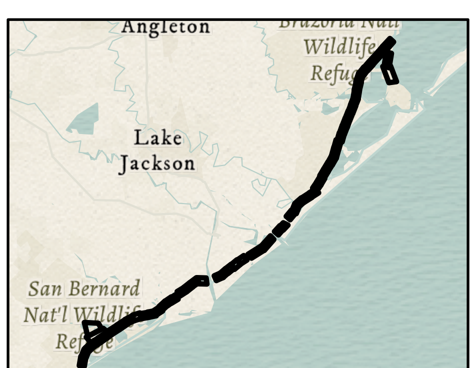
ER Measure

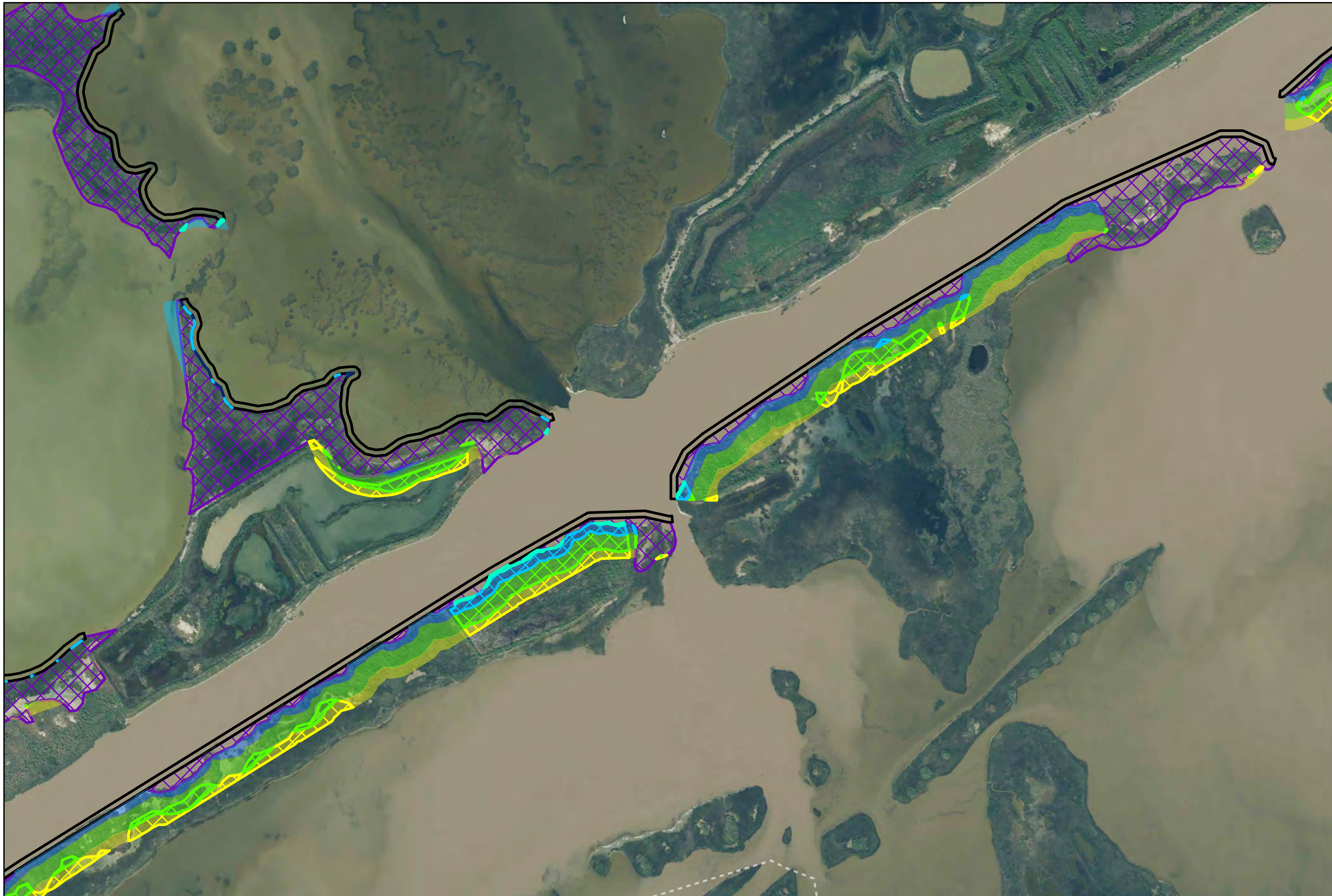
Breakwater

Island Restoration

Oyster Reef Scaling

Wetland / Marsh Restoration





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Coastal Texas Protection and Restoration Feasibility Study

Ecosystem Restoration Passive Benefits

DATUM: NAD 1983
PROJECTION: STATE PLANE
ZONE: TX-SC 4204

Basemap: 2018 NAIP

0 0.5 1 Miles

Date: 30 March 2021

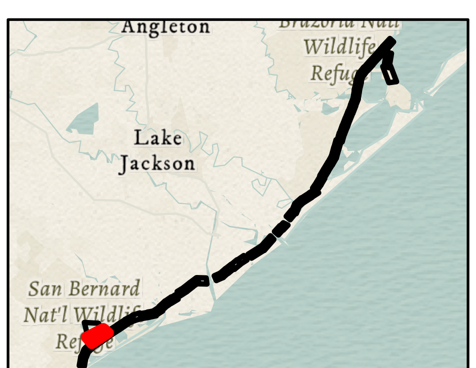
Page: 8

ER Measure B12 Bastrop Bay, West Bay, and GIWW Shoreline Protection

- Shoreline (2018)
- NWI Polygon
- 2035 Interstitial Benefit Area
- NWI Polygon
- 2035 Benefit Area
- NWI Polygon
- 2065 Benefit Area
- NWI Polygon
- 2085 Benefit Area

ER Measure

- Breakwater
- Island Restoration
- Oyster Reef Scaling
- Wetland / Marsh Restoration



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Galveston District

Coastal Texas Protection and Restoration Feasibility Study

Ecosystem Restoration Passive Benefits

DATUM: NAD 1983
PROJECTION: STATE PLANE
ZONE: TX-SC 4204

Basemap: 2018 NAIP

0 500 1,000 Feet

Date: 30 March 2021

ER Measure B12 Bastrop Bay, West Bay, and GIWW Shoreline Protection

Shoreline (2018)

NWI Polygon

2035 Interstitial Benefit Area

NWI Polygon

2035 Benefit Area

NWI Polygon

2065 Benefit Area

NWI Polygon

2085 Benefit Area

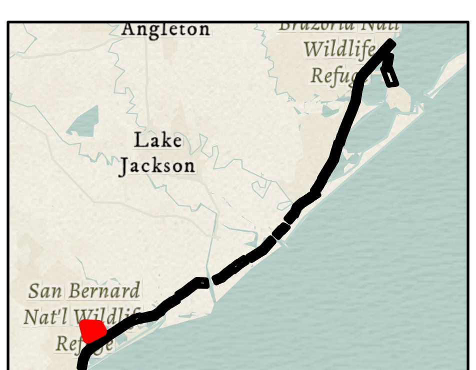
ER Measure

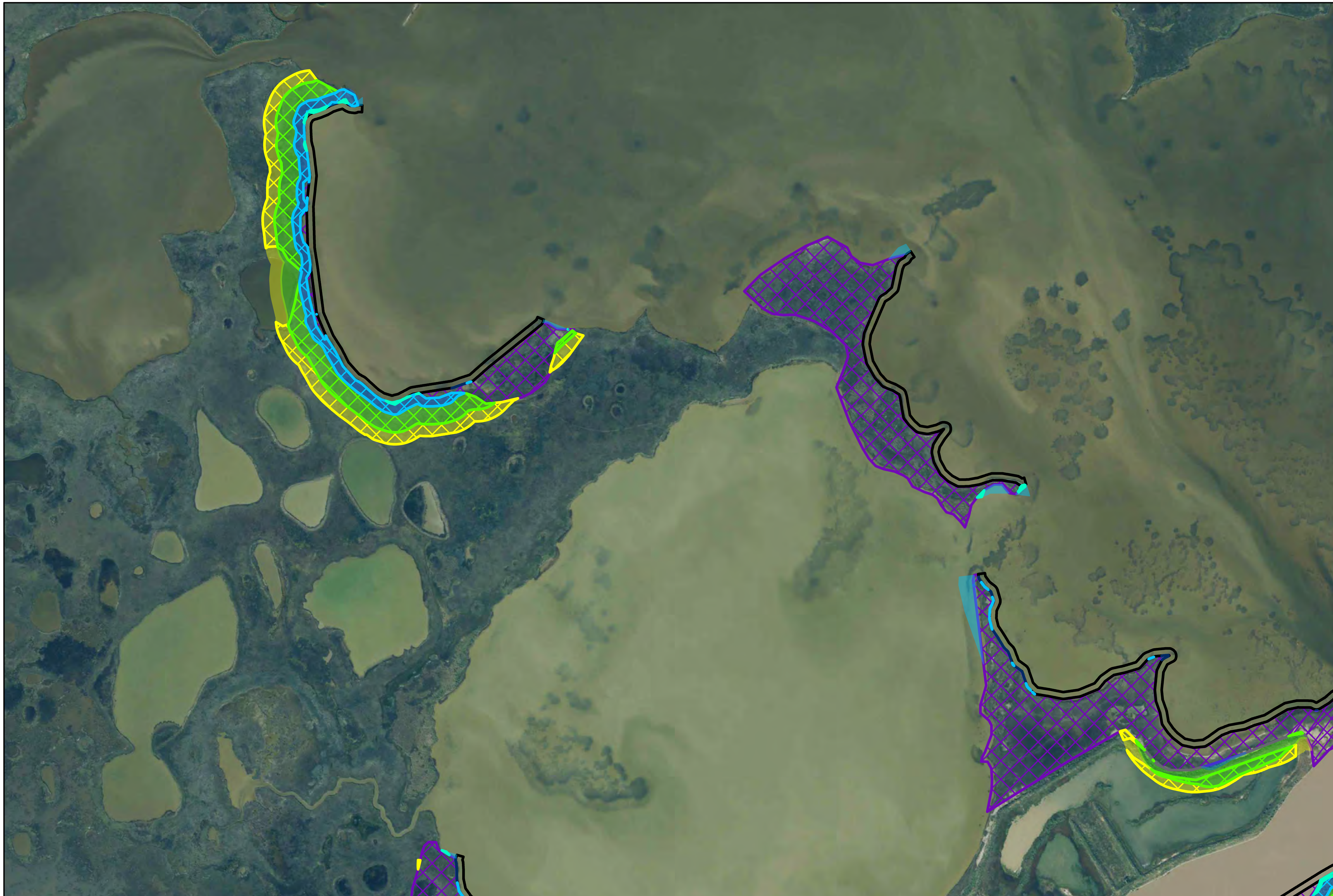
Breakwater

Island Restoration

Oyster Reef Scaling

Wetland / Marsh Restoration





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Coastal Texas Protection and Restoration Feasibility Study

Ecosystem Restoration Passive Benefits

DATUM: NAD 1983
PROJECTION: STATE PLANE
ZONE: TX-SC 4204

Basemap: 2018 NAIP

0 500 1,000 Feet

Date: 30 March 2021

ER Measure B12 Bastrop Bay, West Bay, and GIWW Shoreline Protection

Shoreline (2018)

NWI Polygon

2035 Interstitial Benefit Area

NWI Polygon

2035 Benefit Area

NWI Polygon

2065 Benefit Area

NWI Polygon

2085 Benefit Area

ER Measure

Breakwater

Island Restoration

Oyster Reef Scaling

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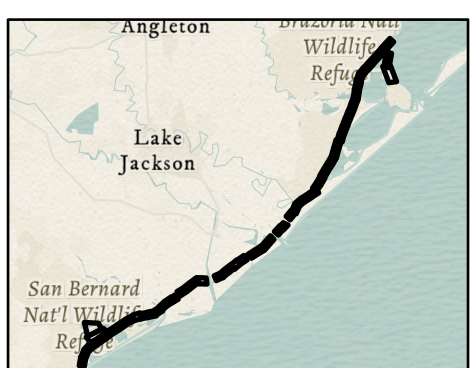

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Galveston District

Coastal Texas Protection and Restoration Feasibility Study

Ecosystem Restoration Passive Benefits

DATUM: NAD 1983
PROJECTION: STATE PLANE
ZONE: TX-SC 4204

Basemap: 2018 NAIP

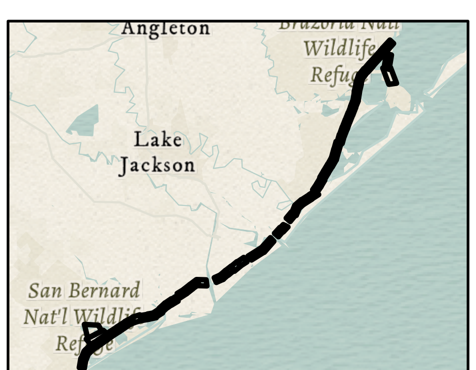
0 0.5 1 Miles

Date: 30 March 2021

ER Measure B12
Bastrop Bay, West Bay, and GIWW Shoreline Protection

Shoreline (2018)
NWI Polygon
2035 Interstitial Benefit Area
NWI Polygon
2035 Benefit Area
NWI Polygon
2065 Benefit Area
NWI Polygon
2085 Benefit Area

ER Measure
Breakwater
Island Restoration
Oyster Reef Scaling
Wetland / Marsh Restoration



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Galveston District

Coastal Texas Protection and Restoration Feasibility Study

Ecosystem Restoration Passive Benefits

DATUM: NAD 1983
PROJECTION: STATE PLANE
ZONE: TX-SC 4204

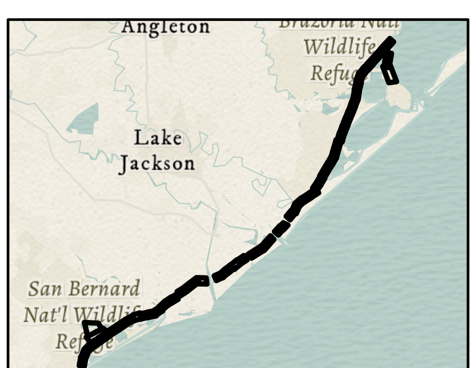
Basemap: 2018 NAIP
0 0.5 1 Miles

Date: 30 March 2021

ER Measure B12 Bastrop Bay, West Bay, and GIWW Shoreline Protection

- Shoreline (2018)
- NWI Polygon
- 2035 Interstitial Benefit Area
- NWI Polygon
- 2035 Benefit Area
- NWI Polygon
- 2065 Benefit Area
- NWI Polygon
- 2085 Benefit Area

ER Measure
- Breakwater
- Island Restoration
- Oyster Reef Scaling
- Wetland / Marsh Restoration



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Galveston District

TEXAS GENERAL LAND OFFICE
ESTABLISHED 1836

Coastal Texas Protection and Restoration Feasibility Study

Ecosystem Restoration Passive Benefits

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DATUM: NAD 1983
PROJECTION: STATE PLANE
ZONE: TX-SC 4204

Basemap: 2018 NAIP

0 0.5 1 Miles

Date: 30 March 2021

ER Measure B12 Bastrop Bay, West Bay, and GIWW Shoreline Protection

- - - Shoreline (2018)

NWI Polygon

2035 Interstitial Benefit Area

NWI Polygon

2035 Benefit Area

NWI Polygon

2065 Benefit Area

NWI Polygon

2085 Benefit Area

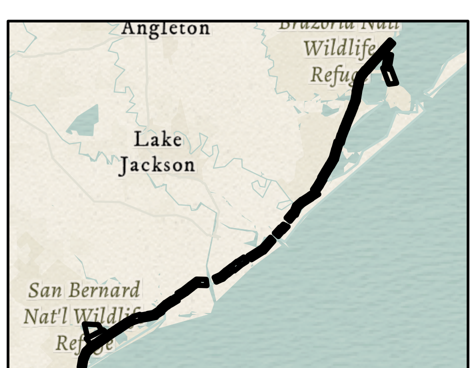
ER Measure

Breakwater

Island Restoration

Oyster Reef Scaling

Wetland / Marsh Restoration



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Coastal Texas Protection and Restoration Feasibility Study

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DATUM: NAD 1983
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ZONE: TX-SC 4204

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NWI Polygon

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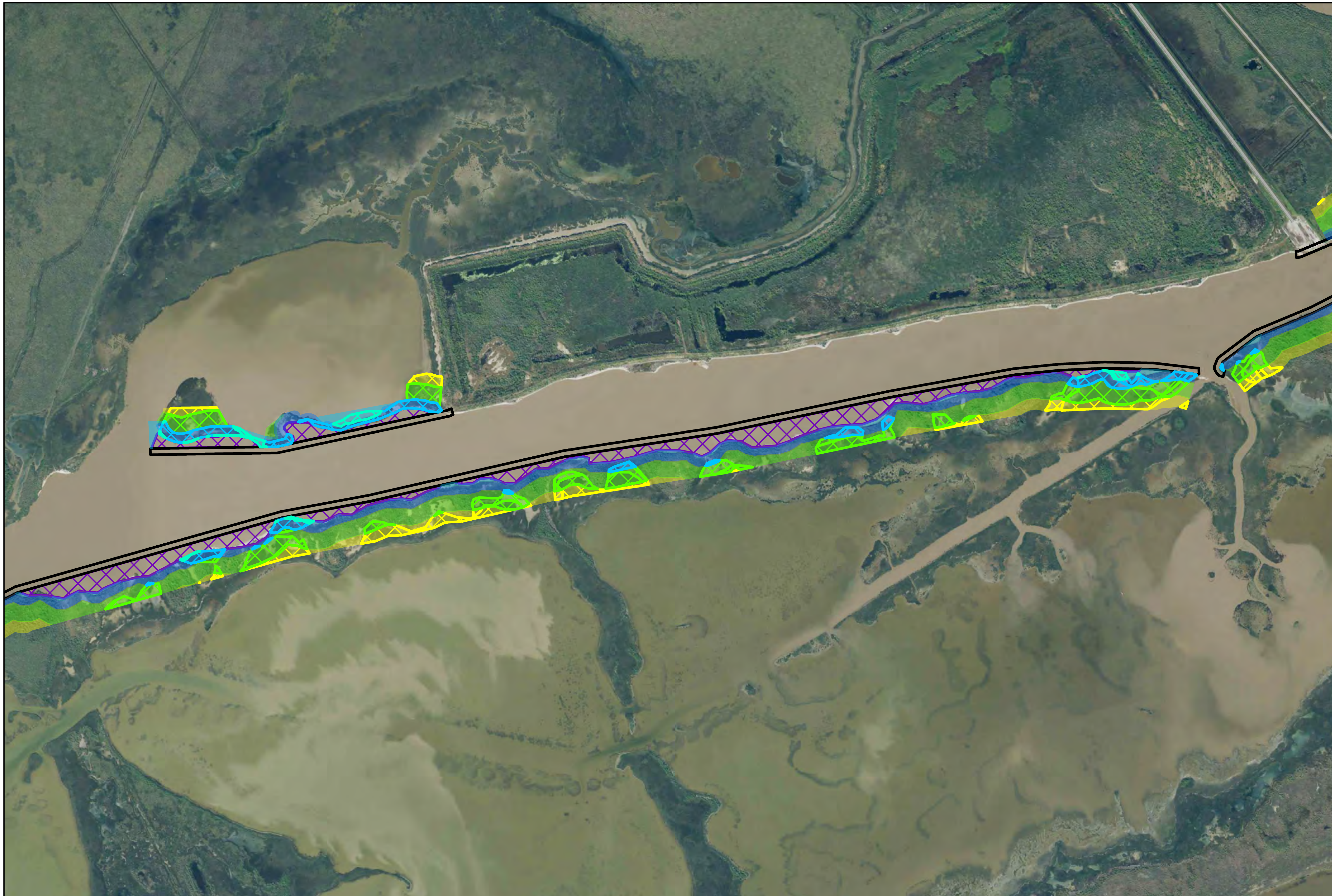

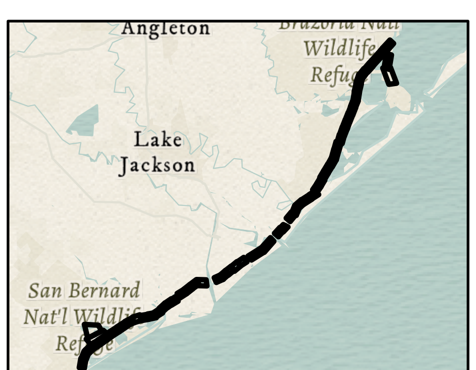

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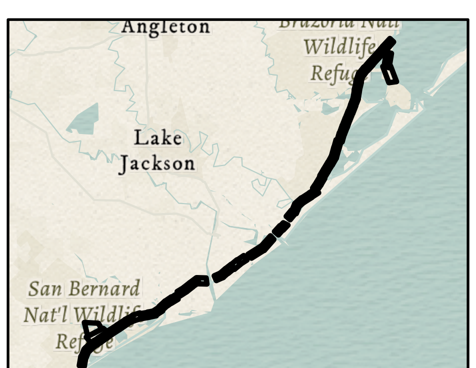

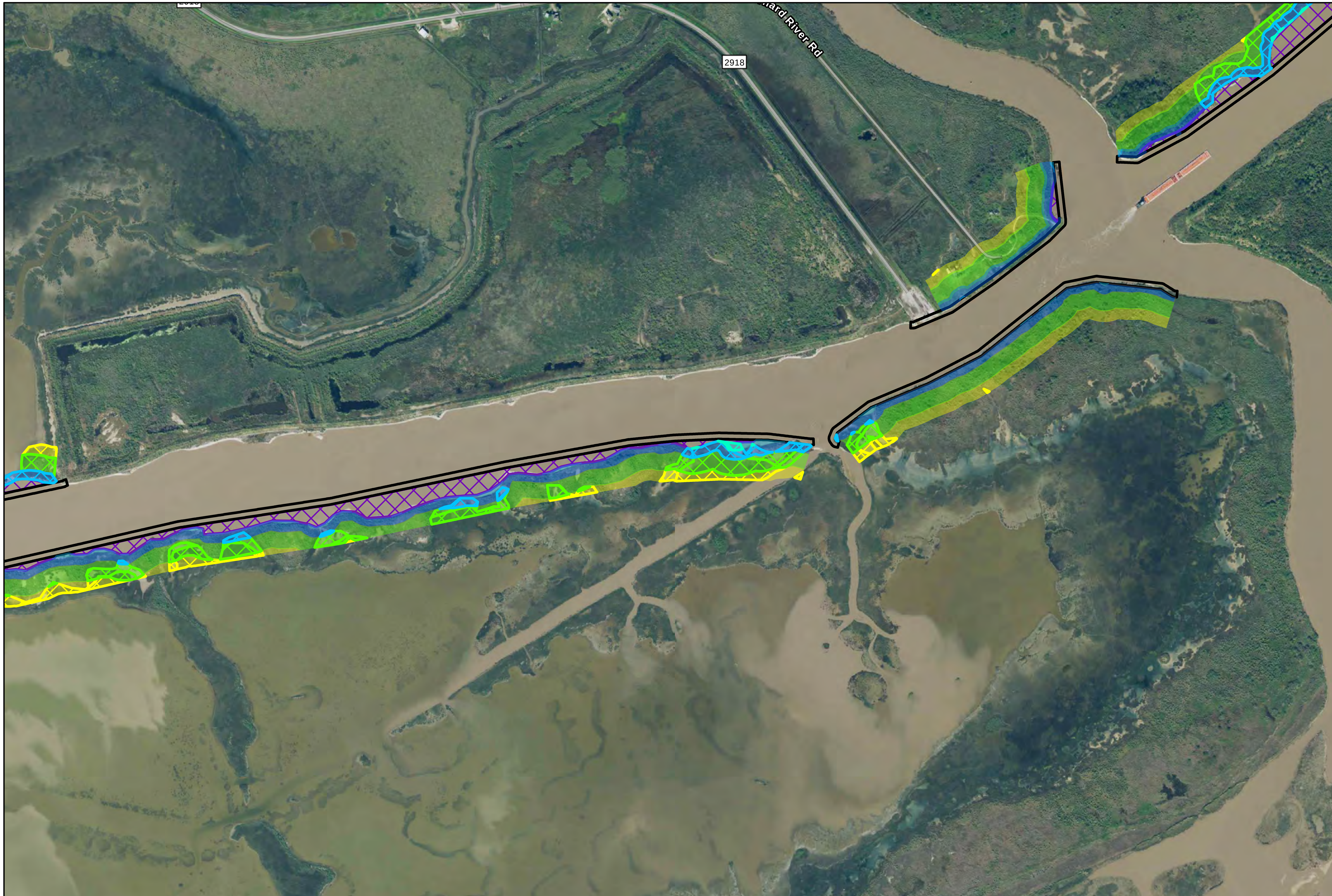

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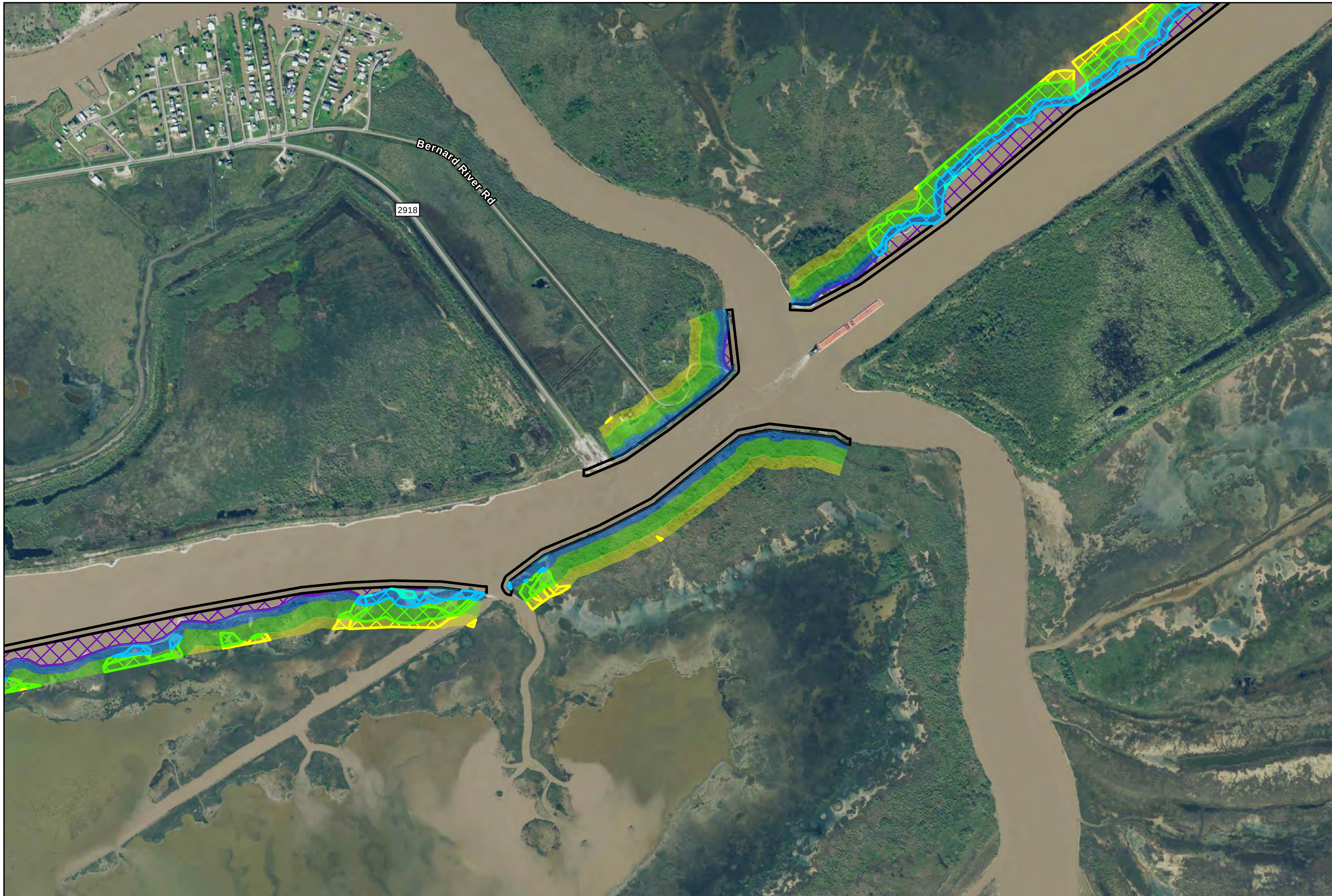

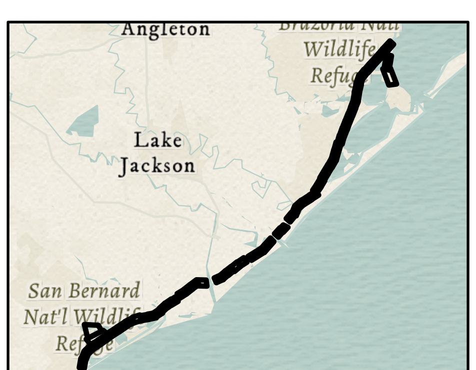

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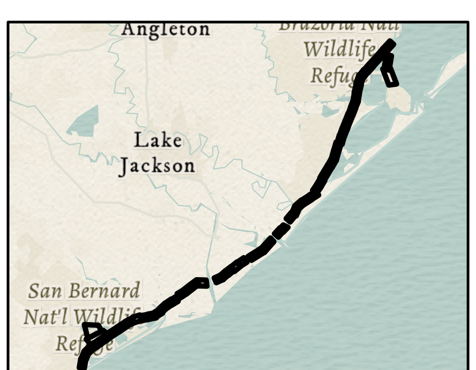

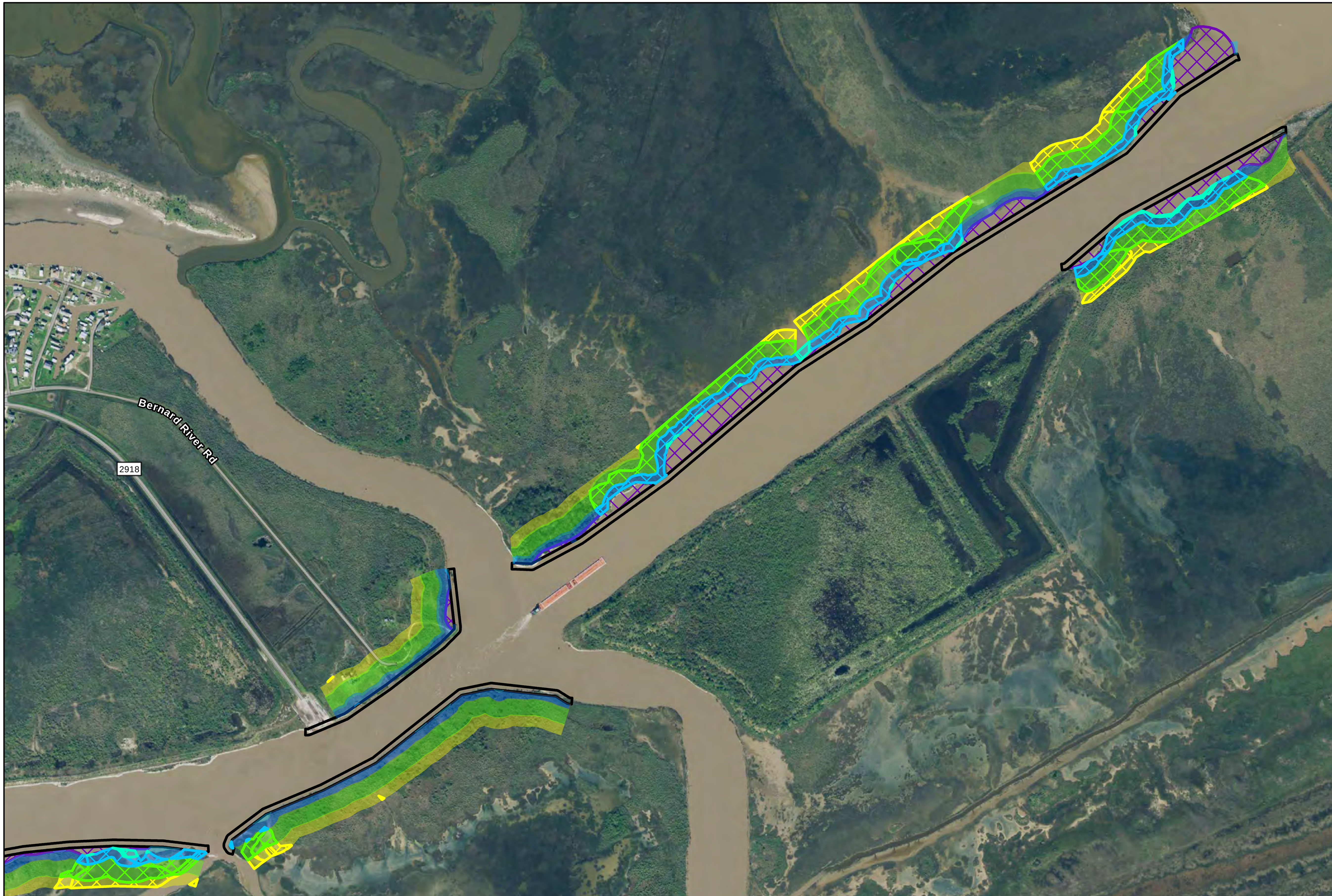

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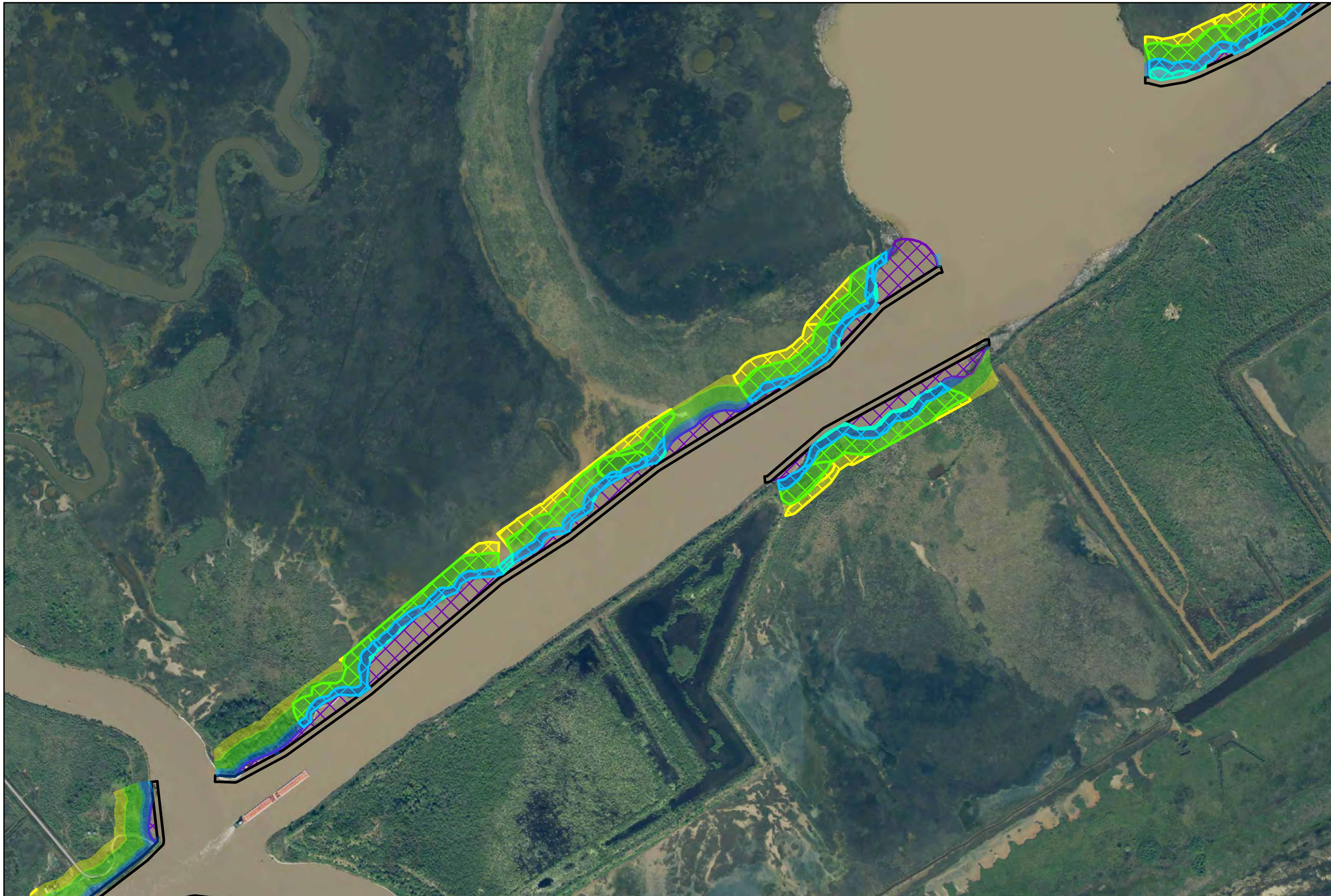

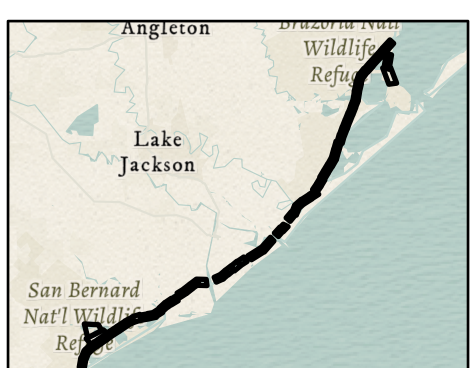

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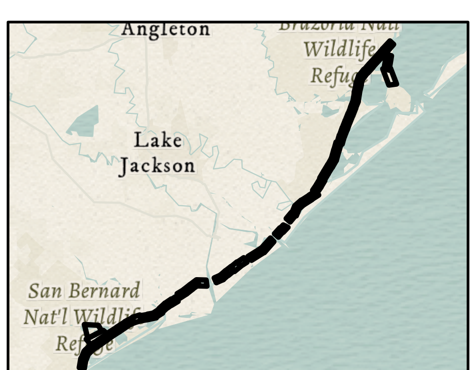

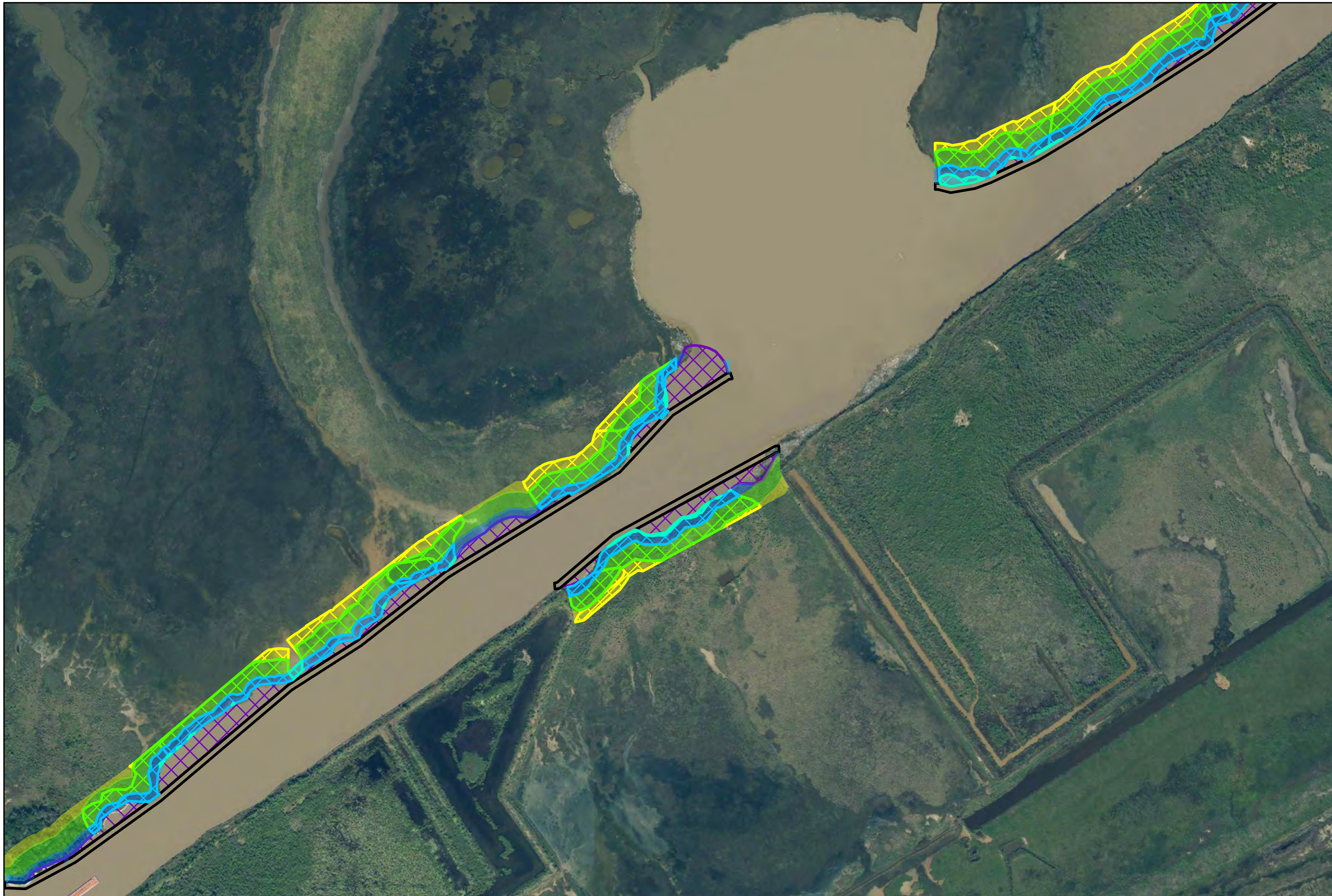

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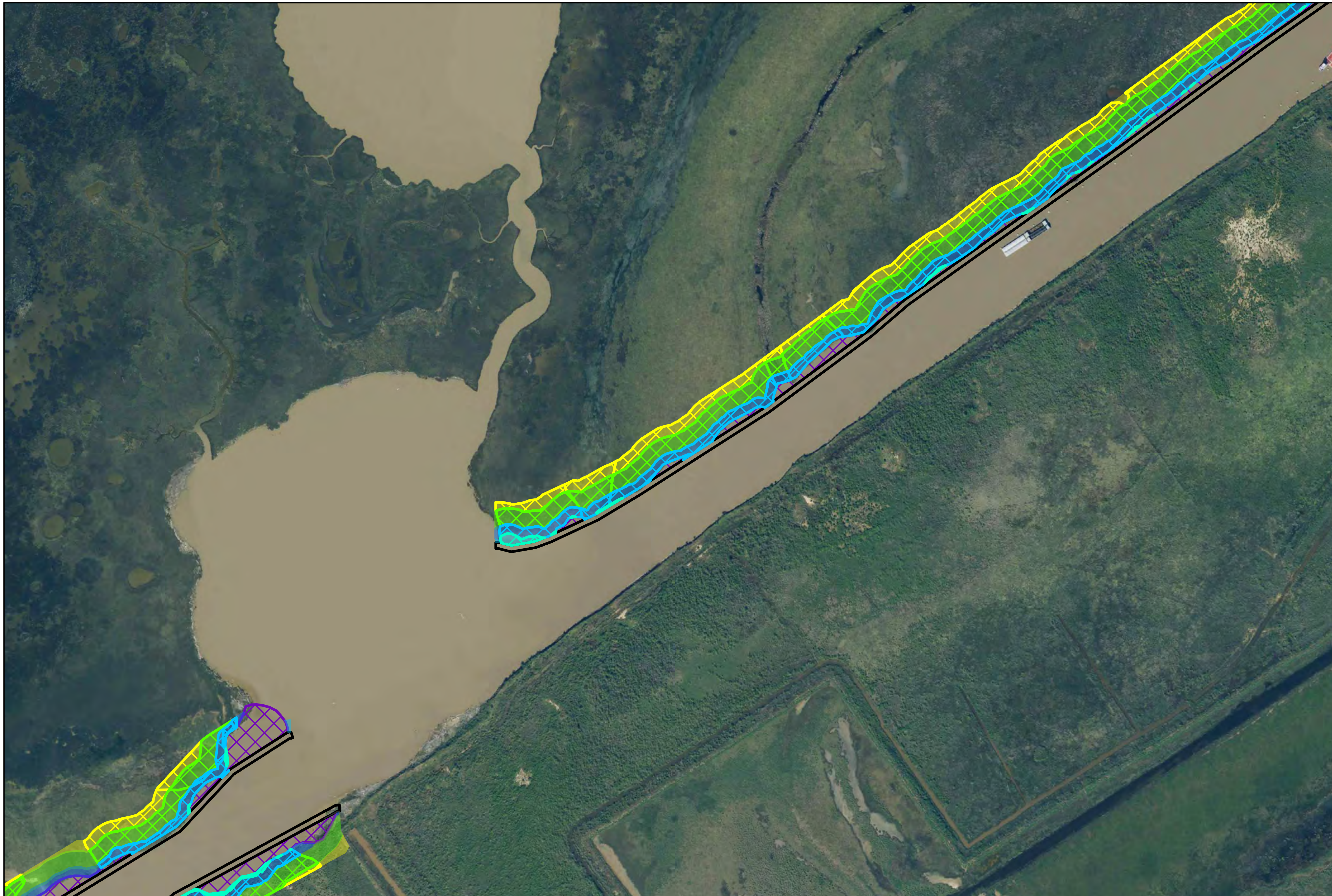

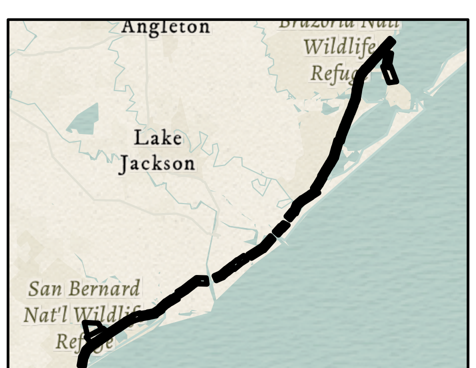

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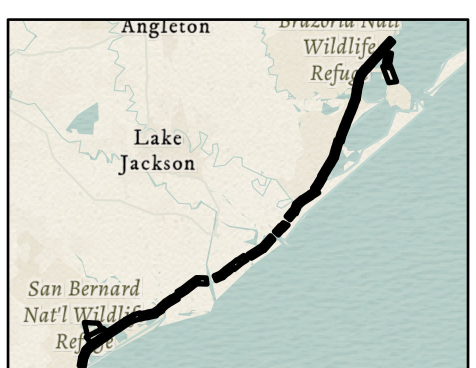

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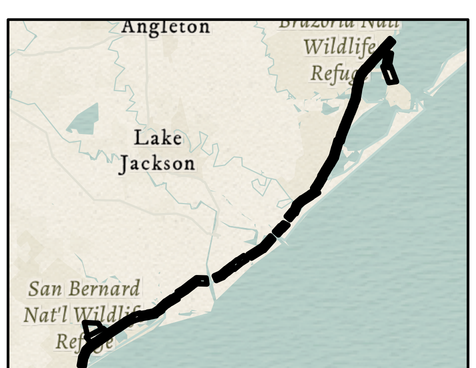

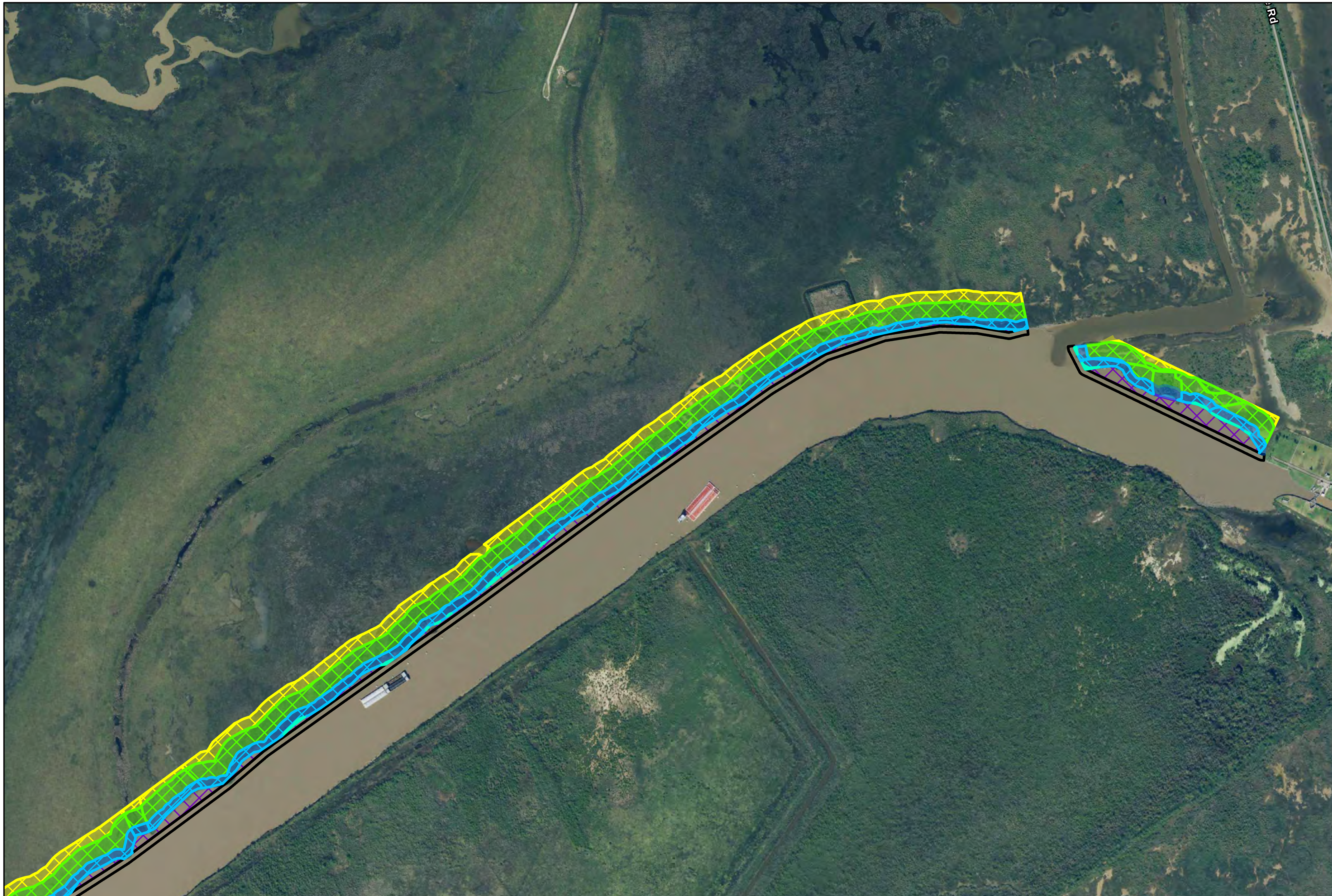

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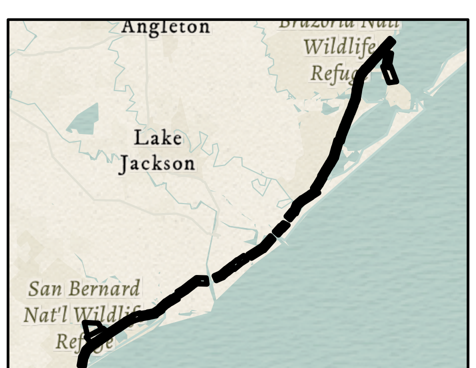

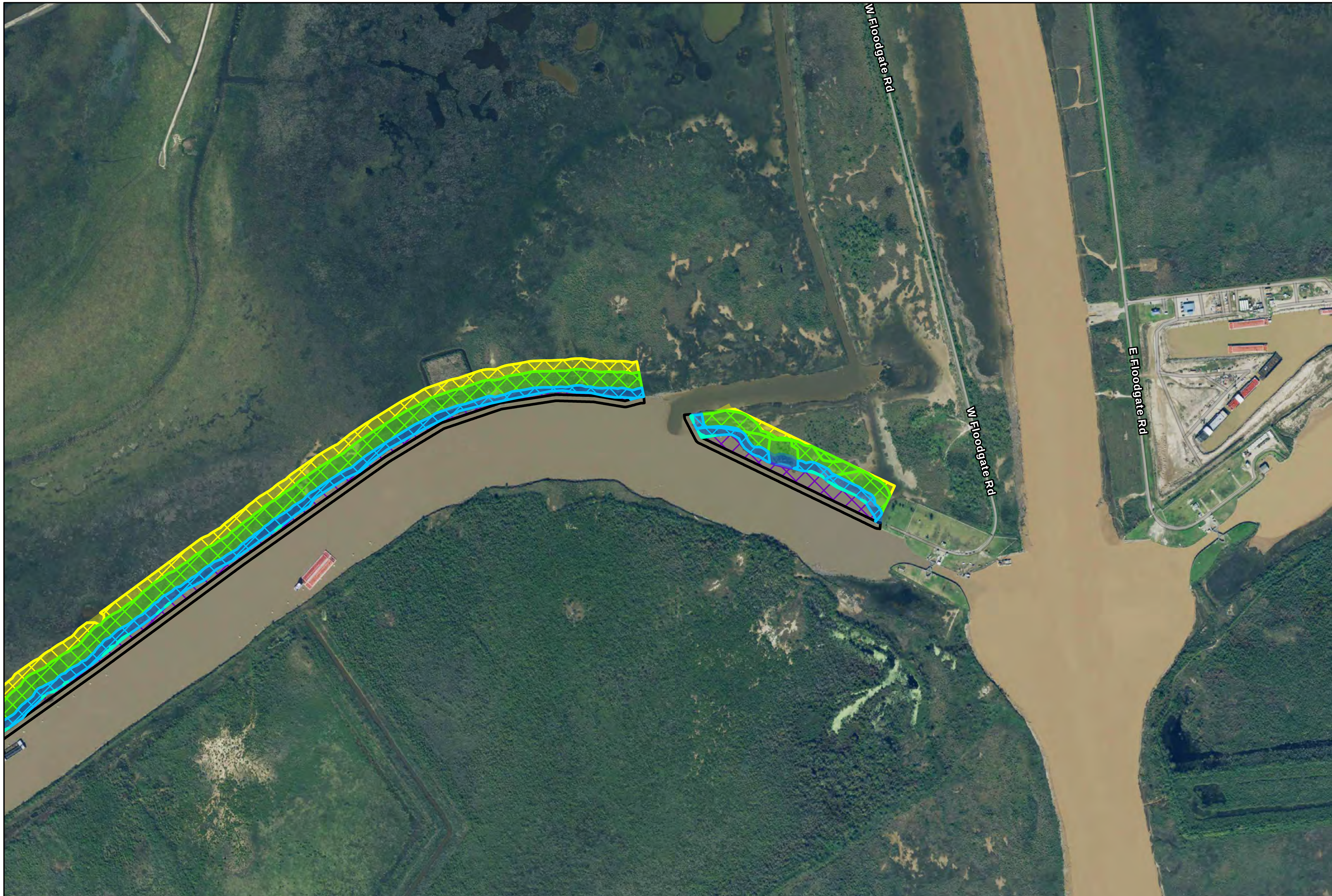

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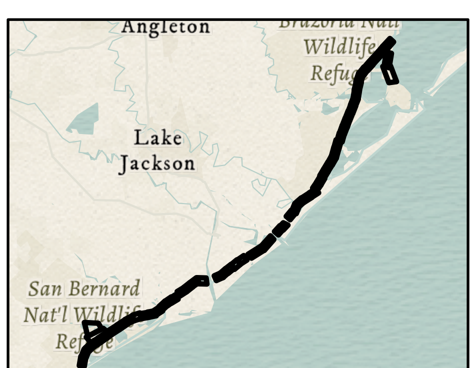

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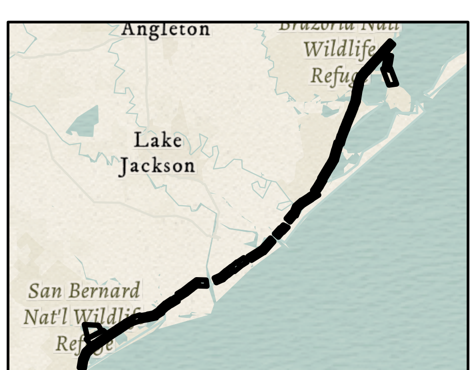

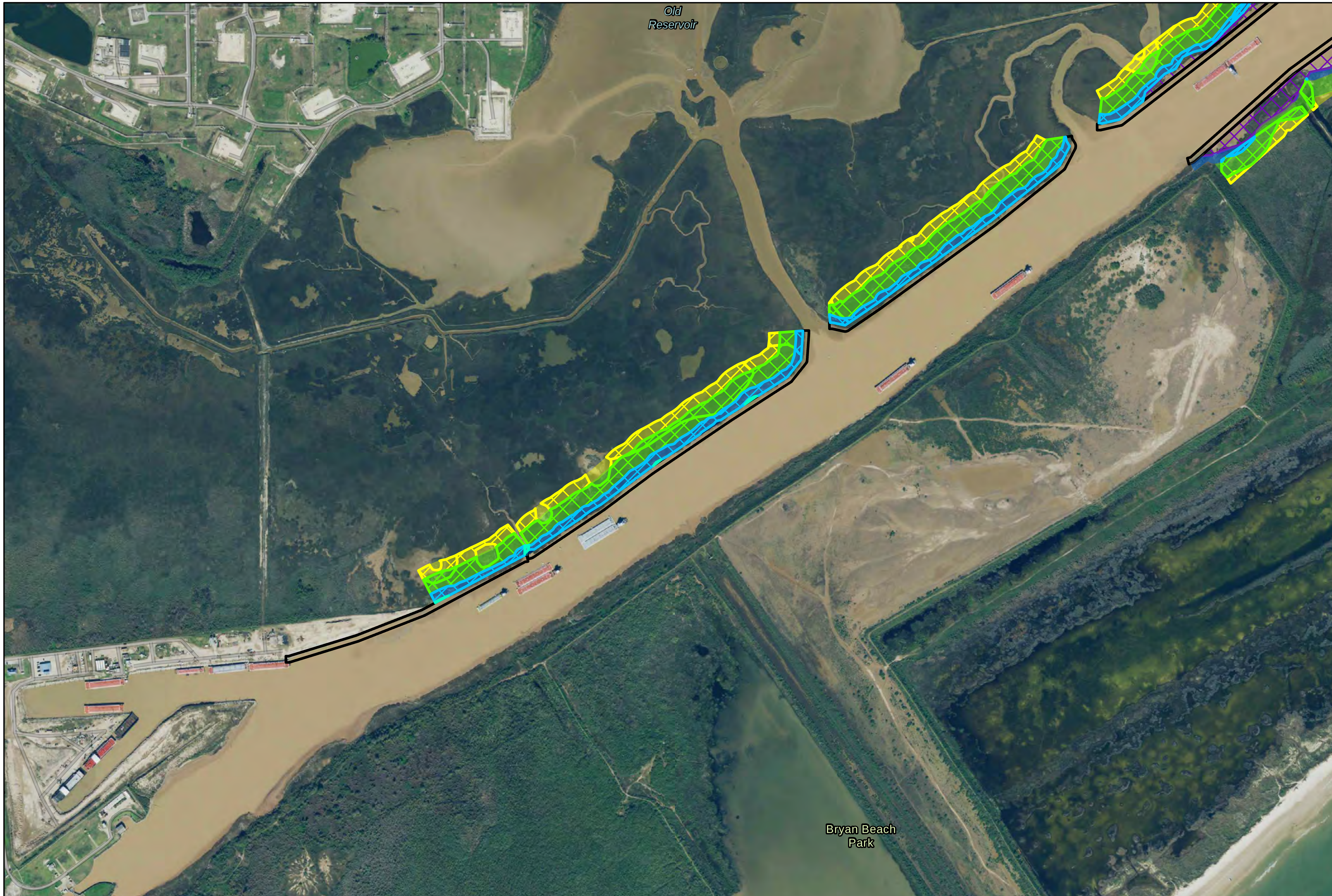

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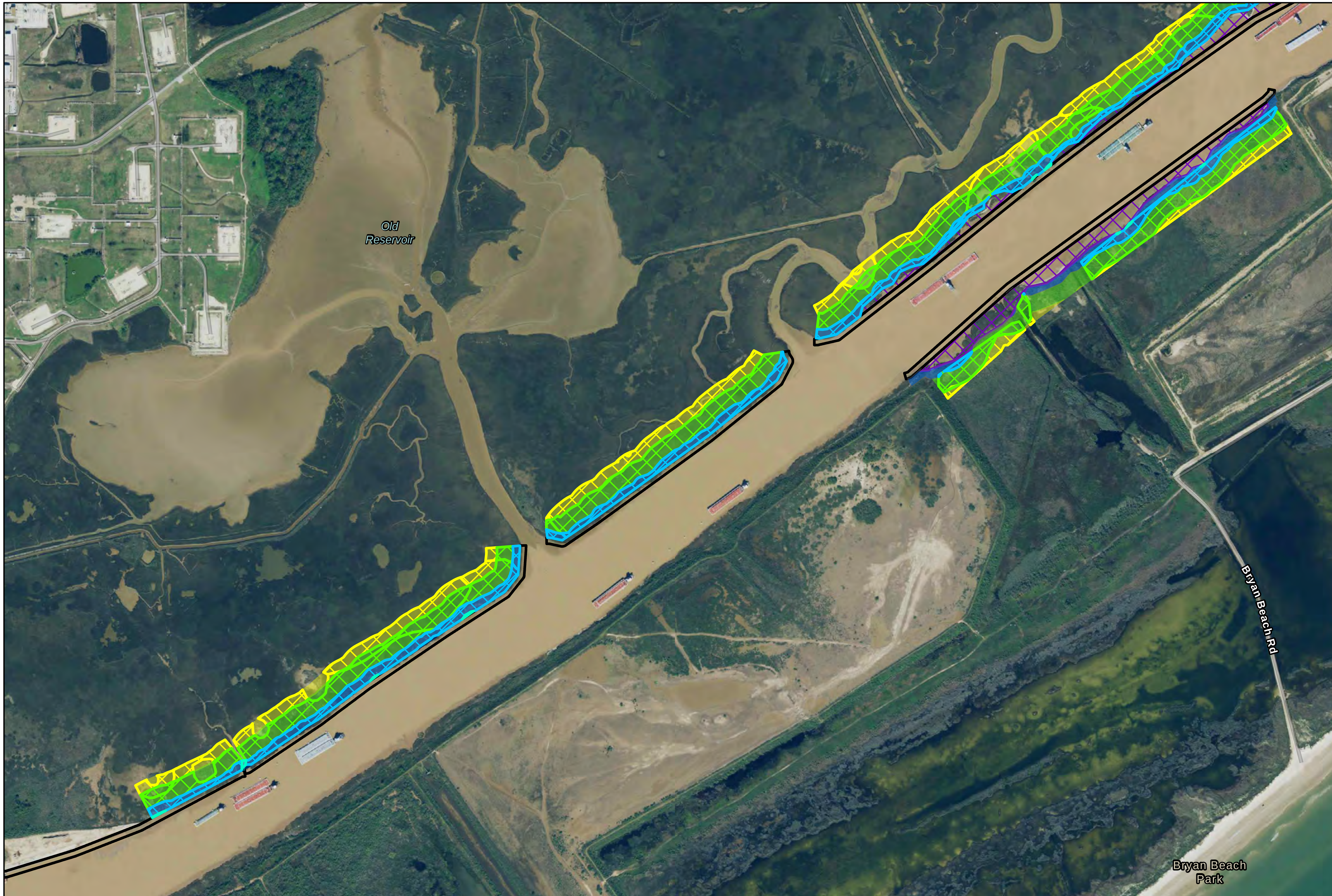

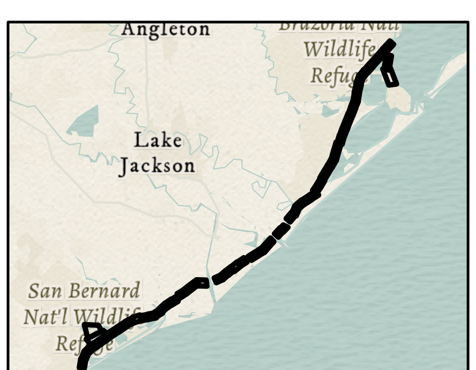

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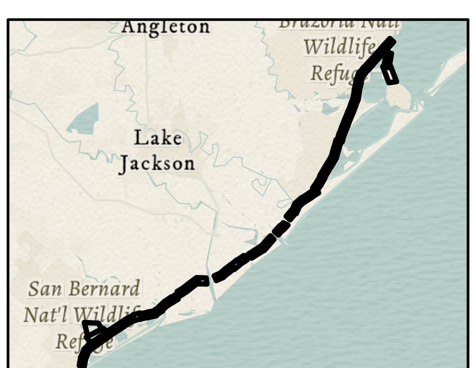

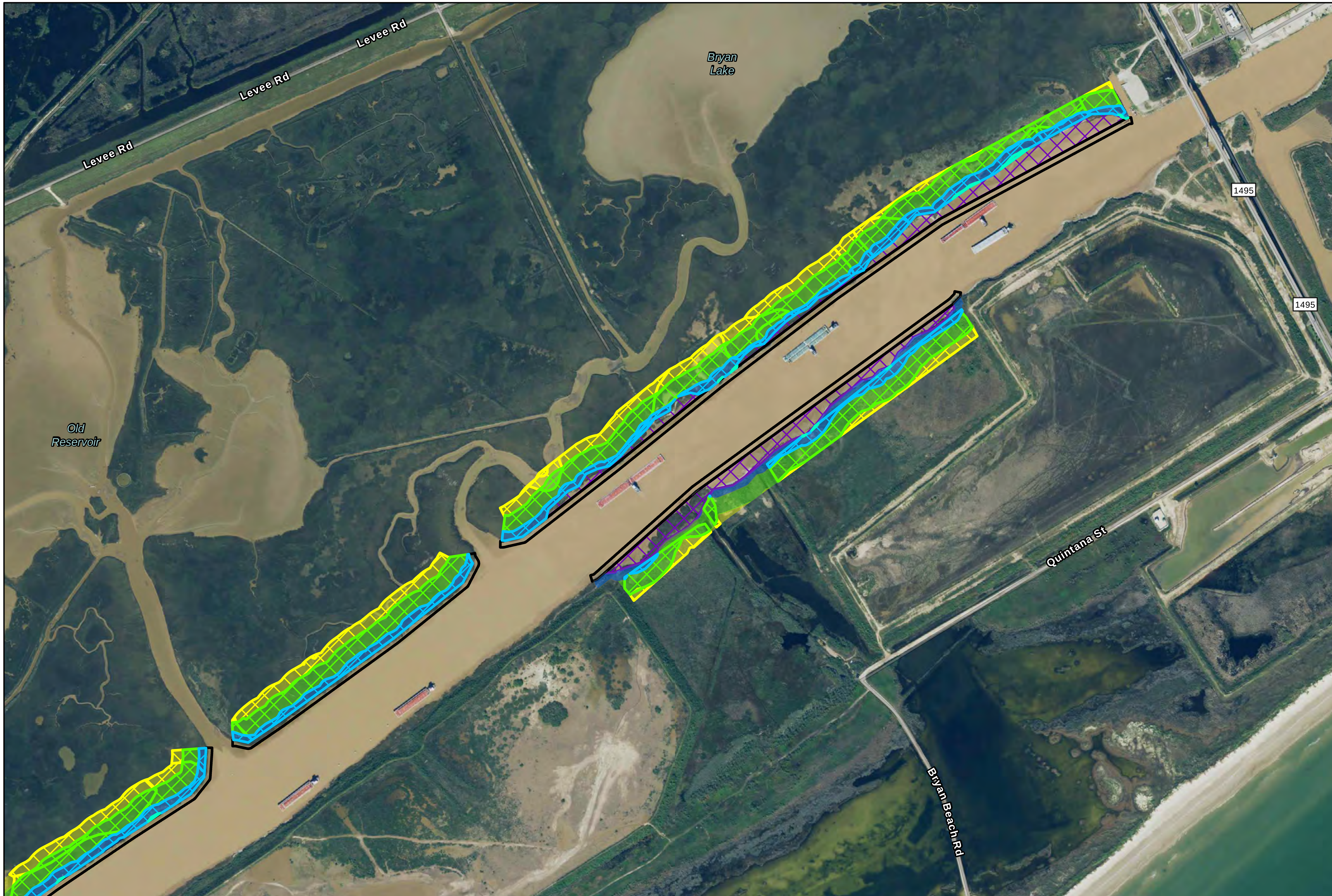

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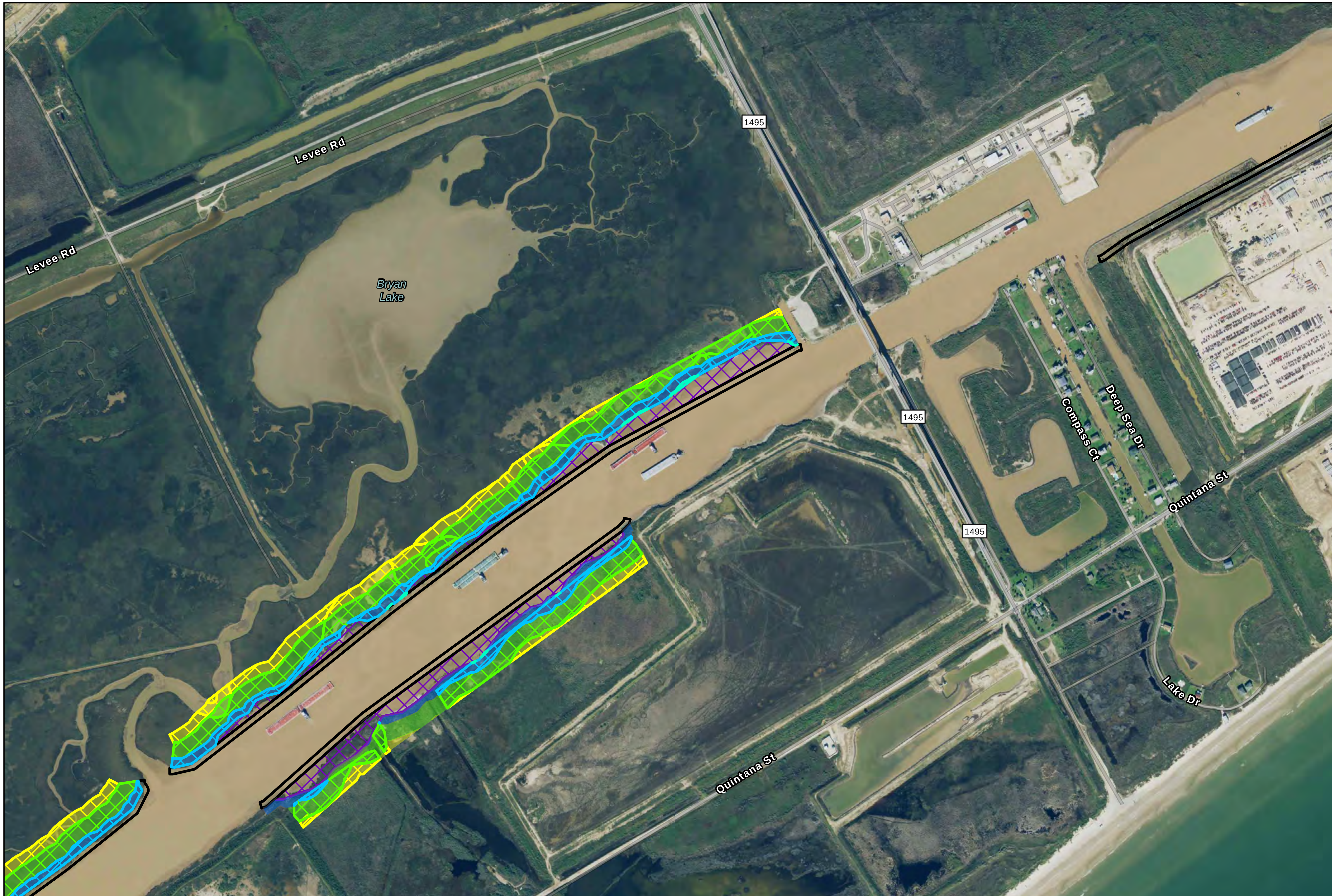

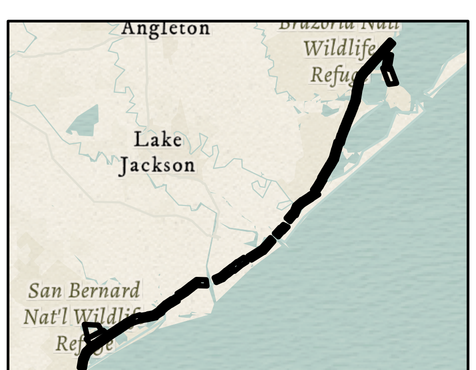

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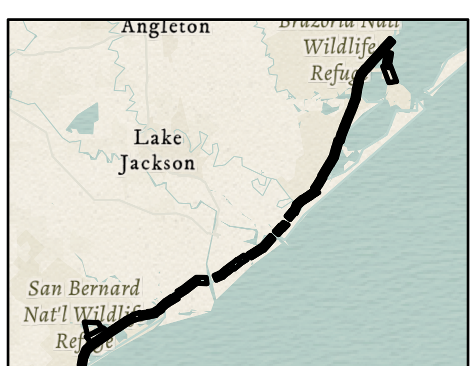

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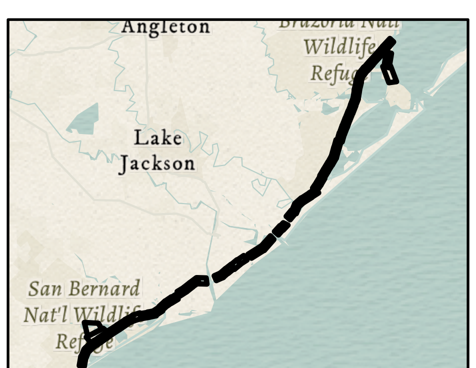

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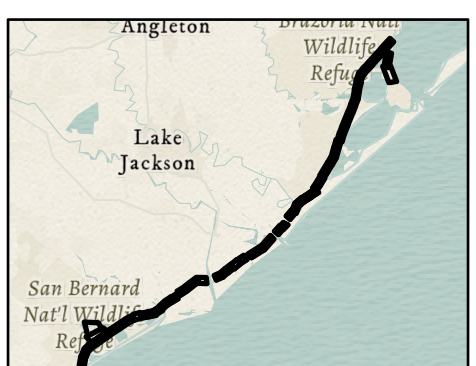

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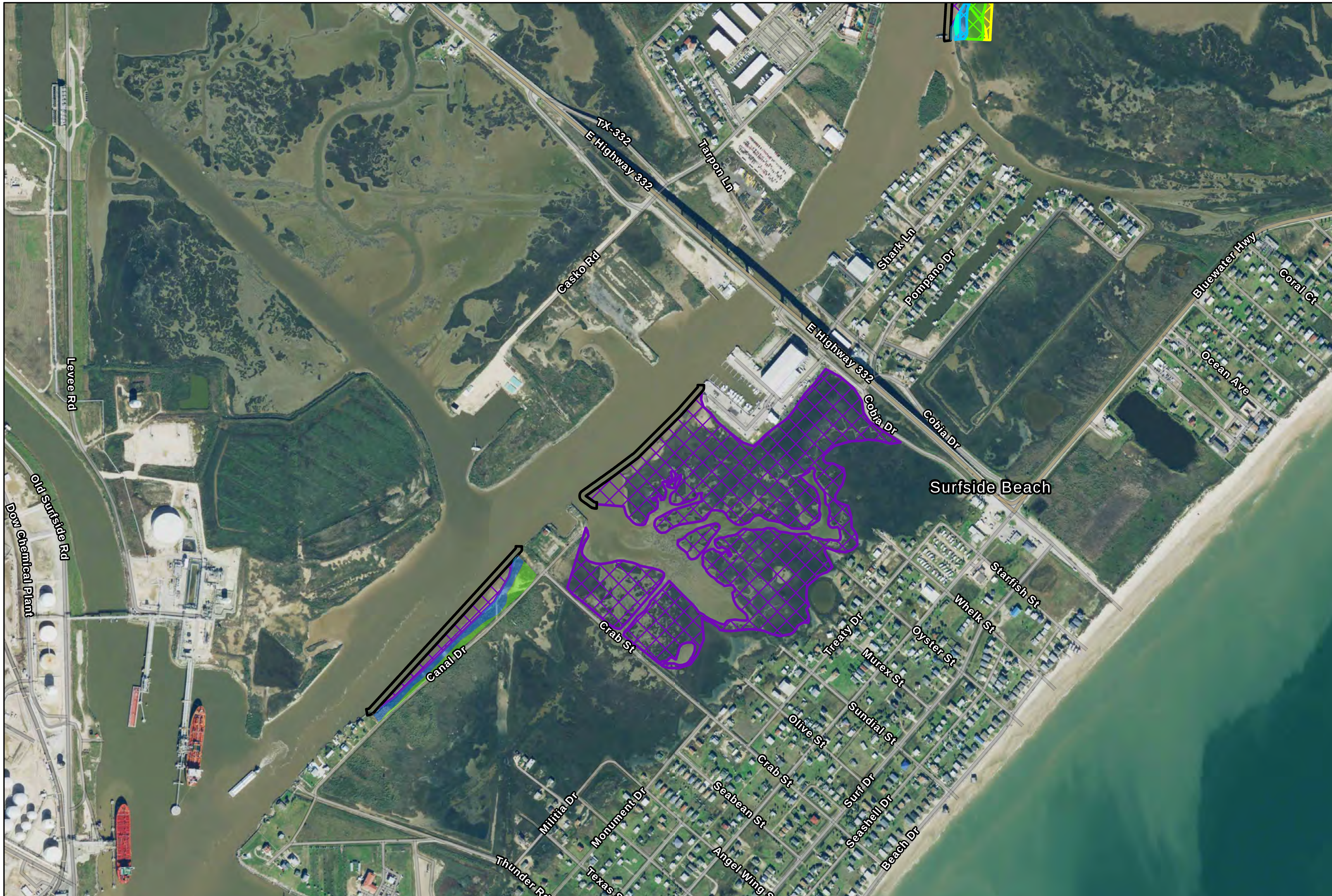

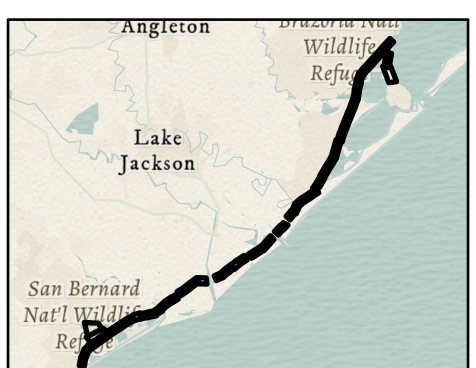

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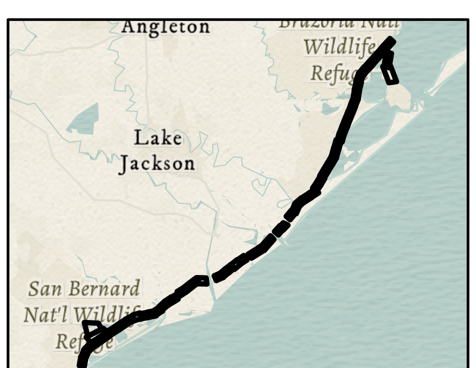

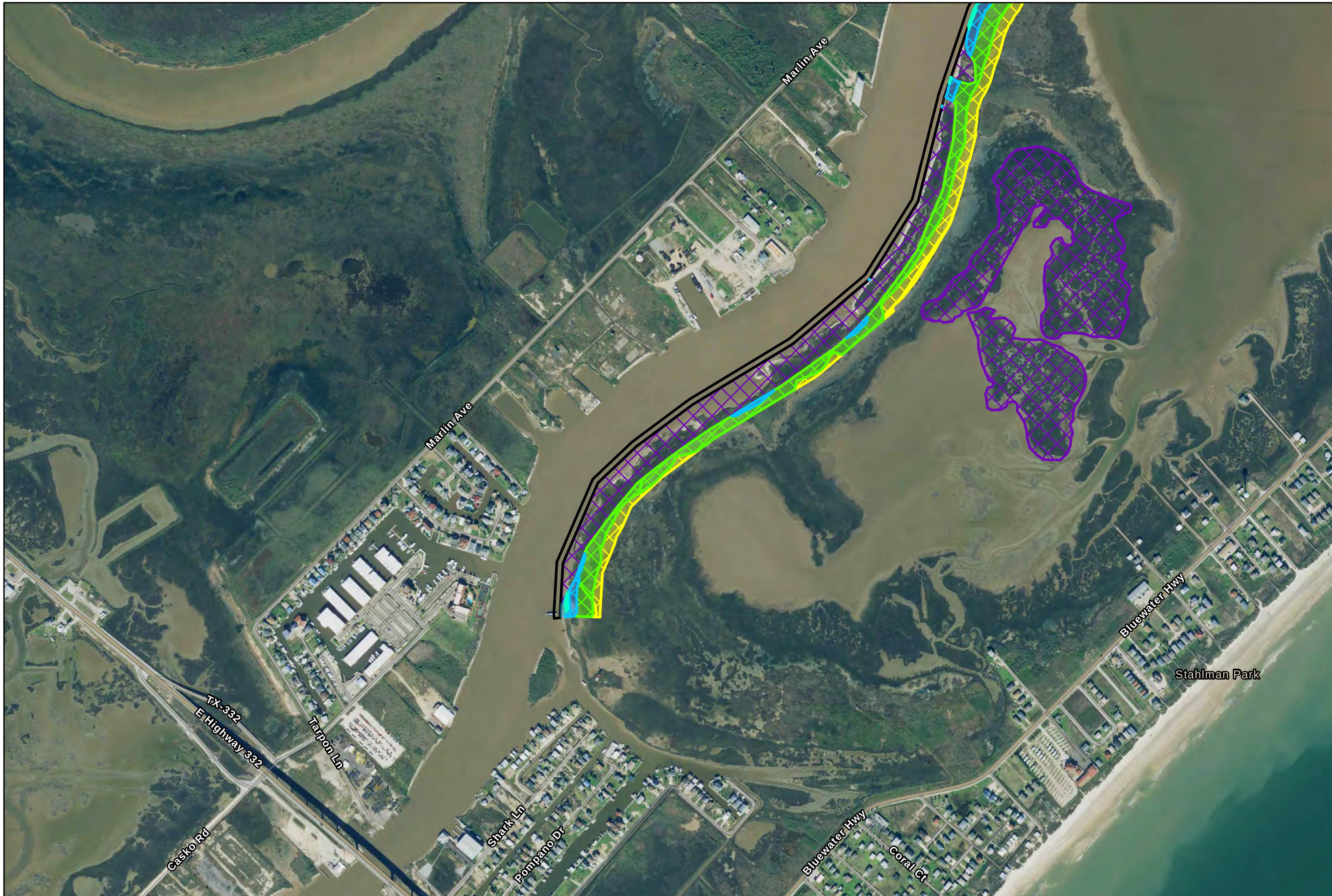

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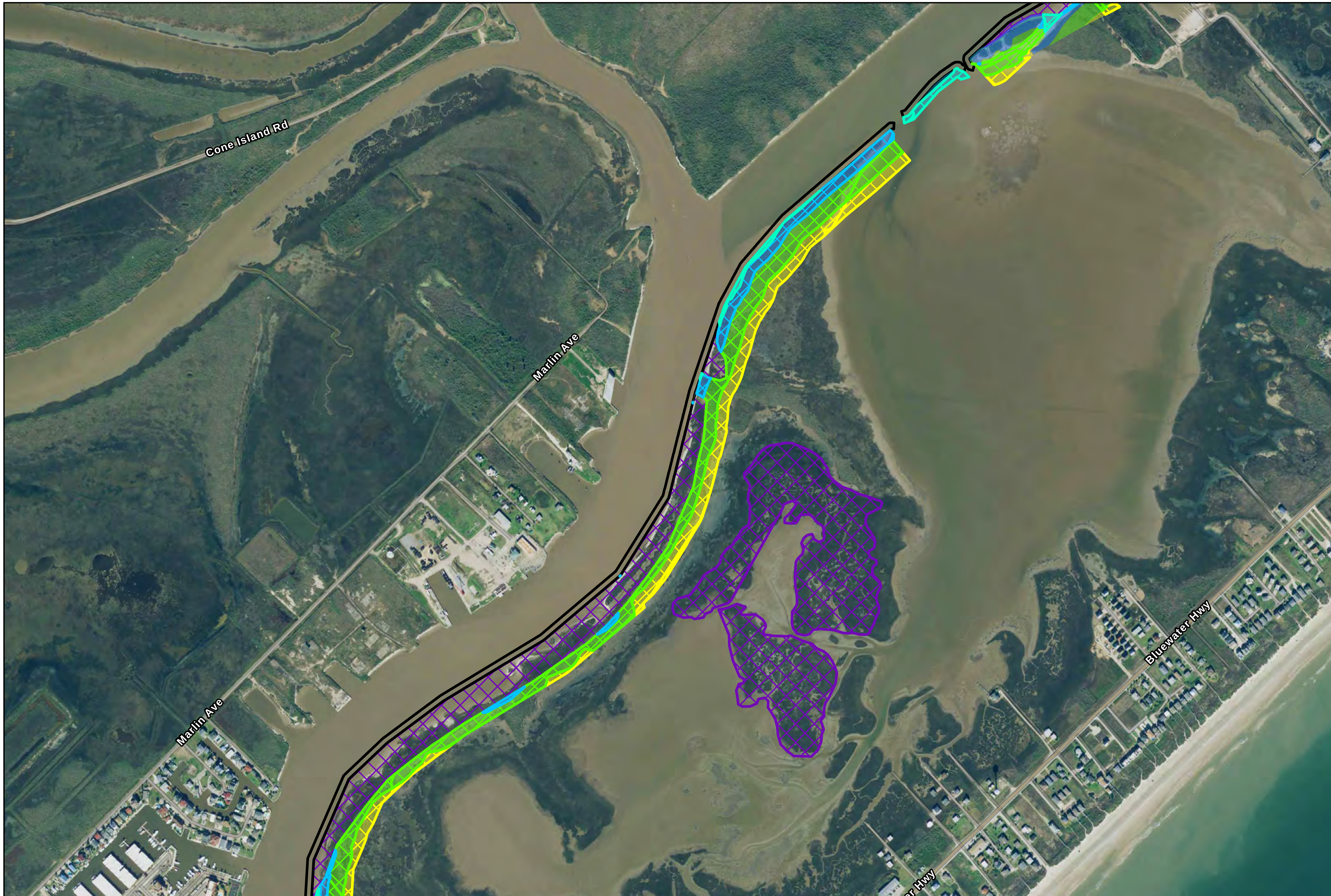

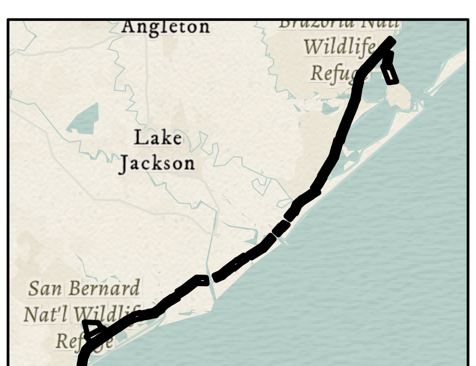

US Army Corps of Engineers®
Galveston District

Coastal Texas Protection and Restoration Feasibility Study

Ecosystem Restoration Passive Benefits

DATUM: NAD 1983
PROJECTION: STATE PLANE
ZONE: TX-SC 4204

Basemap: 2018 NAIP

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Date: 30 March 2021

ER Measure B12 Bastrop Bay, West Bay, and GIWW Shoreline Protection

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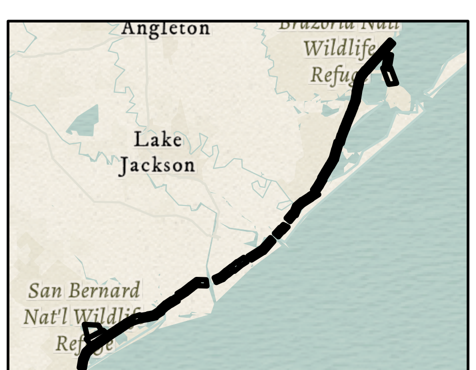
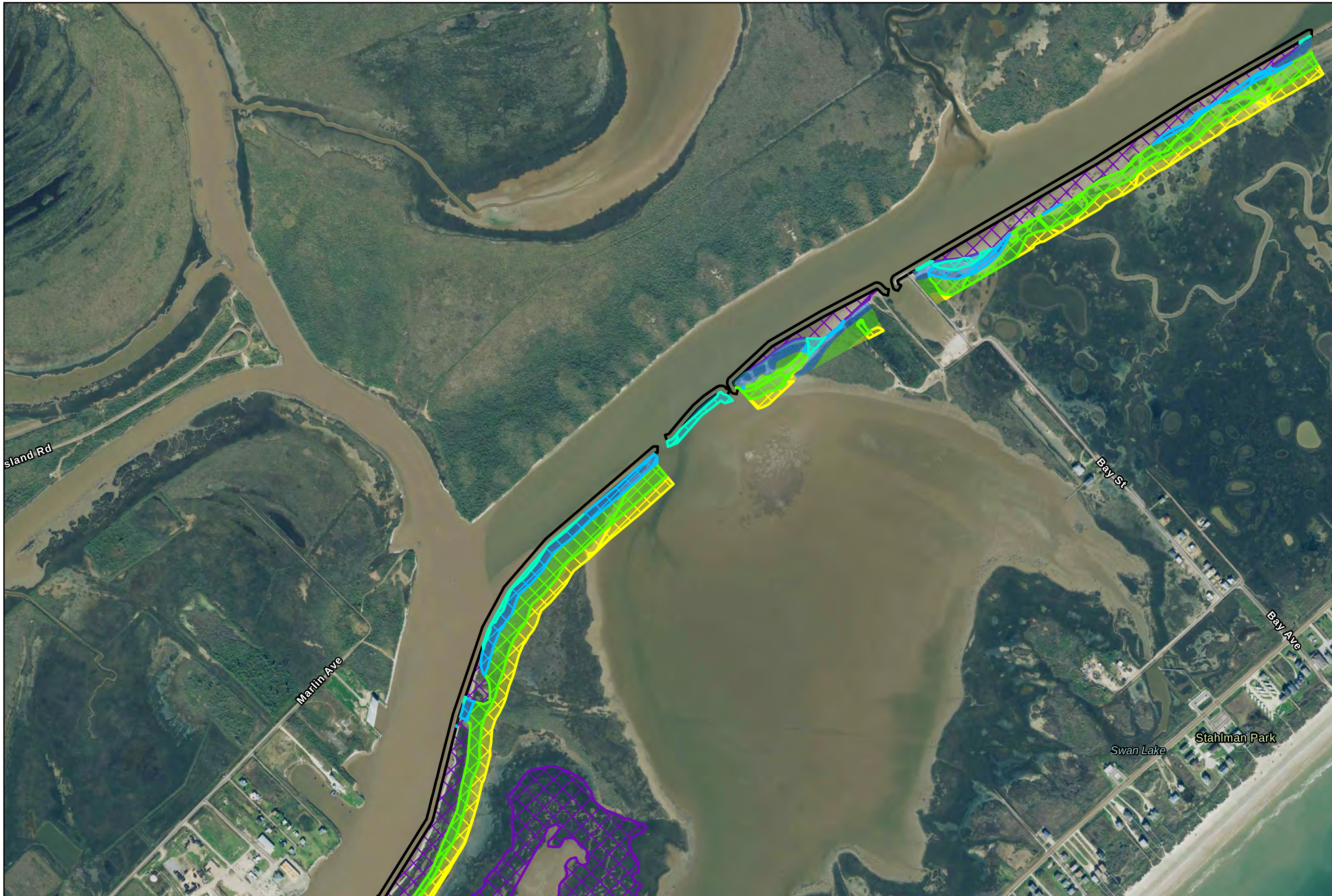
Island Restoration

Oyster Reef Scaling

Wetland / Marsh Restoration





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Galveston District

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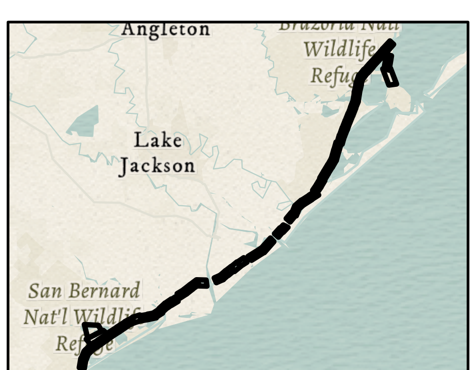

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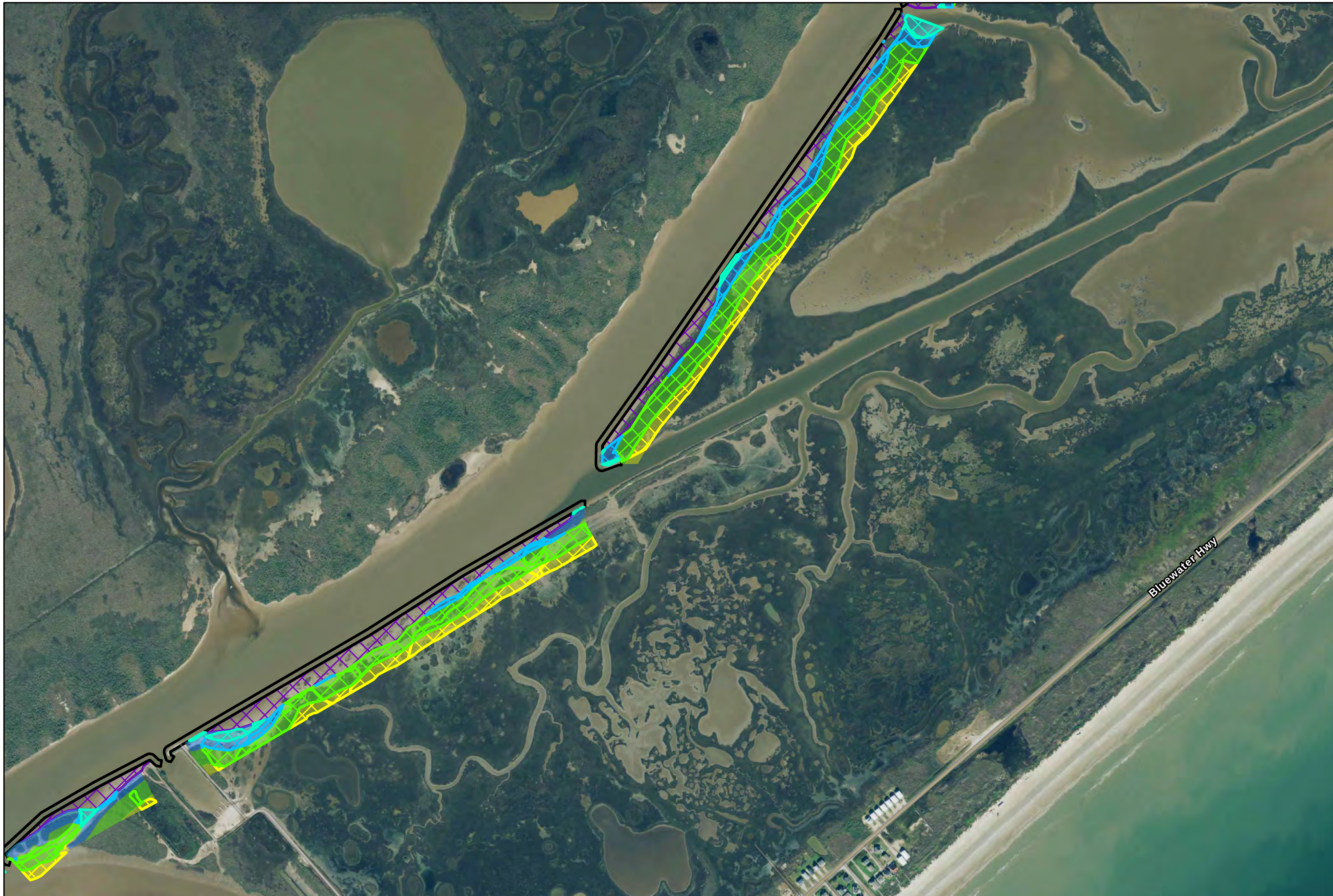

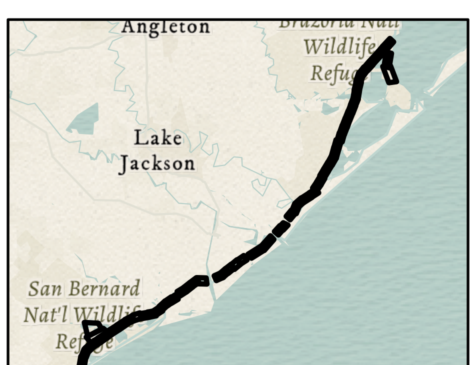

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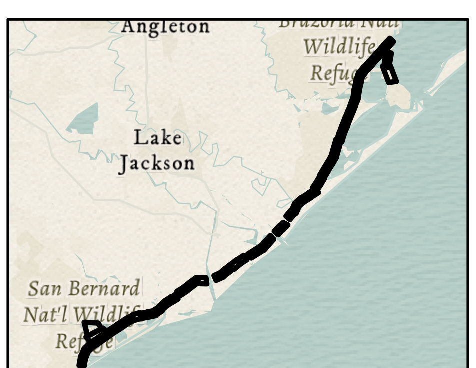

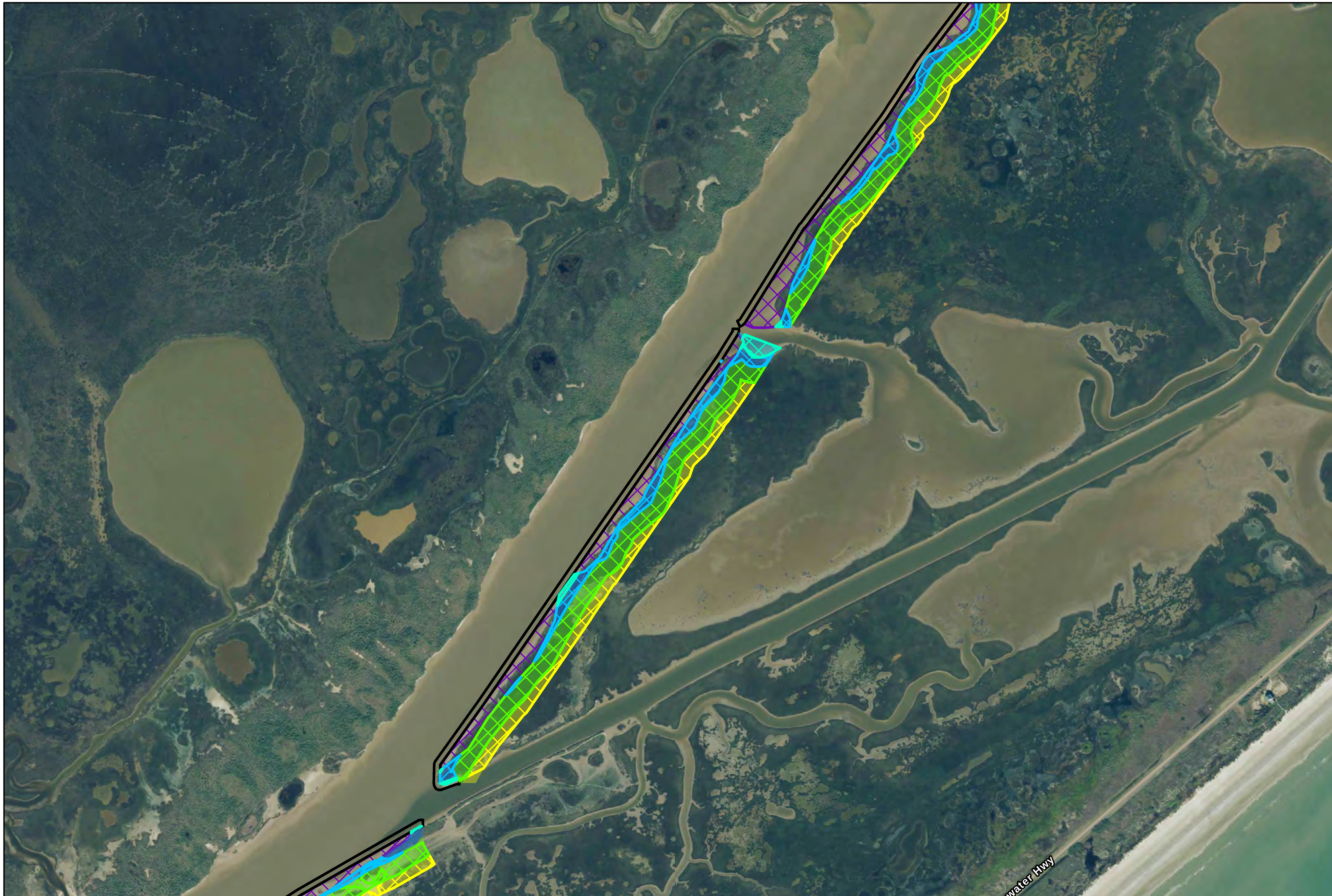

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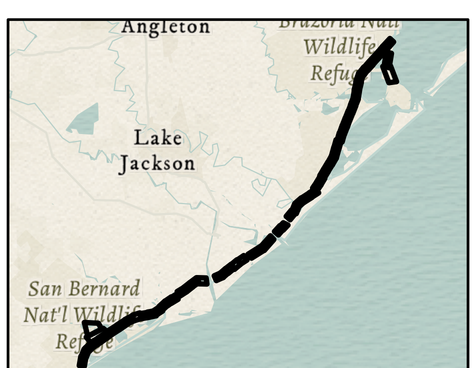

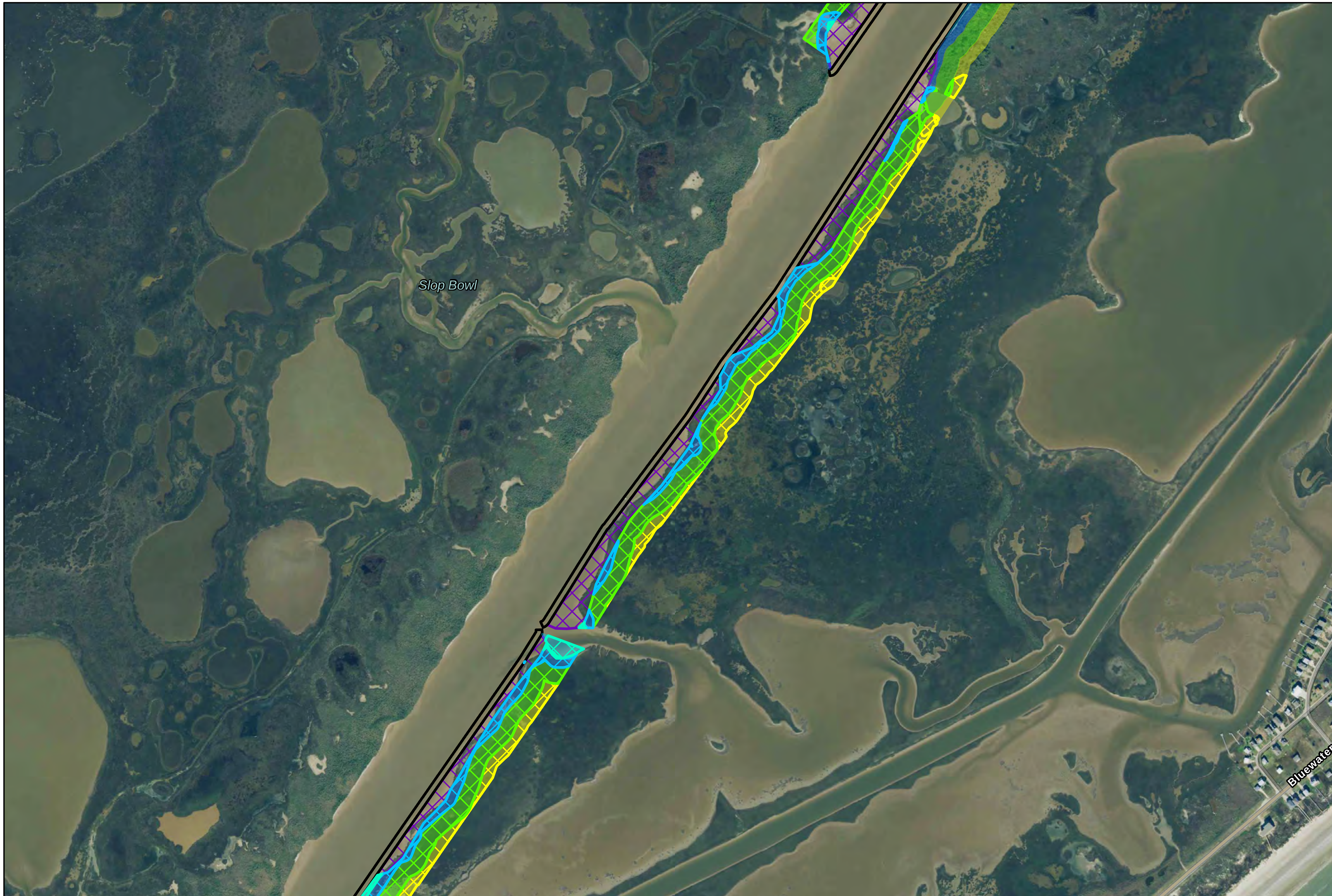

US Army Corps of Engineers ®
Galveston District

Texas General Land Office
Established 1836

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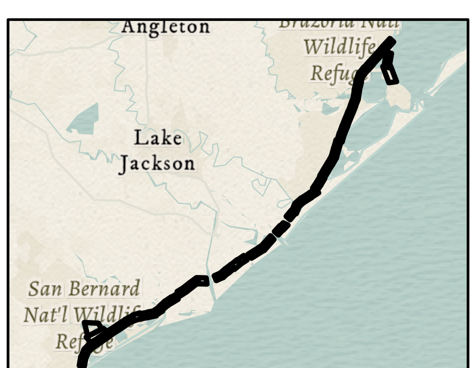

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Galveston District

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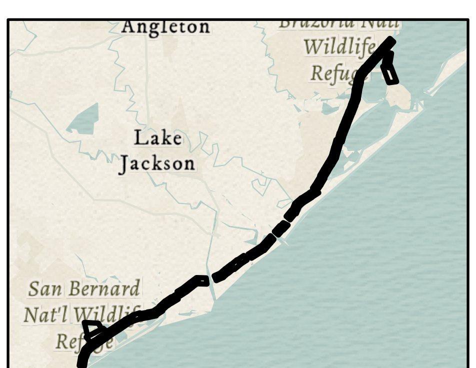

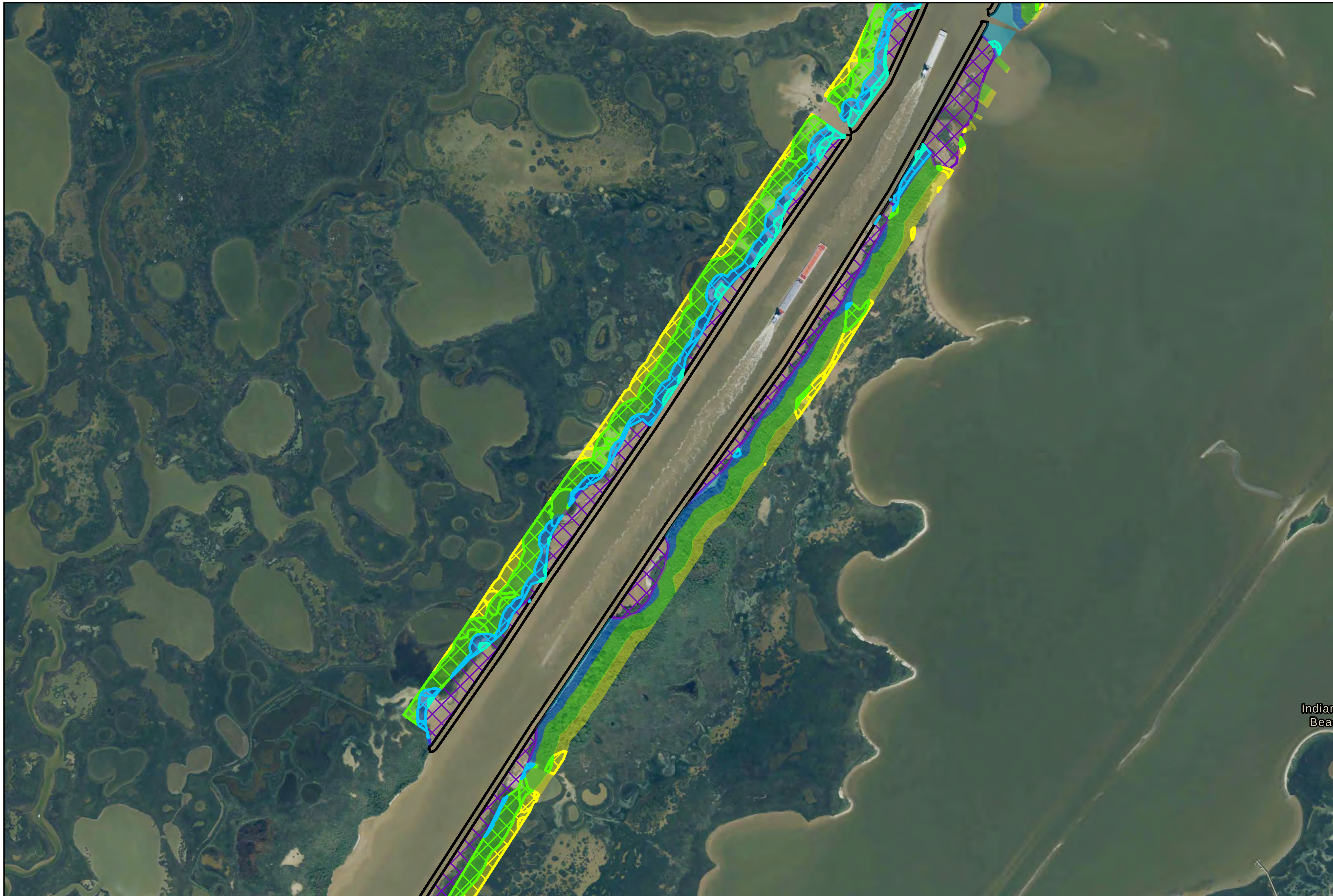

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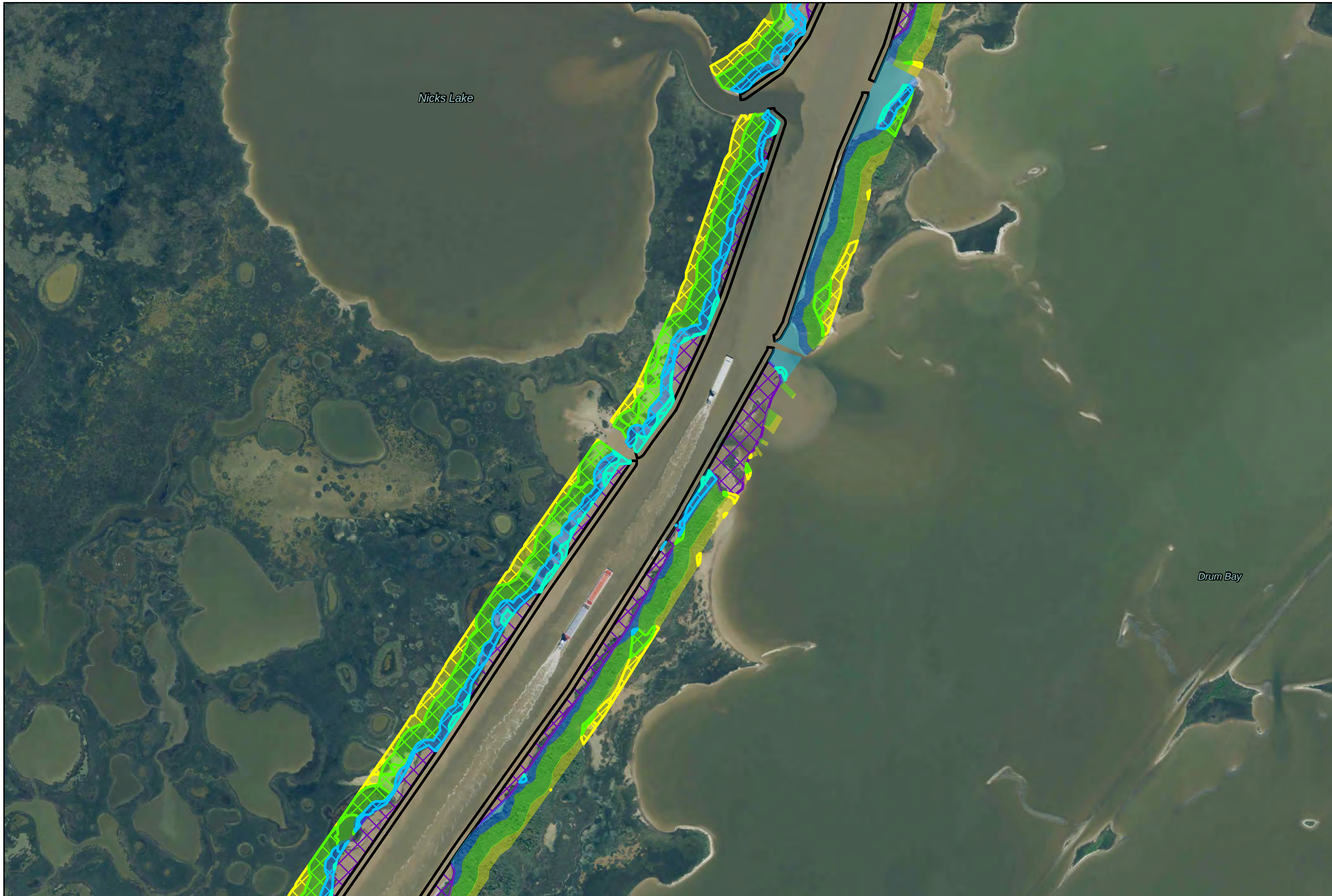

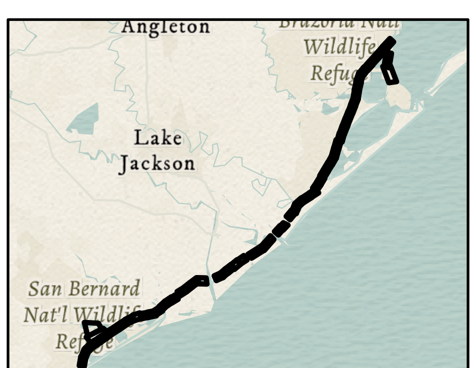

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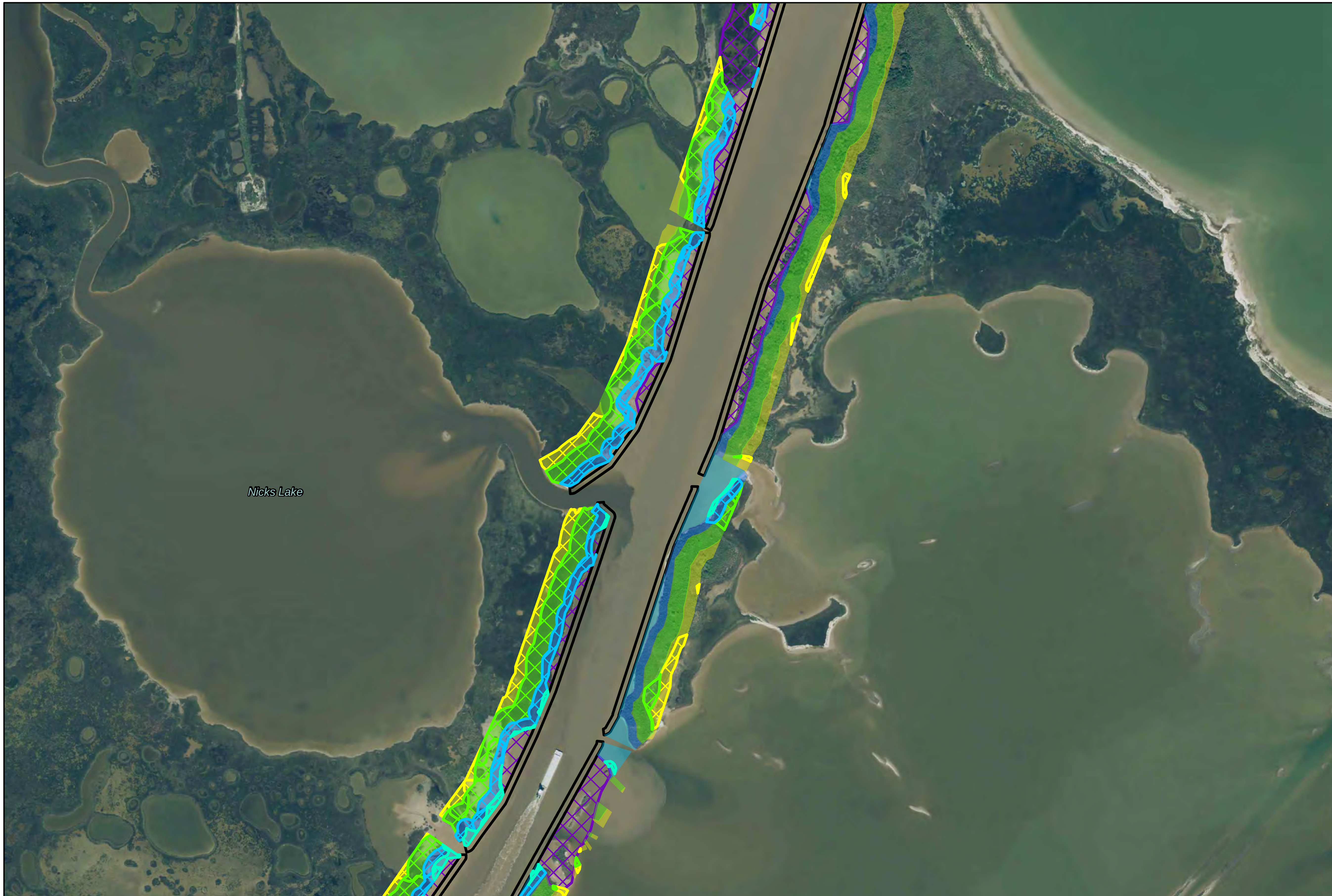

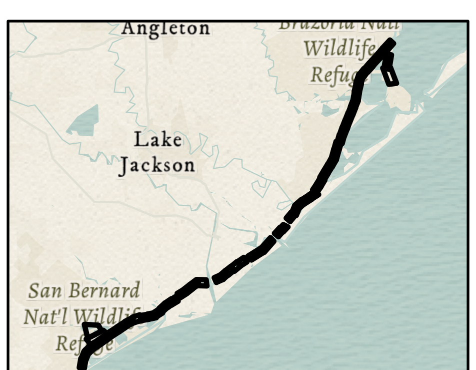

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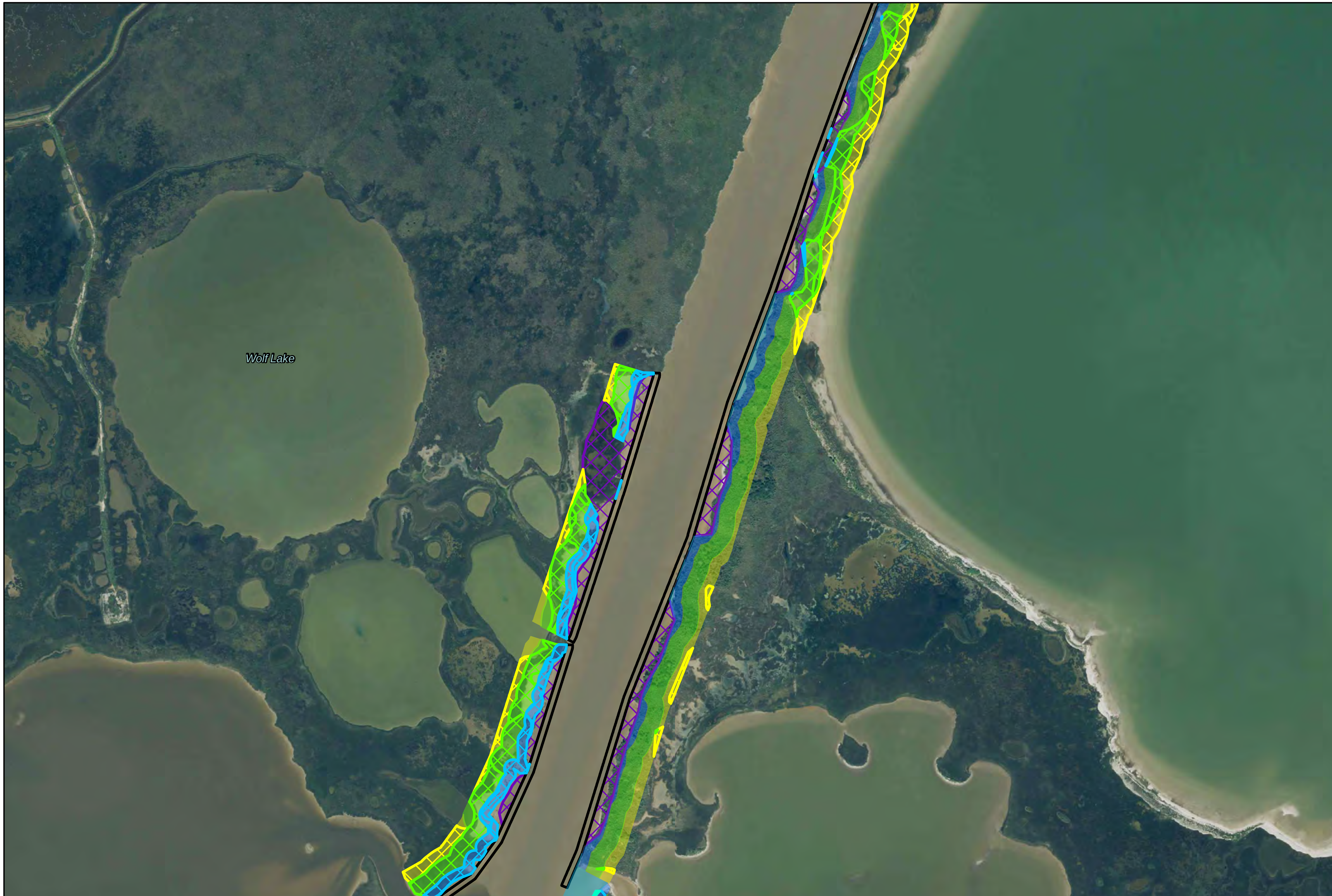

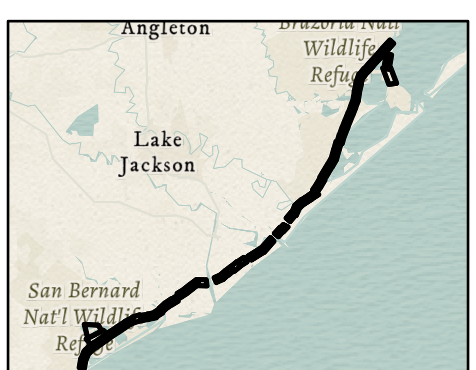

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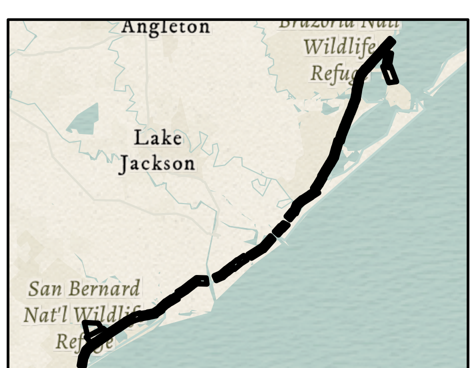

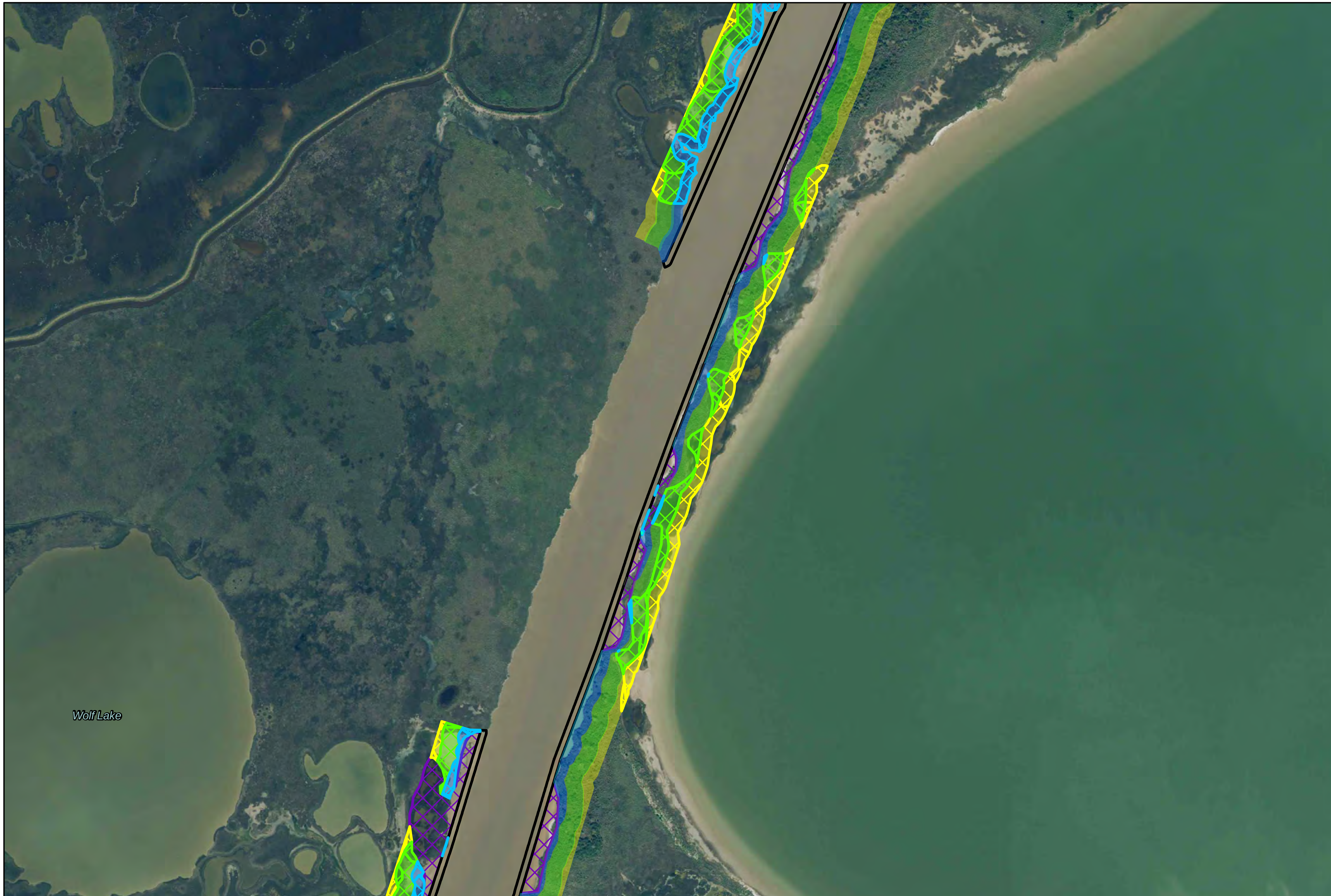

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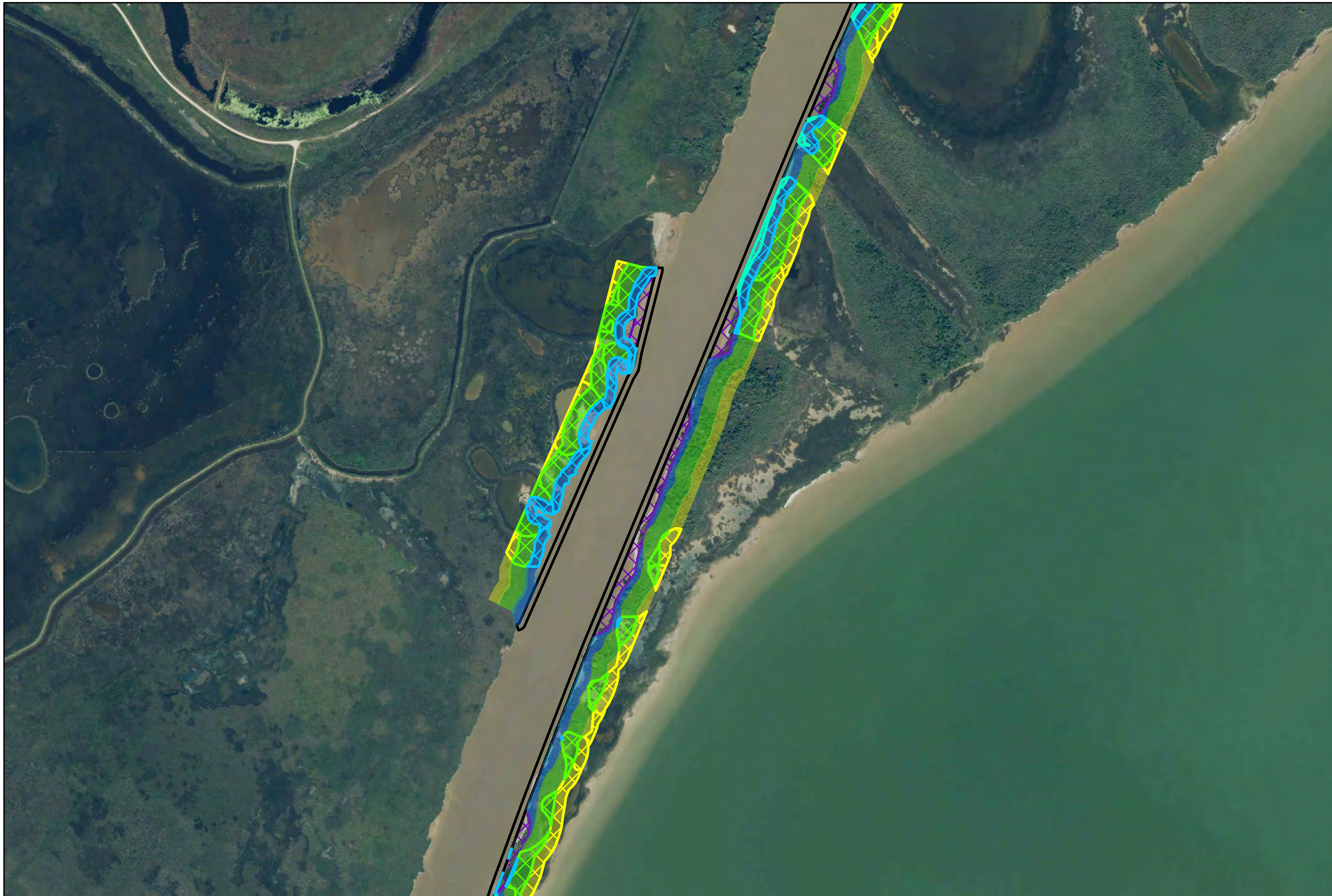

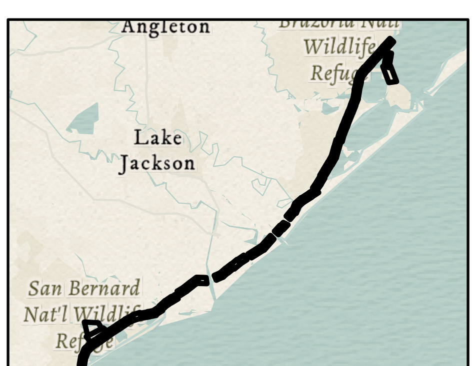

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Galveston District

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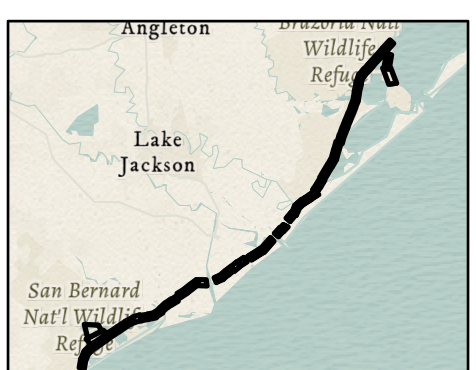

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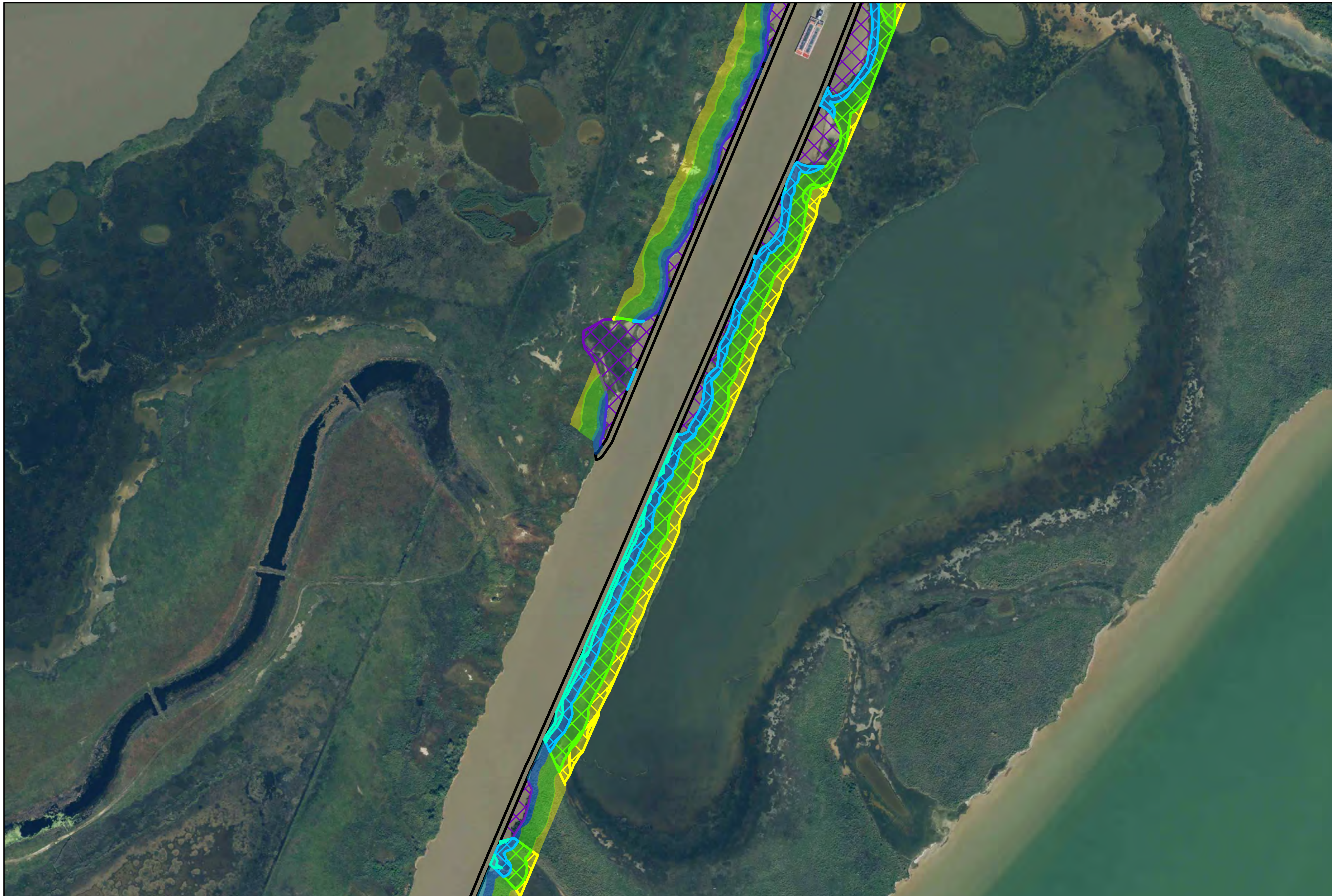

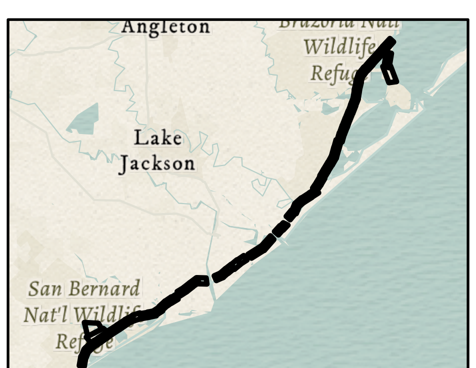

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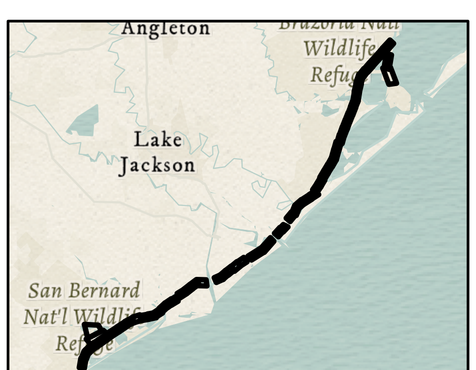

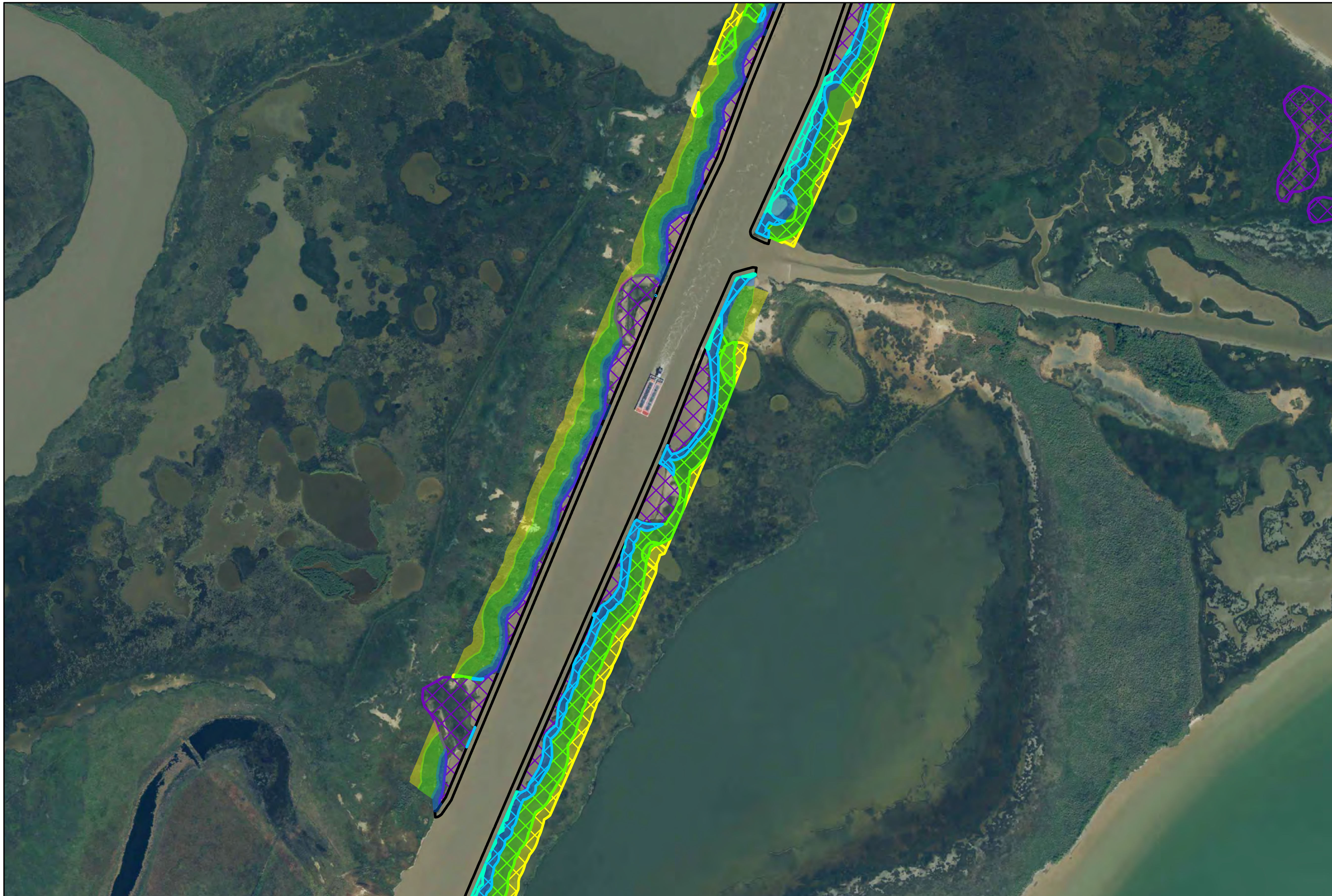

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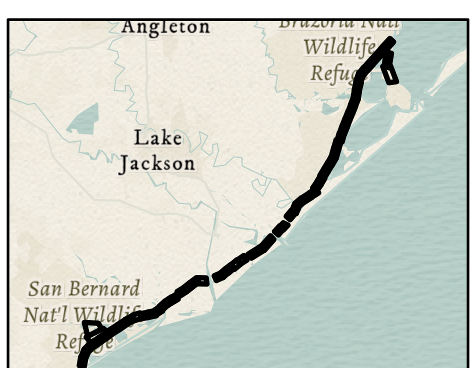

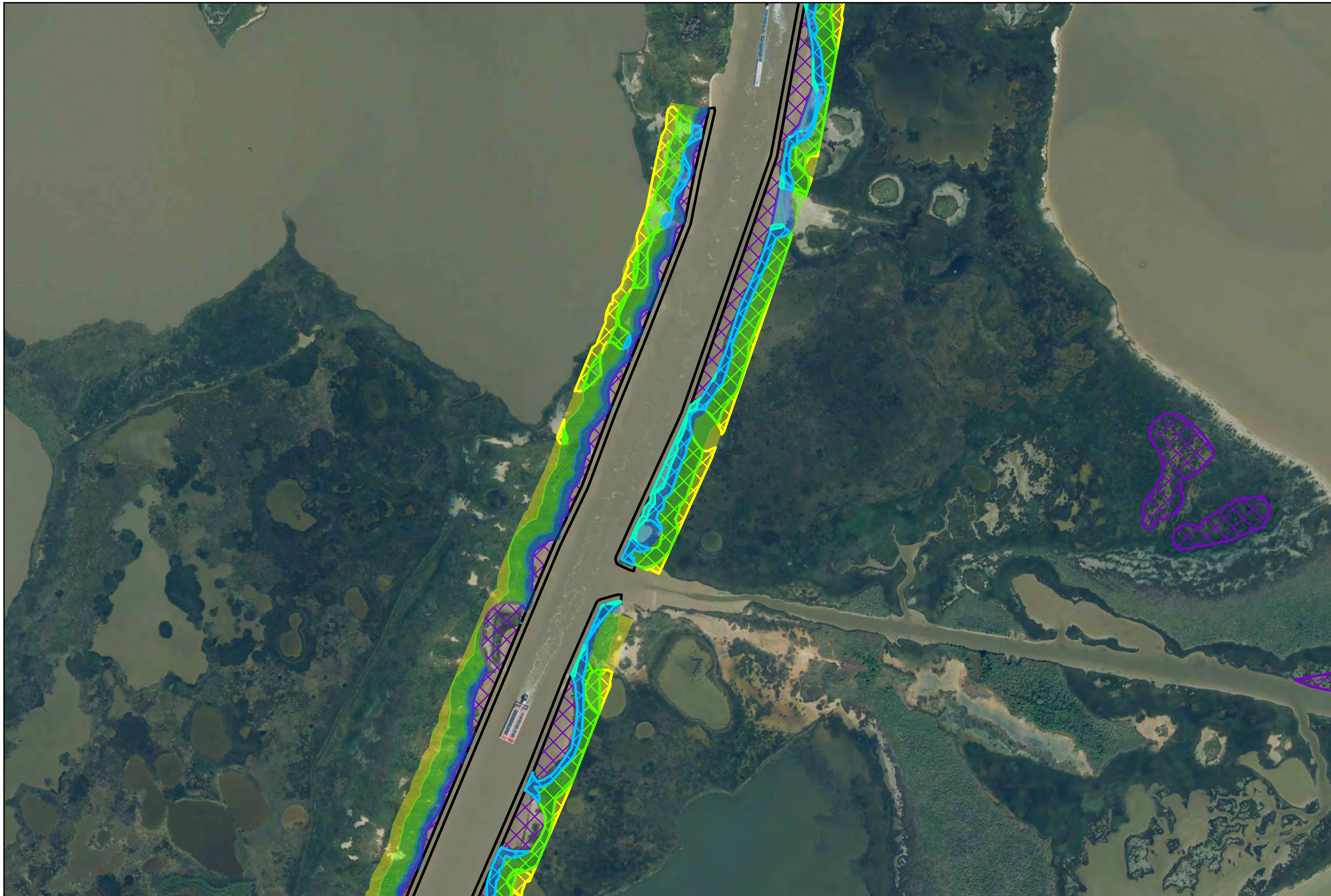

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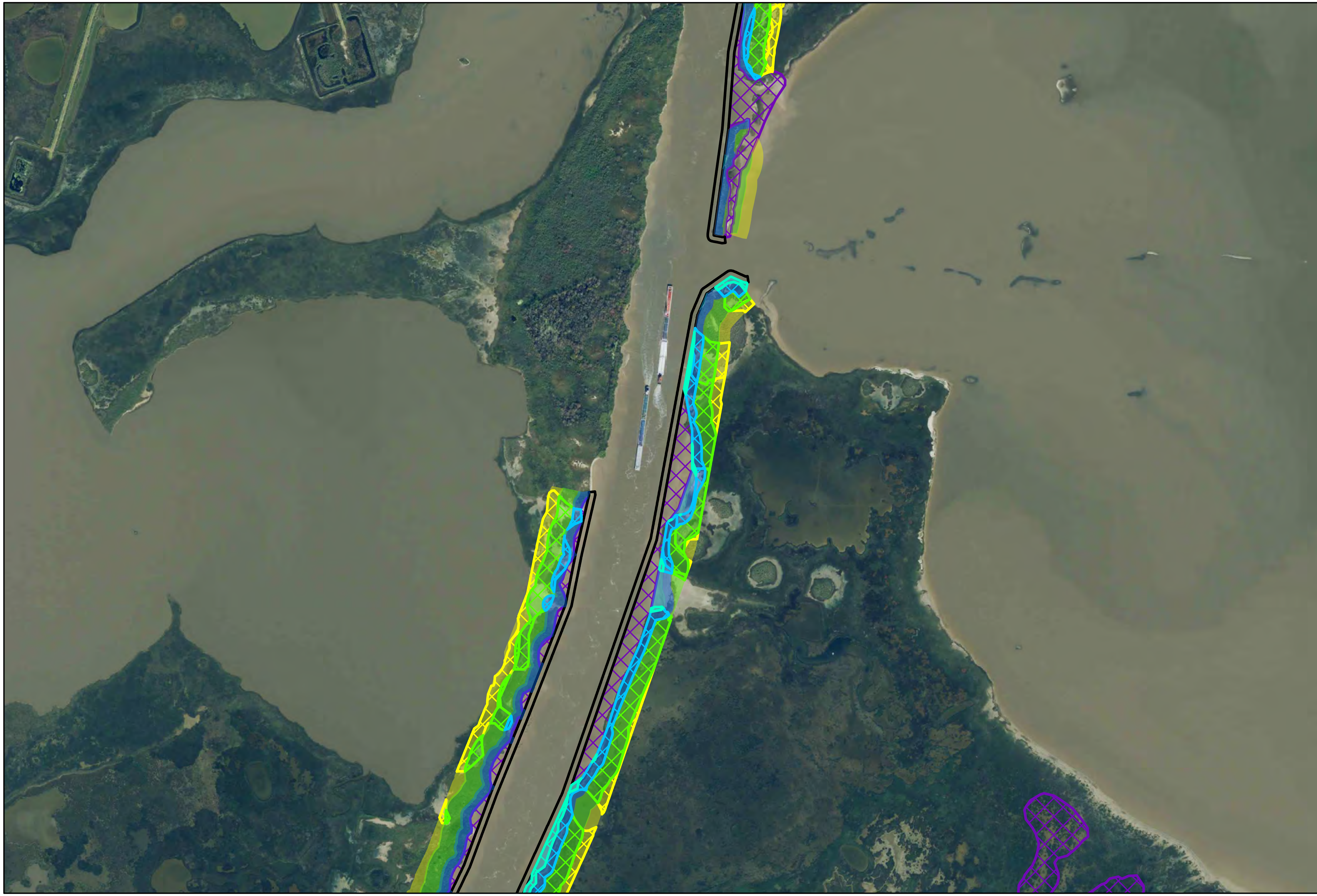

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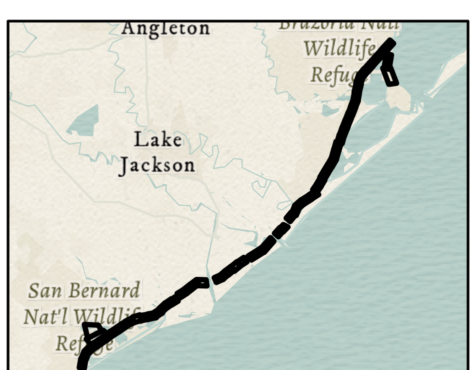

US Army Corps of Engineers®
Galveston District

TEXAS GENERAL LAND OFFICE
ESTABLISHED 1836

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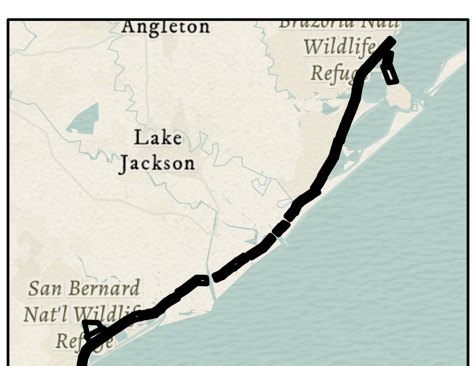

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Galveston District

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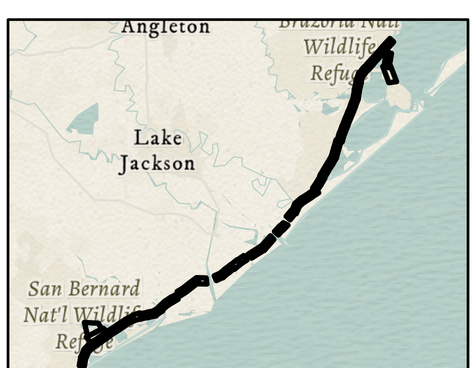

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Galveston District

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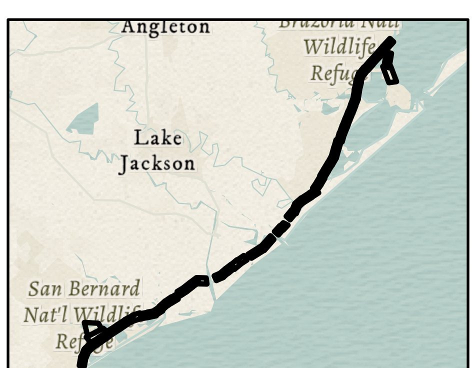

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Galveston District

Texas General Land Office Established 1836

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Bastrop Bay, West Bay, and GIWW Shoreline Protection

Shoreline (2018)

NWI Polygon

2035 Interstitial Benefit Area

NWI Polygon

2035 Benefit Area

NWI Polygon

2065 Benefit Area

NWI Polygon

2085 Benefit Area

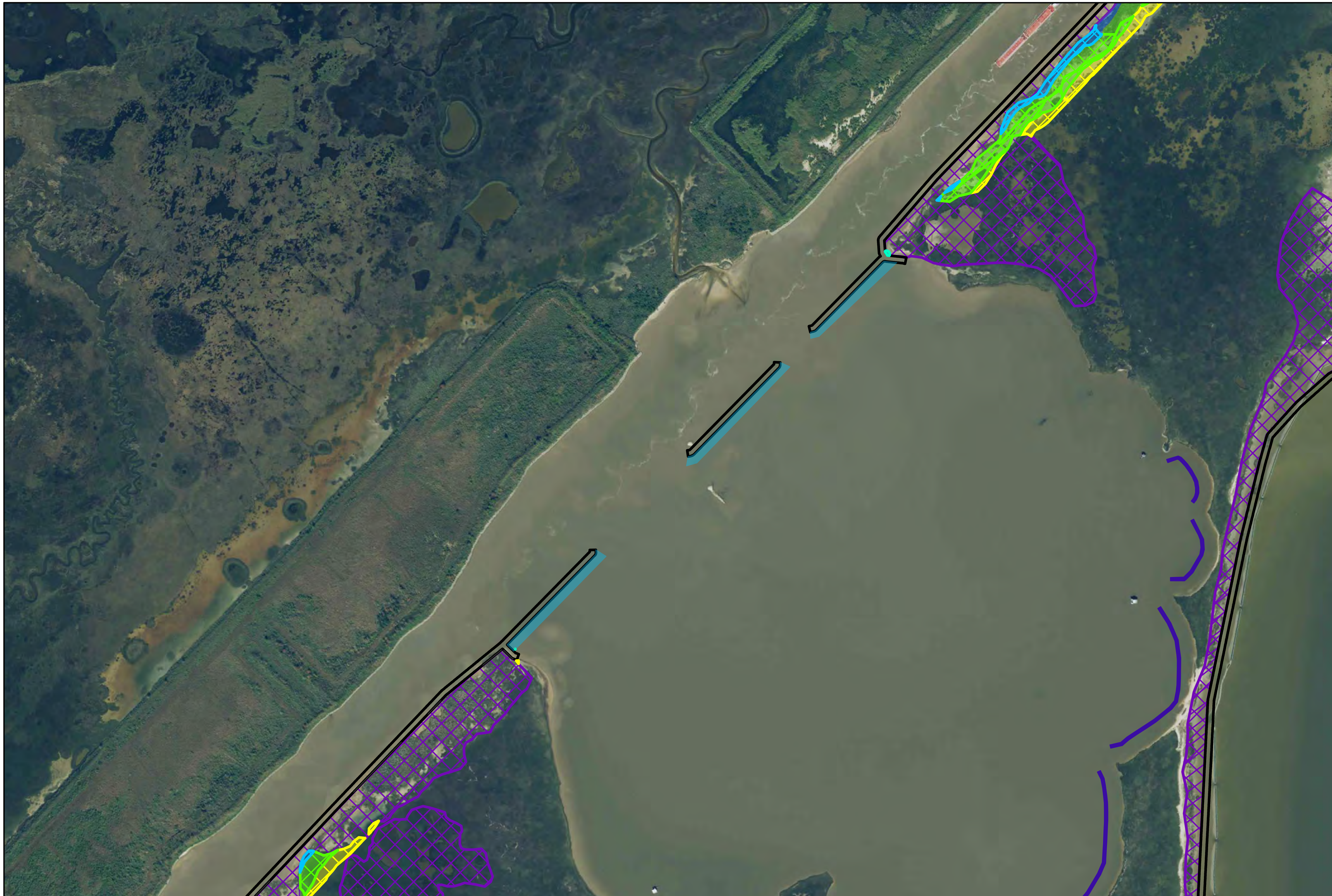
ER Measure

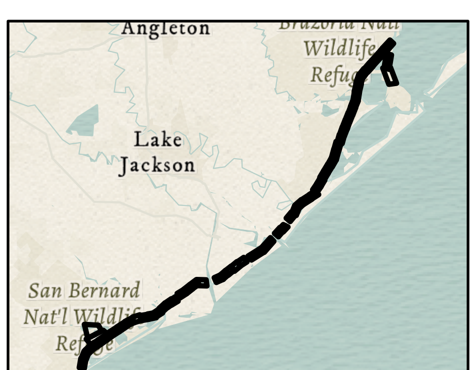
Breakwater

Island Restoration

Oyster Reef Scaling

Wetland / Marsh Restoration





US Army Corps of Engineers ®
Galveston District

Coastal Texas Protection and Restoration Feasibility Study

Ecosystem Restoration Passive Benefits

DATUM: NAD 1983
PROJECTION: STATE PLANE
ZONE: TX-SC 4204

Basemap: 2018 NAIP

0 0.5 1 Miles

Date: 30 March 2021

ER Measure B12 Bastrop Bay, West Bay, and GIWW Shoreline Protection

Shoreline (2018)
NWI Polygon
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ER Measure
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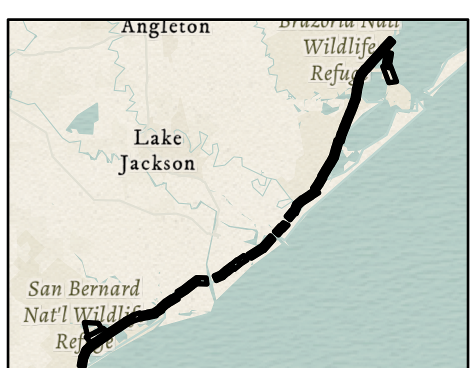

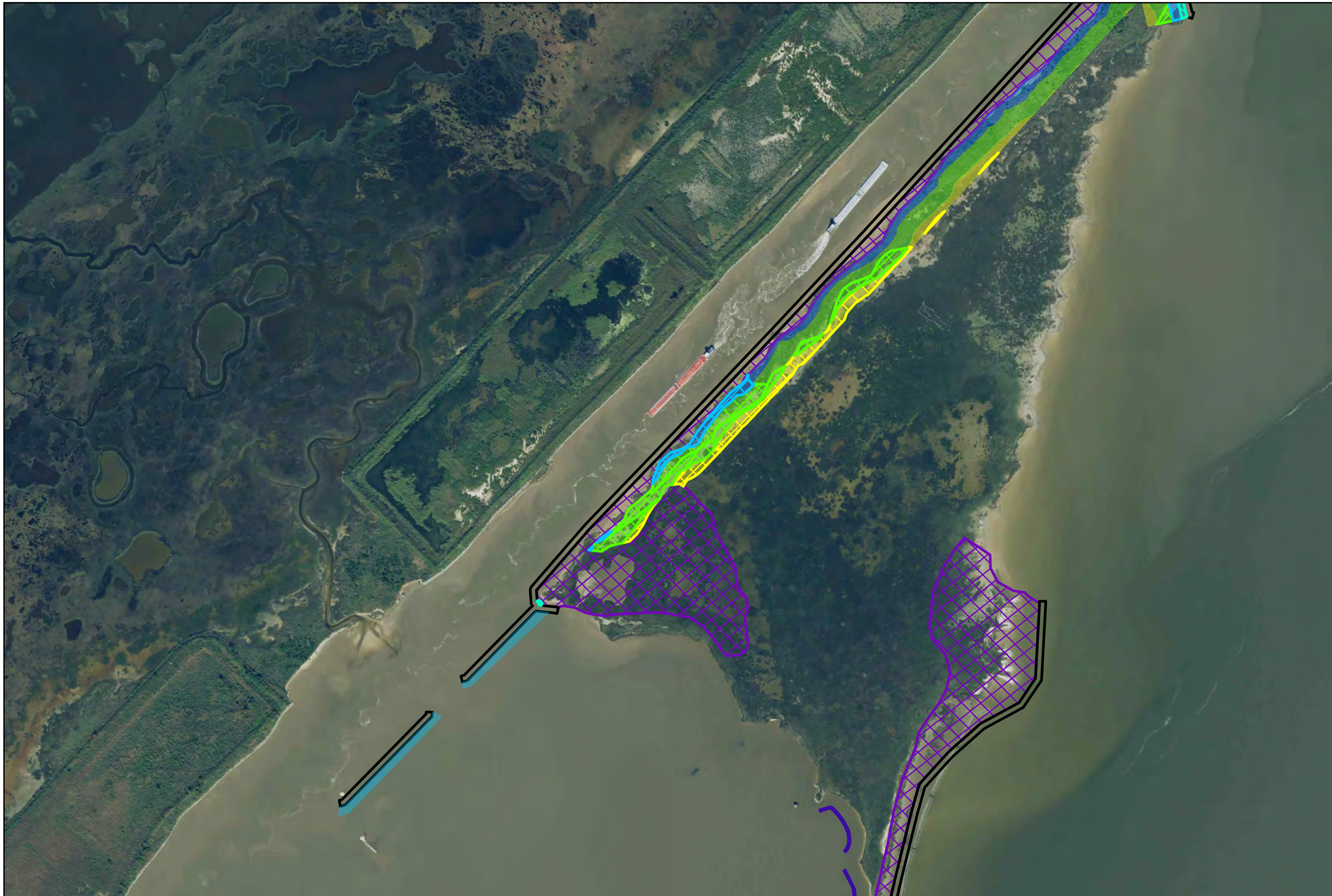

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Galveston District

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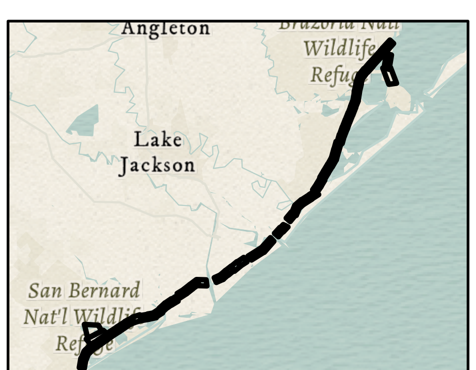

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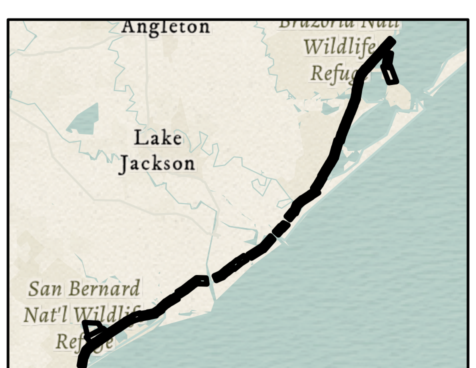

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Ecosystem Restoration Passive Benefits

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0 0.5 1 Miles

Date: 30 March 2021

ER Measure B12 Bastrop Bay, West Bay, and GIWW Shoreline Protection

Shoreline (2018)
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2035 Interstitial Benefit Area
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ER Measure
Breakwater
Island Restoration
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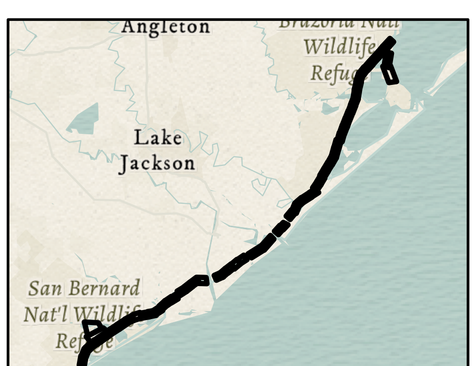


US Army Corps of Engineers ®
Galveston District

Coastal Texas Protection and Restoration Feasibility Study

Ecosystem Restoration Passive Benefits

DATUM: NAD 1983
PROJECTION: STATE PLANE
ZONE: TX-SC 4204

Basemap: 2018 NAIP
0 0.5 1 Miles

Date: 30 March 2021

M-8

Habitat Modeling

M-8 -- Oyster Habitat

Project: M-8 American Oyster

American Oyster HSI Model Spreadsheet

Future Without Project

Acres: 0

Condition: Future Without Project		TY 0	SI	TY 1	SI	TY 31	SI
V1	Percent cultch cover	0	0.00	0	0.00	0	0.00
V2	Mean salinity during spawning season	27	0.56	29	0.39	31	0.26
V3	Minimum annual salinity	22	1	23	1	25	1
V4	Annual mean salinity	25	0.25	26	0.22	28	0.16
		HSI=	**0.00**	HSI=	**0.00**	HSI=	**0.00**

Condition: Future Without Project		TY 51	SI	TY	SI	TY	SI
V1	Percent cultch cover	0	0.00				
V2	Mean salinity during spawning season	33	0.18				
V3	Minimum annual salinity	26	1				
V4	Annual mean salinity	30	0.1				
		HSI=	**0.00**	HSI=		HSI=	

Condition: Future Without Project		TY	SI	TY	SI	TY	SI
V1	Percent cultch cover						
V2	Mean salinity during spawning season						
V3	Minimum annual salinity						
V4	Annual mean salinity						
		HSI=		HSI=		HSI=	

Future With Project

Acres: 15

Condition: Future With Project		TY 0	SI	TY 1	SI	TY 31	SI
V1	Percent cultch cover	0	0.00	100	1.00	100	1.00
V2	Mean salinity during spawning season	27	0.56	29	0.39	31	0.26
V3	Minimum annual salinity	22	1	23	1	25	1
V4	Annual mean salinity	25	0.25	26	0.22	28	0.16
		HSI=	**0.00**	HSI=	**0.54**	HSI=	**0.45**

Condition: Future With Project		TY 51	SI	TY	SI	TY	SI
V1	Percent cultch cover	100	1.00				
V2	Mean salinity during spawning season	33	0.18				
V3	Minimum annual salinity	26	1				
V4	Annual mean salinity	30	0.1				
		HSI=	**0.37**	HSI=		HSI=	

Condition: Future With Project		TY	SI	TY	SI	TY	SI
V1	Percent cultch cover						
V2	Mean salinity during spawning season						
V3	Minimum annual salinity						
V4	Annual mean salinity						
		HSI=		HSI=		HSI=	

M-8 -- Oyster Habitat

American Oyster HSI Model Spreadsheet

Condition: Future Without Project

TY	Acres	HSI	Total HUs	Cumulative HUs
0	0	0.00	0.00	
1	0	0.00	0.00	0.00
31	0	0.00	0.00	0.00
51	0	0.00	0.00	0.00
Max TY=	51		**AAHUs=**	0.00

Net Change in AAHUs due to Project

Future With Project AAHUs	6.83
Future Without Project AAHUs	0.00
Net Change	**6.83**

Condition: Future With Project

TY	Acres	HSI	Total HUs	Cumulative HUs
0	0	0.00	0.00	
1	15	0.54	8.11	2.70
31	15	0.45	6.77	223.19
51	15	0.37	5.49	122.69
Max TY=	51		**AAHUs=**	6.83

M-8 -- Brown Pelican

Project: M-8 Brown Pelican

What State is the Project Location TX

Acres 3

Brown Pelican HSI Model Spreadsheet

Acres 96

Condition: Future Without Project

Variable		TY 0	**SI**	TY 1	**SI**	TY 31	**SI**
V1	Island surface area	Less than 2 ha (4.9 ac)	0.40	Less than 2 ha (4.9 ac)	0.40	Less than 2 ha (4.9 ac)	0.40
V2	Distance of island from mainland*	0.25	0.63	0.25	0.63	0.25	0.63
V3	Distance of island from nearest human activity center*	13	1.00	13	1.00	13	1.00
V4 (WDY)							
V4	Percent of Island surface area at least 0.6 m elevation	0	0.00	0	0.00	0	0.00
		HSI=	0.00	HSI=	0.00	HSI=	0.00

Condition: Future With Project

Variable		TY 0	**SI**	TY 1	**SI**	TY 31	**SI**
V1	Island surface area	Less than 2 ha (4.9 ac)	0.40	Greater than 8 ha (19.8 ac)	0.40	Greater than 8 ha (19.8 ac)	0.40
V2	Distance of island from mainland*	0.25	0.63	0.25	0.63	0.25	0.63
V3	Distance of island from nearest human activity center*	13	1.00	13	1.00	13	1.00
V4 (WDY)							
V4	Percent of Island surface area at least 0.6 m elevation	0	0.00	91	1.00	90	1.00
		HSI=	0.00	HSI=	0.71	HSI=	0.71

Condition: Future Without Project

Variable		TY 51	**SI**	TY	**SI**	TY	**SI**
V1	Island surface area	Less than 2 ha (4.9 ac)	0.40				
V2	Distance of island from mainland*	0.25	0.63				
V3	Distance of island from nearest human activity center*	13	1.00				
V4 (WDY)							
V4	Percent of Island surface area at least 0.6 m elevation	0	0.00				
		HSI=	0.00	HSI=		HSI=	

Condition: Future With Project

Variable		TY 51	**SI**	TY	**SI**	TY	**SI**
V1	Island surface area	Greater than 8 ha (19.8 ac)	0.40				
V2	Distance of island from mainland*	0.25	0.63				
V3	Distance of island from nearest human activity center*	13	1.00				
V4 (WDY)							
V4	Percent of Island surface area at least 0.6 m elevation	90	1.00				
		HSI=	0.71	HSI=		HSI=	

Condition: Future Without Project

Variable		TY	**SI**	TY	**SI**	TY	**SI**
V1	Island surface area						
V2	Distance of island from mainland*						
V3	Distance of island from nearest human activity center*						
V4 (WDY)							
V4	Percent of Island surface area at least 0.6 m elevation						
		HSI=		HSI=		HSI=	

Condition: Future With Project

Variable		TY	**SI**	TY	**SI**	TY	**SI**
V1	Island surface area						
V2	Distance of island from mainland*						
V3	Distance of island from nearest human activity center*						
V4 (WDY)							
V4	Percent of Island surface area at least 0.6 m elevation						
		HSI=		HSI=		HSI=	

* Measured as a straight-line distance in km.

M-8 -- Brown Pelican

Brown Pelican HSI Model Spreadsheet

Condition: Future Without Project

TY	Acres	HSI	Total HUs	Cumulative HUs
0	3	0.00	0.00	
1	3	0.00	0.00	0.00
31	0	0.00	0.00	0.00
51	0	0.00	0.00	0.00
Max TY=	**51**		**AAHUs=**	0.00

Condition: Future With Project

TY	Acres	HSI	Total HUs	Cumulative HUs
0	3	0.00	0.00	
1	96	0.71	67.88	22.98
31	88	0.71	62.23	1951.61
51	79	0.71	55.86	1180.87
Max TY=	**51**		**AAHUs=**	61.87

Net Change in AAHUs due to Project

Future With Project AAHUs	61.87
Future Without Project AAHUs	0.00
Net Change	61.87

M-8 -- Estuarine Marsh Habitat (Direct Benefits of Marsh Nourishment)

Project: M-8 East Matagorda Bay Shoreline Protection (BU)

Brown Shrimp HSI Model Spreadsheet

Condition: Future Without Project

		TY	0	TY	1	TY	31
	Acreage by TY		237		237		249
Variable			**SI**		**SI**		**SI**
V1	% of estuary covered by vegetation (marsh and seagrass).	0	0.00	0	0.00	0	0.00
V2	Substrate Composition	soft bo	1.00	soft bo	1.00	soft bo	1.00
V3	Mean salinity - spring	25	0.90	27	0.86	29	0.82
V4	Mean water temperature - spring	24	1	24	1	24	1
		HSI=	**0.00**	HSI=	**0.00**	HSI=	**0.00**
		vba fn	**0.00**		**0.00**		**0.00**

Condition: Future With Project

		TY	0	TY	1	TY	31
	Acreage by TY		237		237		249
Variable			**SI**		**SI**		**SI**
V1	% of estuary covered by vegetation (marsh and seagrass).	0	0.00	50	0.50	90	0.90
V2	Substrate Composition	soft bo	1.00	soft bo	1.00	soft bo	1.00
V3	Mean salinity - spring	25	0.90	27	0.86	29	0.82
V4	Mean water temperature - spring	24	1	24	1	24	1
		HSI=	**0.00**	HSI=	**0.63**	HSI=	**0.91**
		vba fn	**0.00**		**0.37**		**0.91**

Condition: Future Without Project

		TY	51	TY		TY	
			400				
Variable			**SI**		**SI**		**SI**
V1	% of estuary covered by vegetation (marsh and seagrass).	0	0.00				
V2	Substrate Composition	soft bo	1.00				
V3	Mean salinity - spring	30	0.80				
V4	Mean water temperature - spring	24	1				
		HSI=	**0.00**	HSI=		HSI=	
		vba fn	**0.00**		**V1_ENTRY**		**V1_ENTRY**

Condition: Future With Project

		TY	51	TY		TY	
			400				
Variable			**SI**		**SI**		**SI**
V1	% of estuary covered by vegetation (marsh and seagrass).	90	0.90				
V2	Substrate Composition	soft bo	1.00				
V3	Mean salinity - spring	30	0.80				
V4	Mean water temperature - spring	24	1				
		HSI=	**0.89**	HSI=		HSI=	
		vba fn	**0.87**		**V1_ENTRY**		**V1_ENTRY**

Condition: Future Without Project

		TY		TY		TY	
Variable			**SI**		**SI**		**SI**
V1	% of estuary covered by vegetation (marsh and seagrass).						
V2	Substrate Composition						
V3	Mean salinity - spring						
V4	Mean water temperature - spring						
		HSI=		HSI=		HSI=	
		vba fn	**V1_ENTRY**		**V1_ENTRY**		**V1_ENTRY**

Condition: Future With Project

		TY		TY		TY	
Variable			**SI**		**SI**		**SI**
V1	% of estuary covered by vegetation (marsh and seagrass).						
V2	Substrate Composition						
V3	Mean salinity - spring						
V4	Mean water temperature - spring						
		HSI=		HSI=		HSI=	
		vba fn	**V1_ENTRY**		**V1_ENTRY**		**V1_ENTRY**

M-8 -- Estuarine Marsh Habitat (Direct Benefits of Marsh Nourishment)

Brown Shrimp HSI Model Spreadsheet

Condition: Future Without Project

TY	Acres	HSI	Total HUs	Cumulative HUs
0	237	0.00	0.00	
1	237	0.00	0.00	0.00
31	249	0.00	0.00	0.00
51	400	0.00	0.00	0.00
Max TY=	**51**		**AAHUs=**	**0.0**

Condition: Future With Project

TY	Acres	HSI	Total HUs	Cumulative HUs
0	237	0.00	0.00	
1	237	0.63	149.30	74.65
31	249	0.91	225.48	5605.16
51	400	0.89	357.77	5838.09
Max TY=	**51**		**AAHUs=**	**225.8**

Net Change in AAHUs due to Project

Future With Project AAHUs	225.8
Future Without Project AAHUs	0.0
Net Change	225.8

M-8 -- Estuarine Marsh Habitat (Passive Benefits of Breakwater Accretion)

Brown Shrimp HSI Model Spreadsheet

Project: M-8 East Matagorda Bay Shoreline Protection (Breakwaters - Accretion)

Condition: Future Without Project

		TY	0	TY	1	TY	31
	Acreage by TY		65		65		65
Variable			**SI**		**SI**		**SI**
V1	% of estuary covered by vegetation (marsh and seagrass).	0	0.00	0	0.00	0	0.00
V2	Substrate Composition	soft bo	1.00	soft bo	1.00	soft bo	1.00
V3	Mean salinity - spring	25	0.90	27	0.86	29	0.82
V4	Mean water temperature - spring	24	1	24	1	24	1
		HSI=	**0.00**	HSI=	**0.00**	HSI=	**0.00**
		vba fn	**0.00**		**0.00**		**0.00**

Condition: Future With Project

		TY	0	TY	1	TY	31
	Acreage by TY		65		65		65
Variable			**SI**		**SI**		**SI**
V1	% of estuary covered by vegetation (marsh and seagrass).	0	0.00	90	0.90	90	0.90
V2	Substrate Composition	soft bo	1.00	soft bo	1.00	soft bo	1.00
V3	Mean salinity - spring	25	0.90	27	0.86	29	0.82
V4	Mean water temperature - spring	24	1	24	1	24	1
		HSI=	**0.00**	HSI=	**0.93**	HSI=	**0.91**
		vba fn	**0.00**		**0.55**		**0.91**

Condition: Future Without Project

		TY	51	TY		TY	
			65				
Variable			**SI**		**SI**		**SI**
V1	% of estuary covered by vegetation (marsh and seagrass).	0	0.00				
V2	Substrate Composition	soft bo	1.00				
V3	Mean salinity - spring	30	0.80				
V4	Mean water temperature - spring	24	1				
		HSI=	**0.00**	HSI=		HSI=	
		vba fn	**0.00**		**V1_ENTRY**		**V1_ENTRY**

Condition: Future With Project

		TY	51	TY		TY	
			65				
Variable			**SI**		**SI**		**SI**
V1	% of estuary covered by vegetation (marsh and seagrass).	90	0.90				
V2	Substrate Composition	soft bo	1.00				
V3	Mean salinity - spring	30	0.80				
V4	Mean water temperature - spring	24	1				
		HSI=	**0.89**	HSI=		HSI=	
		vba fn	**0.87**		**V1_ENTRY**		**V1_ENTRY**

Condition: Future Without Project

		TY		TY		TY	
Variable			**SI**		**SI**		**SI**
V1	% of estuary covered by vegetation (marsh and seagrass).						
V2	Substrate Composition						
V3	Mean salinity - spring						
V4	Mean water temperature - spring						
		HSI=		HSI=		HSI=	
		vba fn	**V1_ENTRY**		**V1_ENTRY**		**V1_ENTRY**

Condition: Future With Project

		TY		TY		TY	
Variable			**SI**		**SI**		**SI**
V1	% of estuary covered by vegetation (marsh and seagrass).						
V2	Substrate Composition						
V3	Mean salinity - spring						
V4	Mean water temperature - spring						
		HSI=		HSI=		HSI=	
		vba fn	**V1_ENTRY**		**V1_ENTRY**		**V1_ENTRY**

M-8 -- Estuarine Marsh Habitat (Passive Benefits of Breakwater Accretion)

Brown Shrimp HSI Model Spreadsheet

Condition: Future Without Project

TY	Acres	HSI	Total HUs	Cumulative HUs
0	65	0.00	0.00	
1	65	0.00	0.00	0.00
31	65	0.00	0.00	0.00
51	65	0.00	0.00	0.00
Max TY=	**51**		**AAHUs=**	**0.0**

Condition: Future With Project

TY	Acres	HSI	Total HUs	Cumulative HUs
0	65	0.00	0.00	
1	65	0.93	60.28	30.14
31	65	0.91	58.86	1787.08
51	65	0.89	58.14	1169.98
Max TY=	**51**		**AAHUs=**	**58.6**

Net Change in AAHUs due to Project

Future With Project AAHUs	58.6
Future Without Project AAHUs	0.0
Net Change	58.6

M-8 -- Estuarine Marsh Habitat (Passive Benefits of Breakwater Erosion Reduction)

Brown Shrimp HSI Model Spreadsheet

Project: M-8 East Matagorda Bay Shoreline Protection (Breakwaters - Erosion)

Condition: Future Without Project

		TY	0	TY	1	TY	31
	Acreage by TY		275		275		154
Variable			**SI**		**SI**		**SI**
V1	% of estuary covered by vegetation (marsh and seagrass).	90	0.90	90	0.90	90	0.90
V2	Substrate Composition	soft bo	1.00	soft bo	1.00	soft bo	1.00
V3	Mean salinity - spring	25	0.90	27	0.86	29	0.82
V4	Mean water temperature - spring	24	1	24	1	24	1
		HSI=	**0.93**	HSI=	**0.93**	HSI=	**0.91**
		vba fn	**0.93**		**0.93**		**0.87**

Condition: Future With Project

		TY	0	TY	1	TY	31
	Acreage by TY		275		275		275
Variable			**SI**		**SI**		**SI**
V1	% of estuary covered by vegetation (marsh and seagrass).	90	0.90	90	0.90	90	0.90
V2	Substrate Composition	soft bo	1.00	soft bo	1.00	soft bo	1.00
V3	Mean salinity - spring	25	0.90	27	0.86	29	0.82
V4	Mean water temperature - spring	24	1	24	1	24	1
		HSI=	**0.93**	HSI=	**0.93**	HSI=	**0.91**
		vba fn	**0.93**		**0.55**		**0.91**

Condition: Future Without Project

		TY	51	TY		TY	
			0				
Variable			**SI**		**SI**		**SI**
V1	% of estuary covered by vegetation (marsh and seagrass).	90	0.90				
V2	Substrate Composition	soft bo	1.00				
V3	Mean salinity - spring	30	0.80				
V4	Mean water temperature - spring	24	1				
		HSI=	**0.89**	HSI=		HSI=	
		vba fn	**0.89**		**V1_ENTRY**		**V1_ENTRY**

Condition: Future With Project

		TY	51	TY		TY	
			275				
Variable			**SI**		**SI**		**SI**
V1	% of estuary covered by vegetation (marsh and seagrass).	90	0.90				
V2	Substrate Composition	soft bo	1.00				
V3	Mean salinity - spring	30	0.80				
V4	Mean water temperature - spring	24	1				
		HSI=	**0.89**	HSI=		HSI=	
		vba fn	**0.87**		**V1_ENTRY**		**V1_ENTRY**

Condition: Future Without Project

		TY		TY		TY	
Variable			**SI**		**SI**		**SI**
V1	% of estuary covered by vegetation (marsh and seagrass).						
V2	Substrate Composition						
V3	Mean salinity - spring						
V4	Mean water temperature - spring						
		HSI=		HSI=		HSI=	
		vba fn	**V1_ENTRY**		**V1_ENTRY**		**V1_ENTRY**

Condition: Future With Project

		TY		TY		TY	
Variable			**SI**		**SI**		**SI**
V1	% of estuary covered by vegetation (marsh and seagrass).						
V2	Substrate Composition						
V3	Mean salinity - spring						
V4	Mean water temperature - spring						
		HSI=		HSI=		HSI=	
		vba fn	**V1_ENTRY**		**V1_ENTRY**		**V1_ENTRY**

M-8 -- Estuarine Marsh Habitat (Passive Benefits of Breakwater Erosion Reduction)

Brown Shrimp HSI Model Spreadsheet

Condition: Future Without Project

TY	Acres	HSI	Total HUs	Cumulative HUs
0	275	0.93	256.35	
1	275	0.93	255.02	255.69
31	154	0.91	139.45	5903.96
51	0	0.89	0.00	1388.83
Max TY=	**51**		**AAHUs=**	**148.0**

Net Change in AAHUs due to Project

Future With Project AAHUs	250.3
Future Without Project AAHUs	148.0
Net Change	102.3

Condition: Future With Project

TY	Acres	HSI	Total HUs	Cumulative HUs
0	275	0.93	256.35	
1	275	0.93	255.02	255.69
31	275	0.91	249.02	7560.71
51	275	0.89	245.97	4949.91
Max TY=	**51**		**AAHUs=**	**250.3**

M-8 -- Palustrine Marsh Habitat (Passive Benefits of Breakwater Erosion Reduction)

Project: M-8 - East Matagorda Bay Shoreline Protection (Erosion)

American alligator HSI Model Spreadsheet

Acres 78

Condition: Future Without Project

Variable		TY 0	SI	TY 1	SI	TY 31	SI
V1	% wetland that is open water (ponds, bayous, canals).	30	1.00	30	1.00	30	1.00
V2	% open water in bayous, canals or > 1.2m deep	10	1.00	10	1.00	10	1.00
V3	Interspersion Class	Medium	0.50	Mediu	0.50	Mediu	0.50
V4	% ponded area >=15 cm deep (May - September)	60	0.6	60	0.6	60	0.6
V5	% substrate exposed at MLT (May - Sep) - Tidal only						
	CI (tidal) | CI (non-tidal)		0.6694		0.6694		0.6694
		HSI=	0.8182	HSI=	0.8182	HSI=	0.8182

Acres 78

Condition: Future With Project

Variable		TY 0	SI	TY 1	SI	TY 31	SI
V1	% wetland that is open water (ponds, bayous, canals).	30	1.00	30	1.00	30	1.00
V2	% open water in bayous, canals or > 1.2m deep	10	1.00	10	1.00	10	1.00
V3	Interspersion Class	Medium	0.50	Mediu	0.50	Mediu	0.50
V4	% ponded area >=15 cm deep (May - September)	60	0.6	60	0.6	60	0.6
V5	% substrate exposed at MLT (May - Sep) - Tidal only						
	CI (tidal) | CI (non-tidal)		0.6694		0.6694		0.6694
		HSI=	0.8182	HSI=	0.8182	HSI=	0.8182

Condition: Future Without Project

Variable		TY 51	SI	TY	SI	TY	SI
V1	% wetland that is open water (ponds, bayous, canals).	30	1.00				
V2	% open water in bayous, canals or > 1.2m deep	10	1.00				
V3	Interspersion Class	Medium	0.50				
V4	% ponded area >=15 cm deep (May - September)	60	0.6				
V5	% substrate exposed at MLT (May - Sep) - Tidal only						
	CI (tidal) | CI (non-tidal)		0.6694				
		HSI=	0.8182	HSI=		HSI=	

Condition: Future With Project

Variable		TY 51	SI	TY	SI	TY	SI
V1	% wetland that is open water (ponds, bayous, canals).	30	1.00				
V2	% open water in bayous, canals or > 1.2m deep	10	1.00				
V3	Interspersion Class	Medium	0.50				
V4	% ponded area >=15 cm deep (May - September)	60	0.6				
V5	% substrate exposed at MLT (May - Sep) - Tidal only						
	CI (tidal) | CI (non-tidal)		0.6694				
		HSI=	0.8182	HSI=		HSI=	

Condition: Future Without Project

Variable		TY	SI	TY	SI	TY	SI
V1	% wetland that is open water (ponds, bayous, canals).						
V2	% open water in bayous, canals or > 1.2m deep						
V3	Interspersion Class						
V4	% ponded area >=15 cm deep (May - September)						
V5	% substrate exposed at MLT (May - Sep) - Tidal only						
	CI (tidal) | CI (non-tidal)						
		HSI=		HSI=		HSI=	

Condition: Future With Project

Variable		TY	SI	TY	SI	TY	SI
V1	% wetland that is open water (ponds, bayous, canals).						
V2	% open water in bayous, canals or > 1.2m deep						
V3	Interspersion Class						
V4	% ponded area >=15 cm deep (May - September)						
V5	% substrate exposed at MLT (May - Sep) - Tidal only						
	CI (tidal) | CI (non-tidal)						
		HSI=		HSI=		HSI=	

M-8 -- Palustrine Marsh Habitat (Passive Benefits of Breakwater Erosion Reduction)

American alligator HSI Model Spreadsheet

Condition: Future Without Project

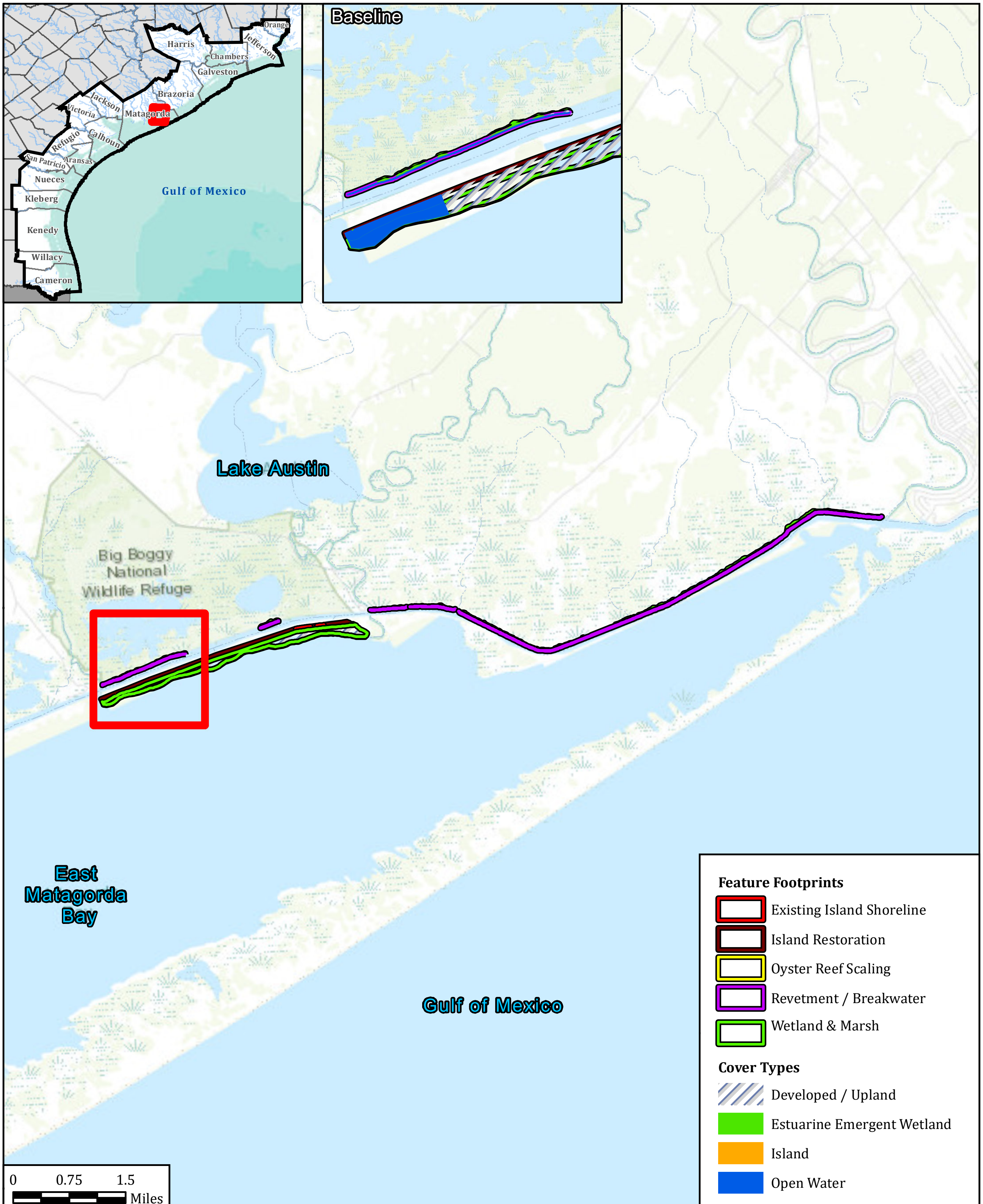
TY	Acres	HSI	Total HUs	Cumulative HUs
0	78	0.82	63.82	
1	78	0.82	63.82	63.82
31	44	0.82	36.00	1497.29
51	0	0.82	0.00	360.00
Max TY=	**51**		**AAHUs=**	**37.7**

Condition: Future With Project

TY	Acres	HSI	Total HUs	Cumulative HUs
0	78	0.82	63.82	
1	78	0.82	63.82	63.82
31	78	0.82	63.82	1914.56
51	78	0.82	63.82	1276.37
Max TY=	**51**		**AAHUs=**	**63.8**

Net Change in AAHUs due to Project

Future With Project AAHUs	63.8
Future Without Project AAHUs	37.7
Net Change	26.1



USACE COASTAL TEXAS
PROTECTION AND RESTORATION STUDY

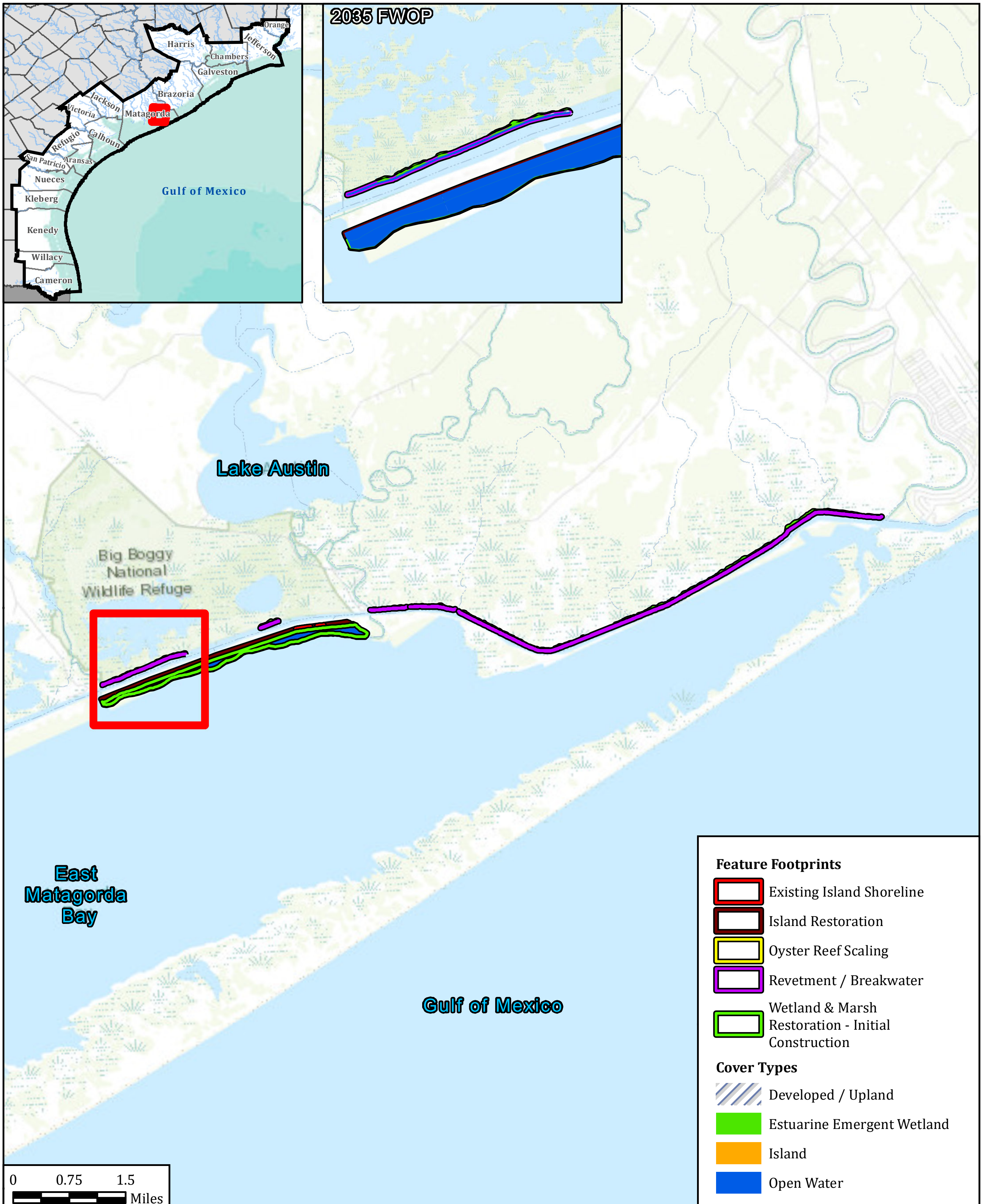
M-8 - East Matagorda Bay Shoreline Protection
Baseline Cover Types

FN JOB NO	TGL18185
FILE NAME	3_M8_Mapbook.mxd
DATE	9/2/2020
SCALE	1:112,190
DESIGNED	KLC
DRAFTED	02588

3.0
FIGURE

Base Map: ESRI World Topographic Map Service

NAD 1983 StatePlane Texas Central FIPS 4203 Feet



USACE COASTAL TEXAS
PROTECTION AND RESTORATION STUDY

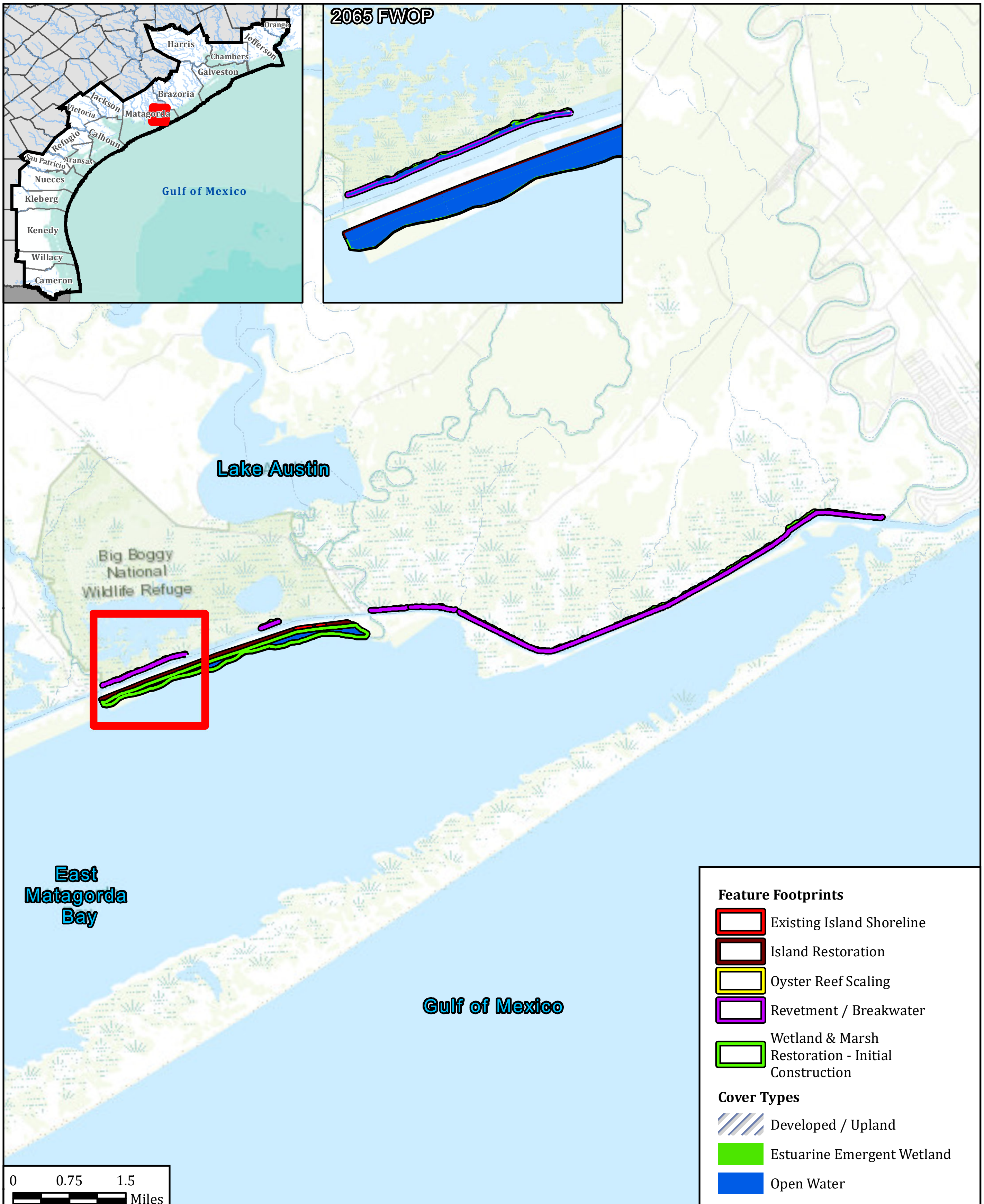
M-8 - East Matagorda Bay Shoreline Protection
2035 FWOP Cover Types

FN JOB NO	TGL18185
FILE NAME	3_M8_Mapbook.mxd
DATE	9/2/2020
SCALE	1:112,190
DESIGNED	KLC
DRAFTED	02588

3.1
FIGURE

Base Map: ESRI World Topographic Map Service

NAD 1983 StatePlane Texas Central FIPS 4203 Feet



USACE COASTAL TEXAS PROTECTION AND RESTORATION STUDY

M-8 - East Matagorda Bay Shoreline Protection 2065 FWOP Cover Types

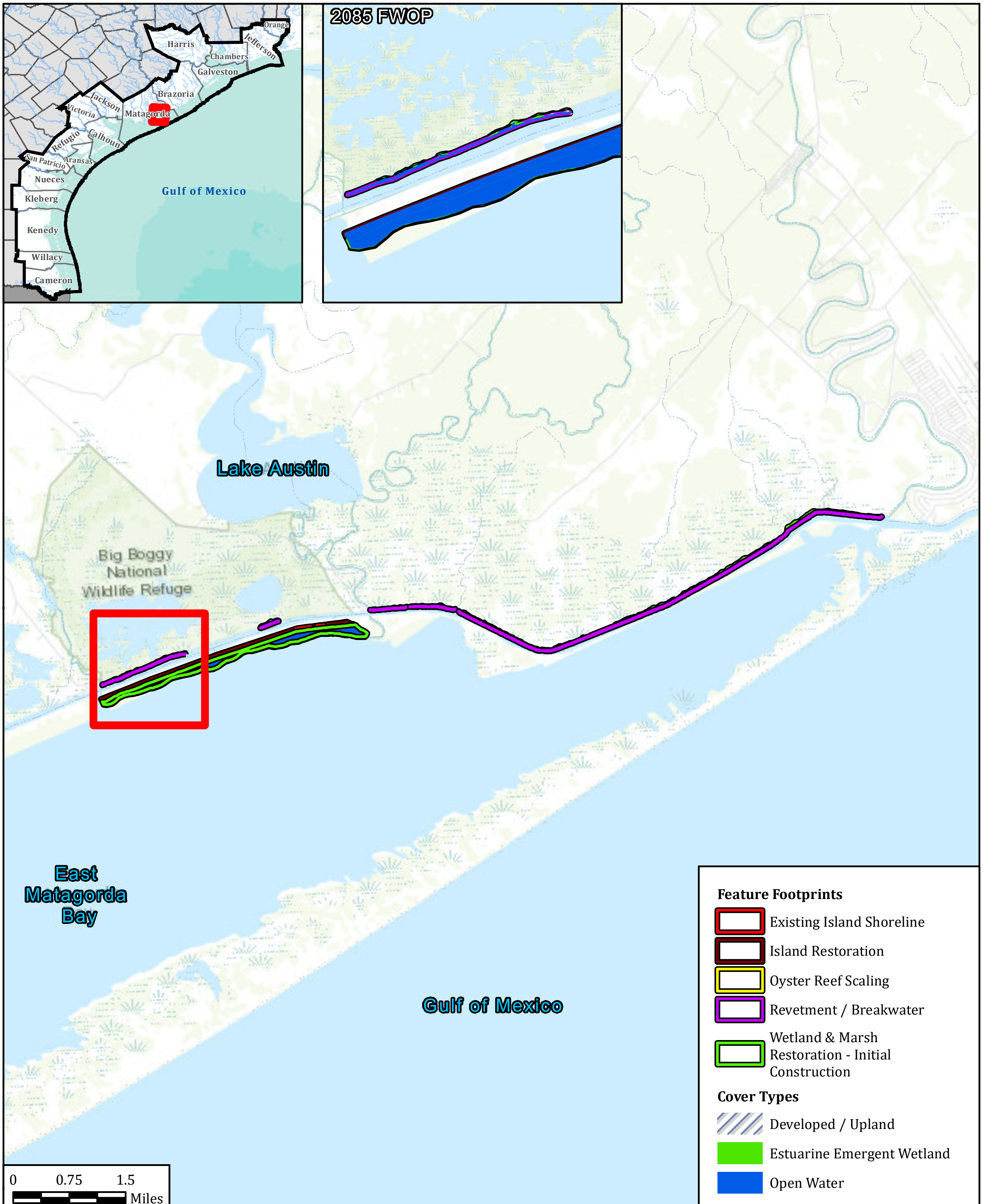
FN JOB NO	TGL18185
FILE NAME	3_M8_Mapbook.mxd
DATE	9/2/2020
SCALE	1:112,190
DESIGNED	KLC
DRAFTED	02588

3.2

FIGURE

Base Map: ESRI World Topographic Map Service

NAD 1983 StatePlane Texas Central FIPS 4203 Feet



USACE COASTAL TEXAS
PROTECTION AND RESTORATION STUDY

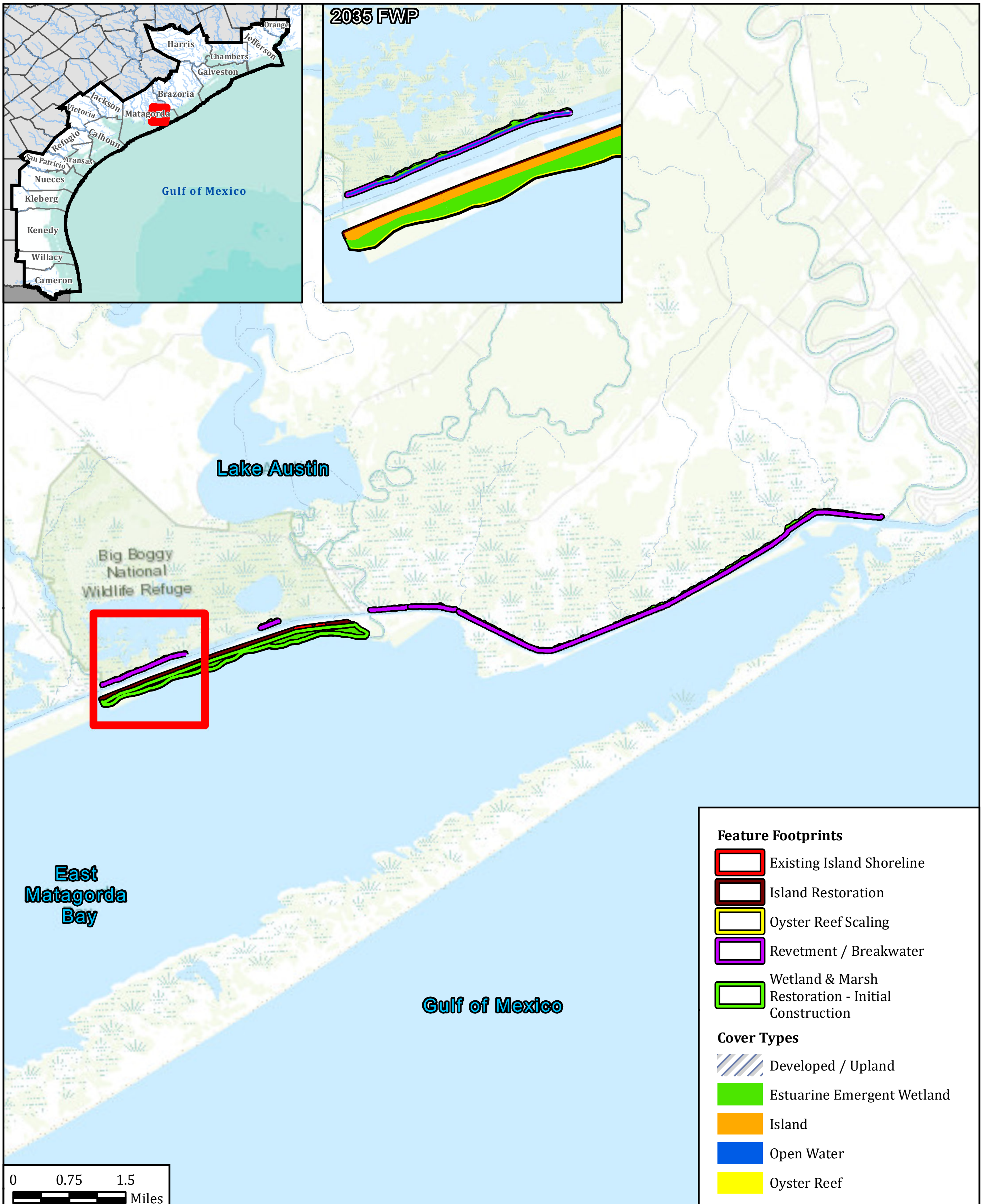
M-8 - East Matagorda Bay Shoreline Protection
2085 FWOP Cover Types

FN JOB NO	TGL18185
FILE NAME	3_M8_Mapbook.mxd
DATE	9/2/2020
SCALE	1:112,190
DESIGNED	KLC
DRAFTED	02588

3.3
FIGURE

Base Map: ESRI World Topographic Map Service

NAD 1983 StatePlane Texas Central FIPS 4203 Feet



USACE COASTAL TEXAS PROTECTION AND RESTORATION STUDY

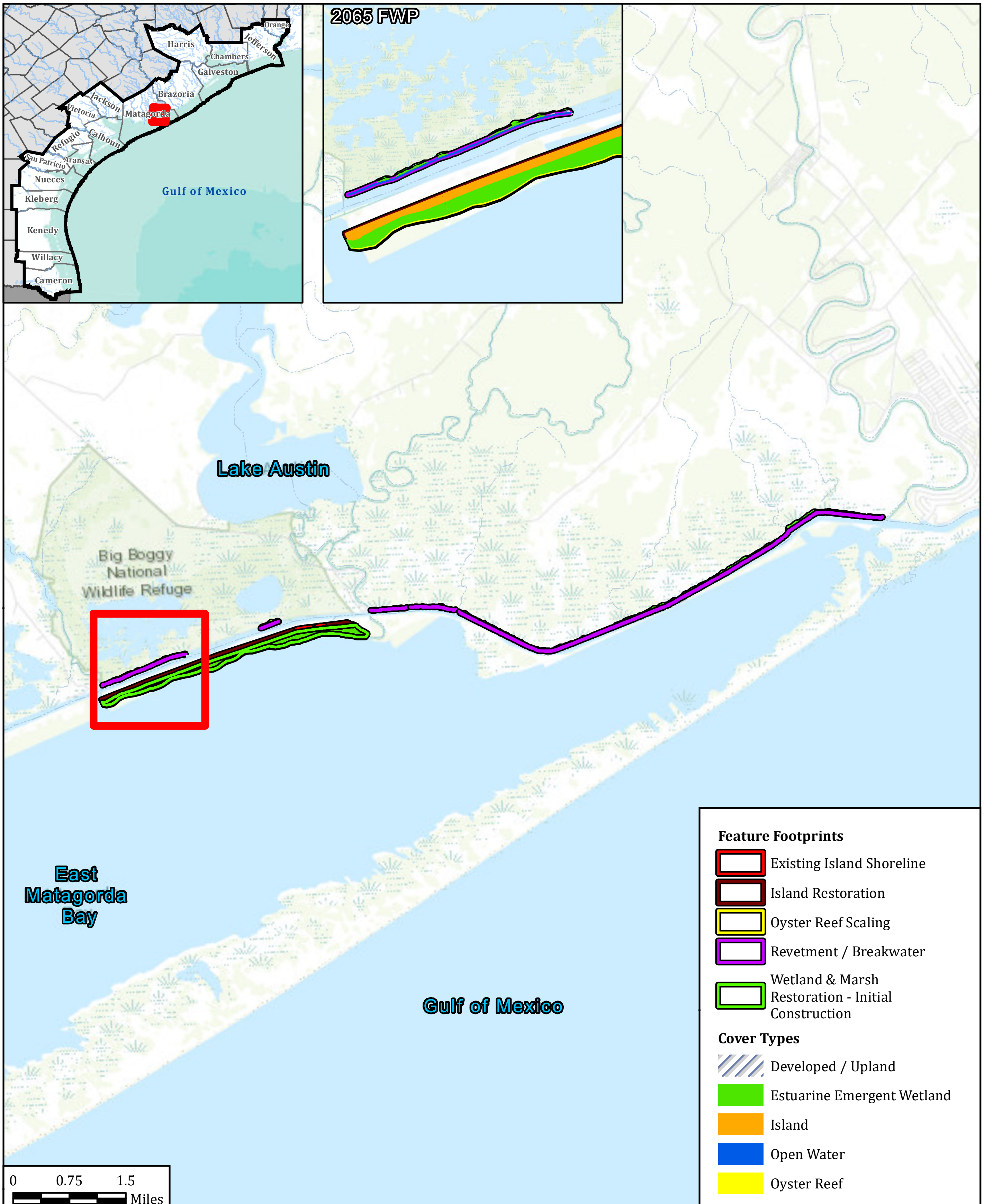
M-8 - East Matagorda Bay Shoreline Protection
2035 FWP Cover Types

FN JOB NO	TGL18185
FILE NAME	3_M8_Mapbook.mxd
DATE	9/2/2020
SCALE	1:112,190
DESIGNED	KLC
DRAFTED	02588

3.4
FIGURE

Base Map: ESRI World Topographic Map Service

NAD 1983 StatePlane Texas Central FIPS 4203 Feet



N W E S

USACE COASTAL TEXAS
PROTECTION AND RESTORATION STUDY

M-8 - East Matagorda Bay Shoreline Protection
2065 FWP Cover Types

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FILE NAME	3_M8_Mapbook.mxd
DATE	9/2/2020
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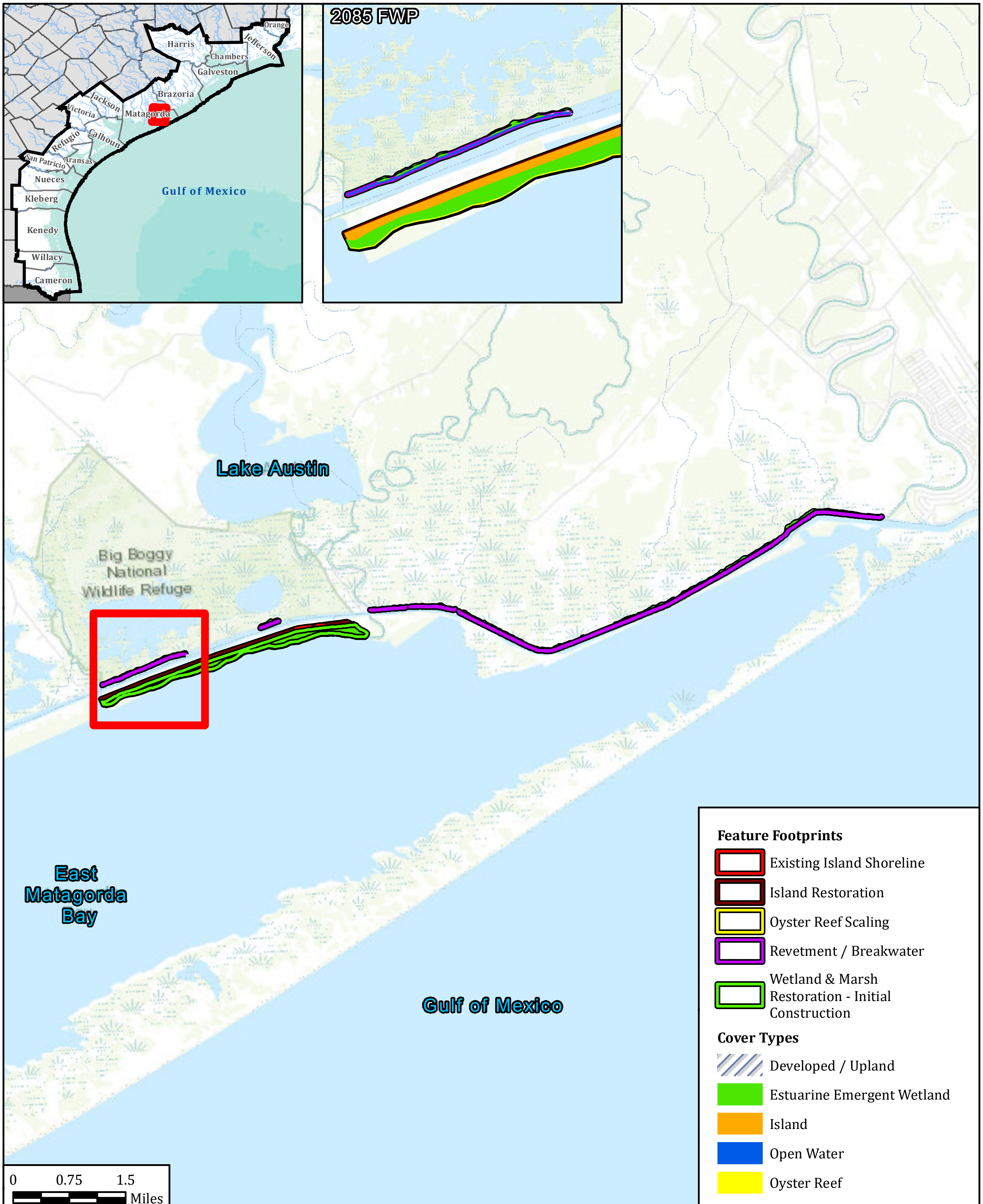
DESIGNED	KLC
DRAFTED	02588

3.5

FIGURE

Base Map: ESRI World Topographic Map Service

NAD 1983 StatePlane Texas Central FIPS 4203 Feet



USACE COASTAL TEXAS
PROTECTION AND RESTORATION STUDY

M-8 - East Matagorda Bay Shoreline Protection
2085 FWP Cover Types

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FILE NAME	3_M8_Mapbook.mxd
DATE	9/2/2020
SCALE	1:112,190
DESIGNED	KLC
DRAFTED	02588

3.6
FIGURE

Base Map: ESRI World Topographic Map Service

NAD 1983 StatePlane Texas Central FIPS 4203 Feet

ER Measure M8 East Matagorda Bay Shoreline Protection

Shoreline (2018)

NWI Polygon

2035 Interstitial Benefit Area

NWI Polygon

2035 Benefit Area

NWI Polygon

2065 Benefit Area

NWI Polygon

2085 Benefit Area

ER Measure

Breakwater

Island Restoration

Oyster Reef Scaling

Wetland / Marsh Restoration

US Army Corps of Engineers ® Galveston District

Coastal Texas Protection and Restoration Feasibility Study

Ecosystem Restoration Passive Benefits

DATUM: NAD 1983
PROJECTION: STATE PLANE
ZONE: TX-SC 4204

Basemap: 2018 NAIP

0 0.5 1 Miles

Date: 30 March 2021

Page: 1

ER Measure M8
East Matagorda Bay
Shoreline Protection

Shoreline (2018)

NWI Polygon

2035 Interstitial Benefit Area

NWI Polygon

2035 Benefit Area

NWI Polygon

2065 Benefit Area

NWI Polygon

2085 Benefit Area

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0 0.5 1 Miles

Date: 30 March 2021

ER Measure M8
East Matagorda Bay
Shoreline Protection

Shoreline (2018)

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2035 Interstitial Benefit Area

NWI Polygon

2035 Benefit Area

NWI Polygon

2065 Benefit Area

NWI Polygon

2085 Benefit Area

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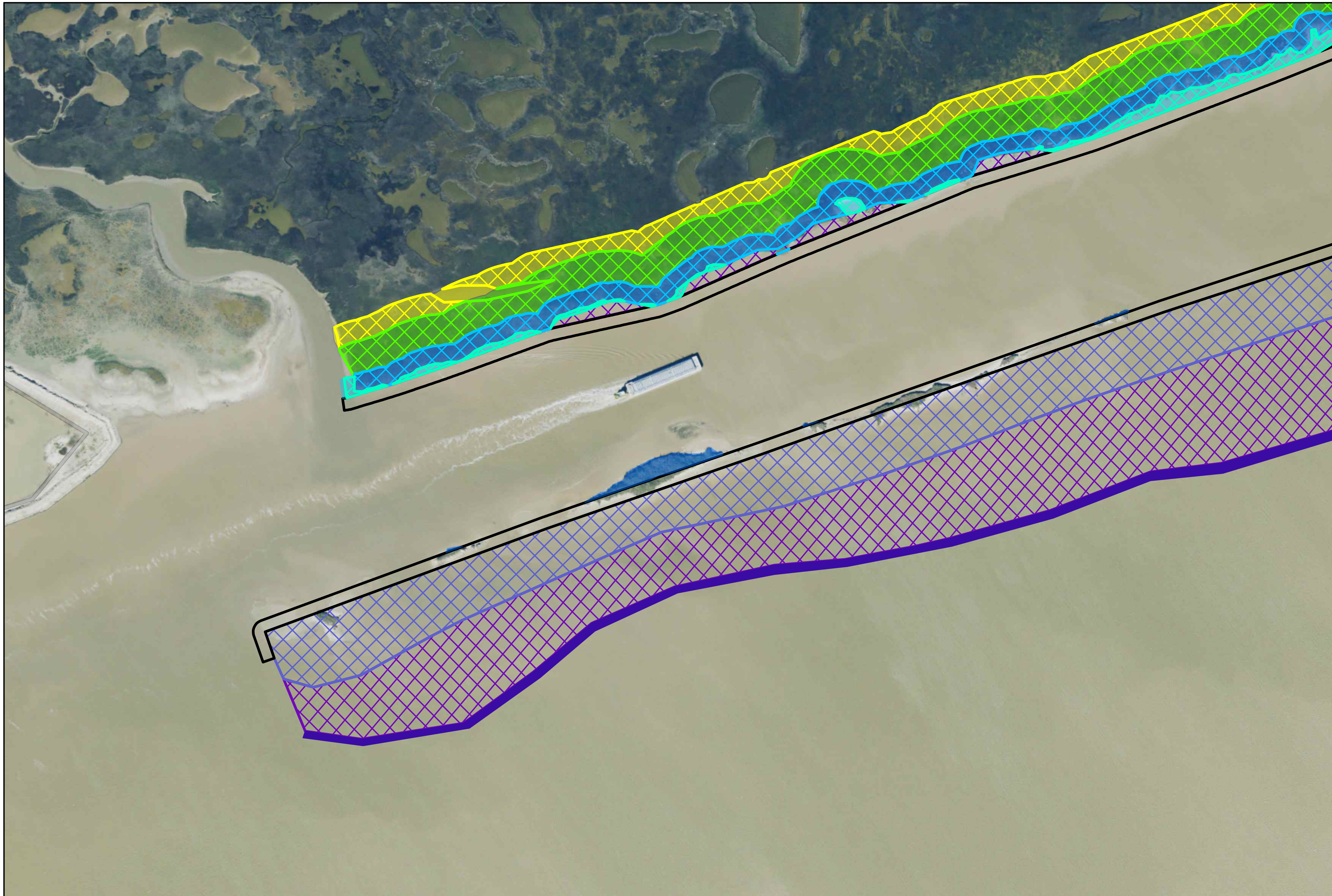

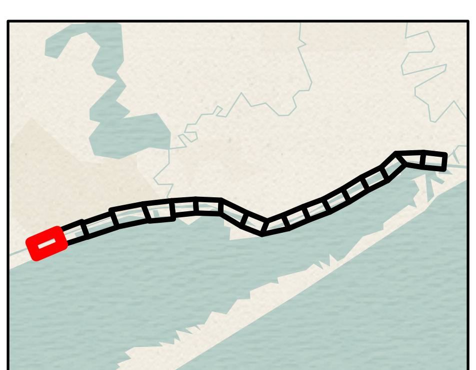

US Army Corps of Engineers ®
Galveston District

Texas General Land Office
Established 1836

Coastal Texas Protection and Restoration Feasibility Study

Ecosystem Restoration Passive Benefits

DATUM: NAD 1983
PROJECTION: STATE PLANE
ZONE: TX-SC 4204

Basemap: 2018 NAIP

0 250 500 Feet

Date: 30 March 2021

ER Measure M8
East Matagorda Bay
Shoreline Protection

Shoreline (2018)
NWI Polygon
2035 Interstitial Benefit Area
NWI Polygon
2035 Benefit Area
NWI Polygon
2065 Benefit Area
NWI Polygon
2085 Benefit Area

ER Measure
Breakwater
Island Restoration
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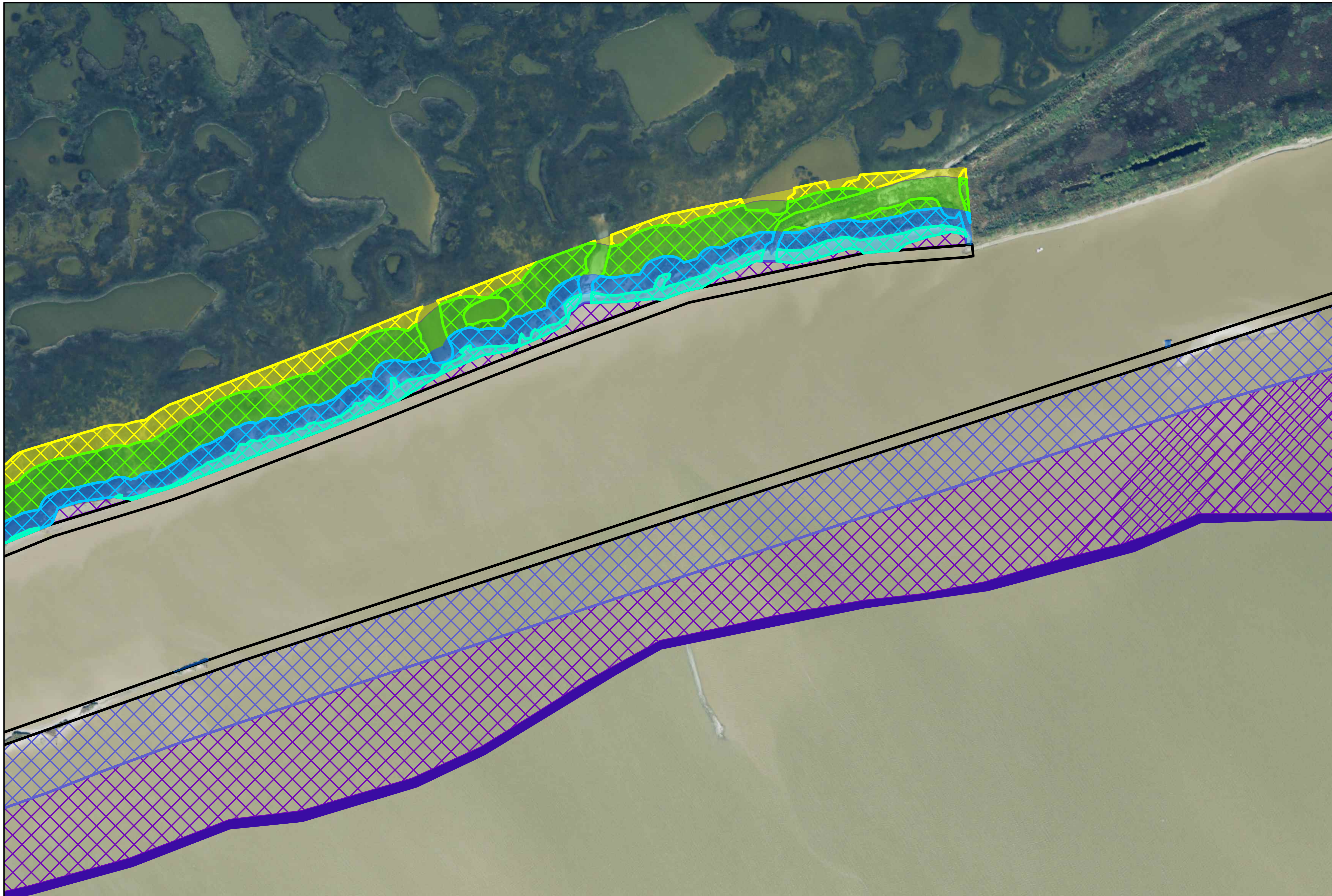

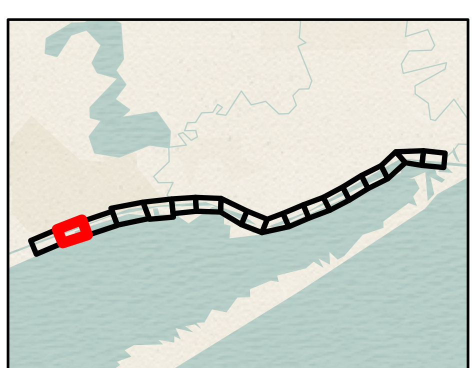

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Coastal Texas Protection and Restoration Feasibility Study

Ecosystem Restoration Passive Benefits

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East Matagorda Bay
Shoreline Protection

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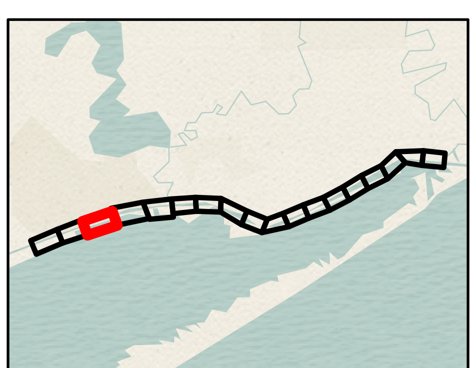

US Army Corps of Engineers ®
Galveston District

TEXAS GENERAL LAND OFFICE
ESTABLISHED 1836

Coastal Texas Protection and Restoration Feasibility Study

Ecosystem Restoration Passive Benefits

DATUM: NAD 1983
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East Matagorda Bay
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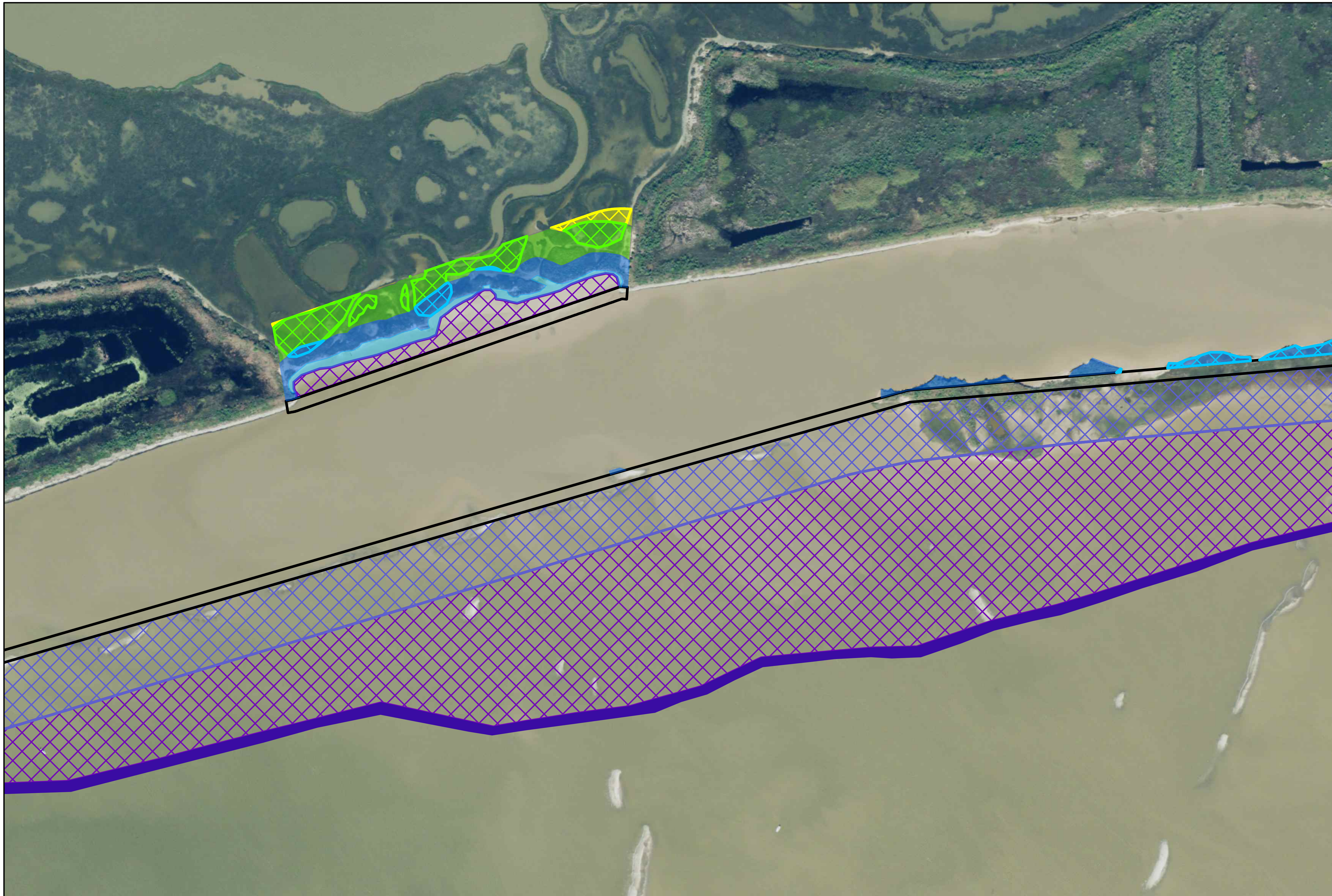

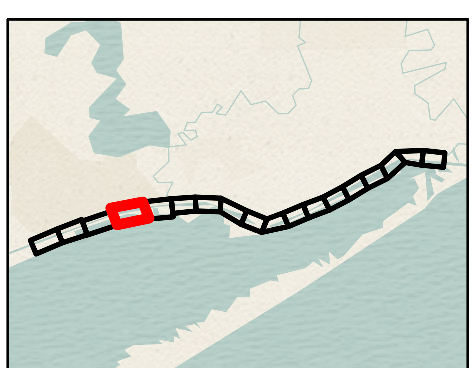

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Coastal Texas Protection and Restoration Feasibility Study

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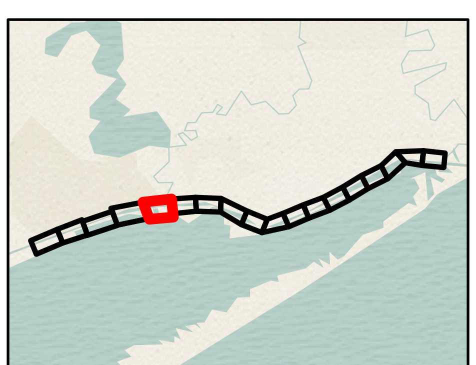

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Galveston District

Coastal Texas Protection and Restoration Feasibility Study

Ecosystem Restoration Passive Benefits

DATUM: NAD 1983
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ER Measure M8
East Matagorda Bay
Shoreline Protection

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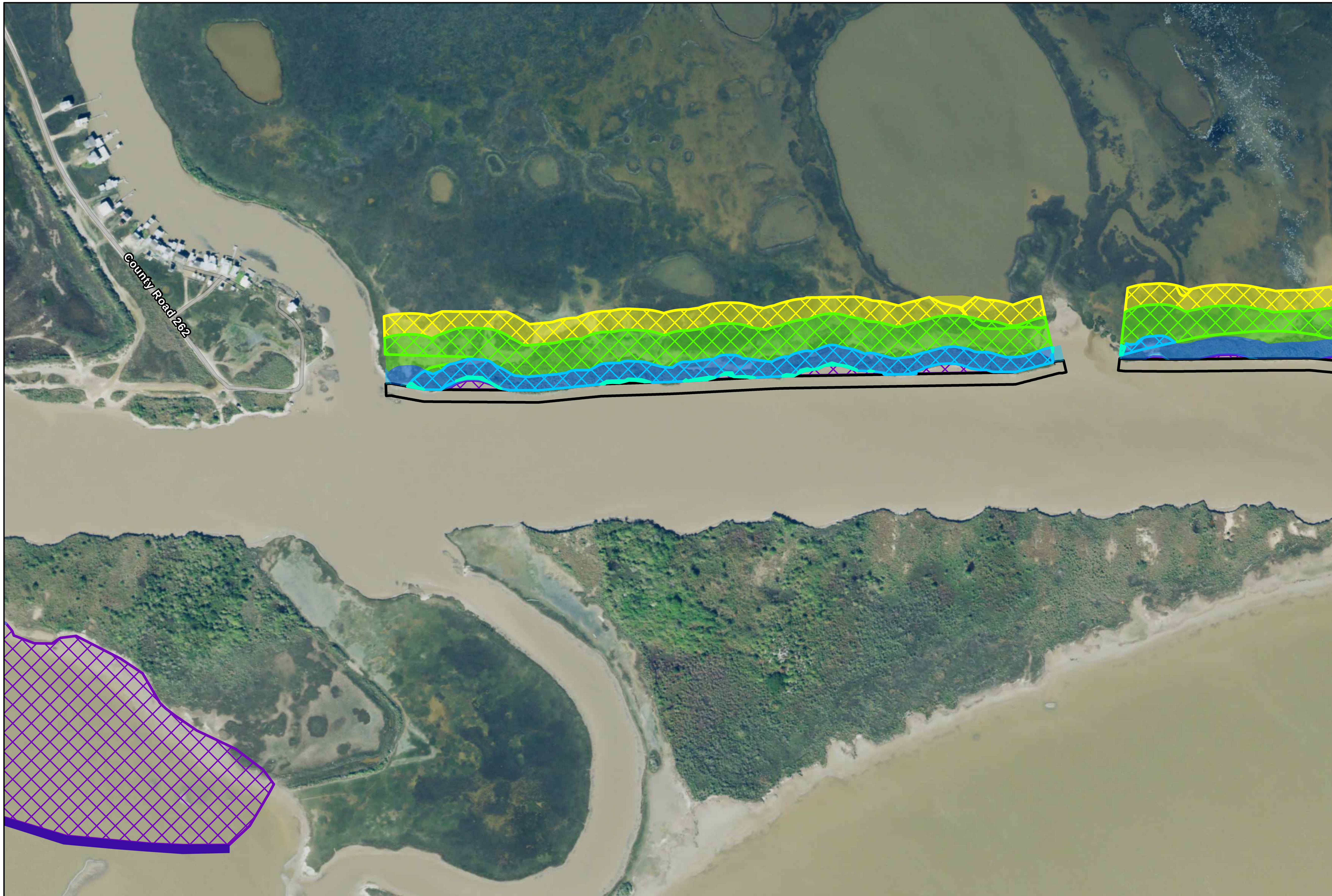

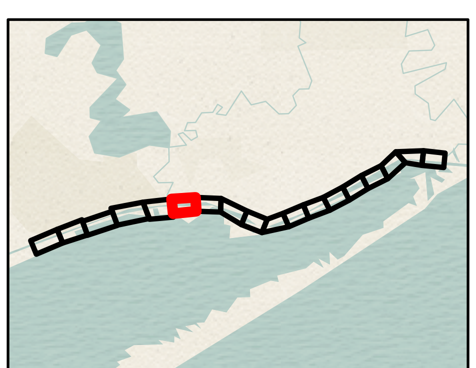

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Coastal Texas Protection and Restoration Feasibility Study

Ecosystem Restoration Passive Benefits

DATUM: NAD 1983
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ER Measure M8
East Matagorda Bay
Shoreline Protection

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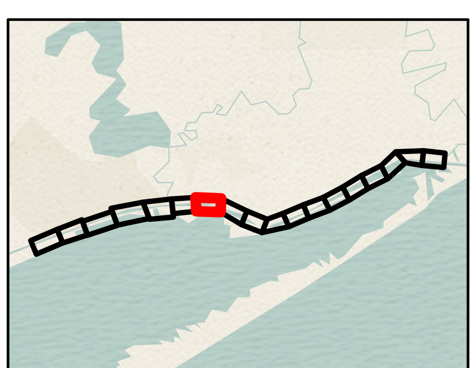

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Coastal Texas Protection and Restoration Feasibility Study

Ecosystem Restoration Passive Benefits

DATUM: NAD 1983
PROJECTION: STATE PLANE
ZONE: TX-SC 4204

Basemap: 2018 NAIP

0 250 500 Feet

Date: 30 March 2021

ER Measure M8 East Matagorda Bay Shoreline Protection

Shoreline (2018)

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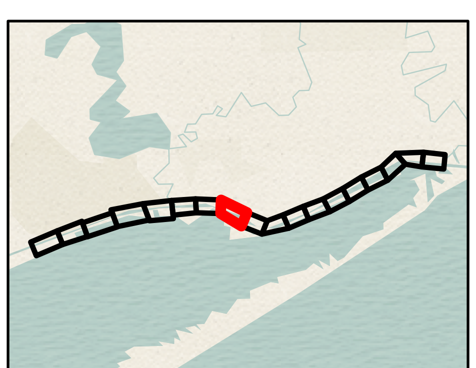

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Coastal Texas Protection and Restoration Feasibility Study

Ecosystem Restoration Passive Benefits

DATUM: NAD 1983
PROJECTION: STATE PLANE
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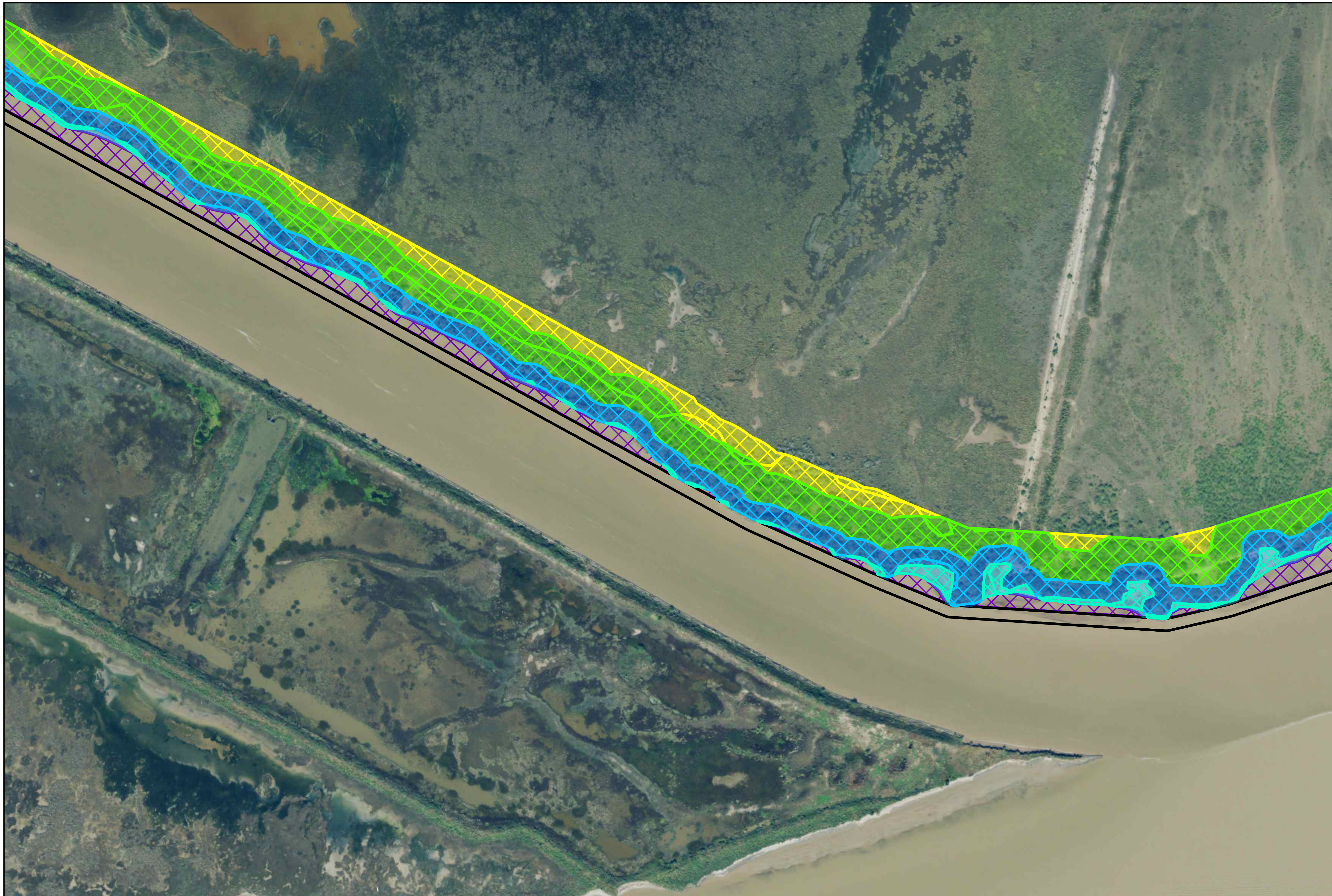

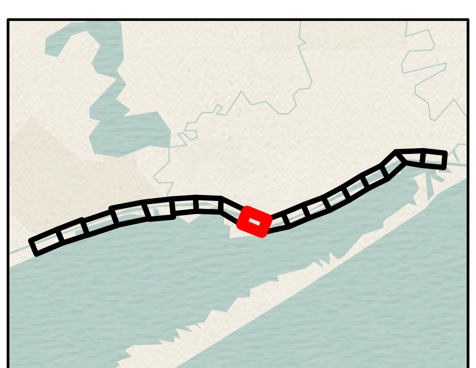

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Galveston District

Coastal Texas Protection and Restoration Feasibility Study

Ecosystem Restoration Passive Benefits

DATUM: NAD 1983
PROJECTION: STATE PLANE
ZONE: TX-SC 4204

Basemap: 2018 NAIP

0 250 500 Feet

Date: 30 March 2021

ER Measure M8
East Matagorda Bay
Shoreline Protection

Shoreline (2018)

NWI Polygon

2035 Interstitial Benefit Area

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2035 Benefit Area

NWI Polygon

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NWI Polygon

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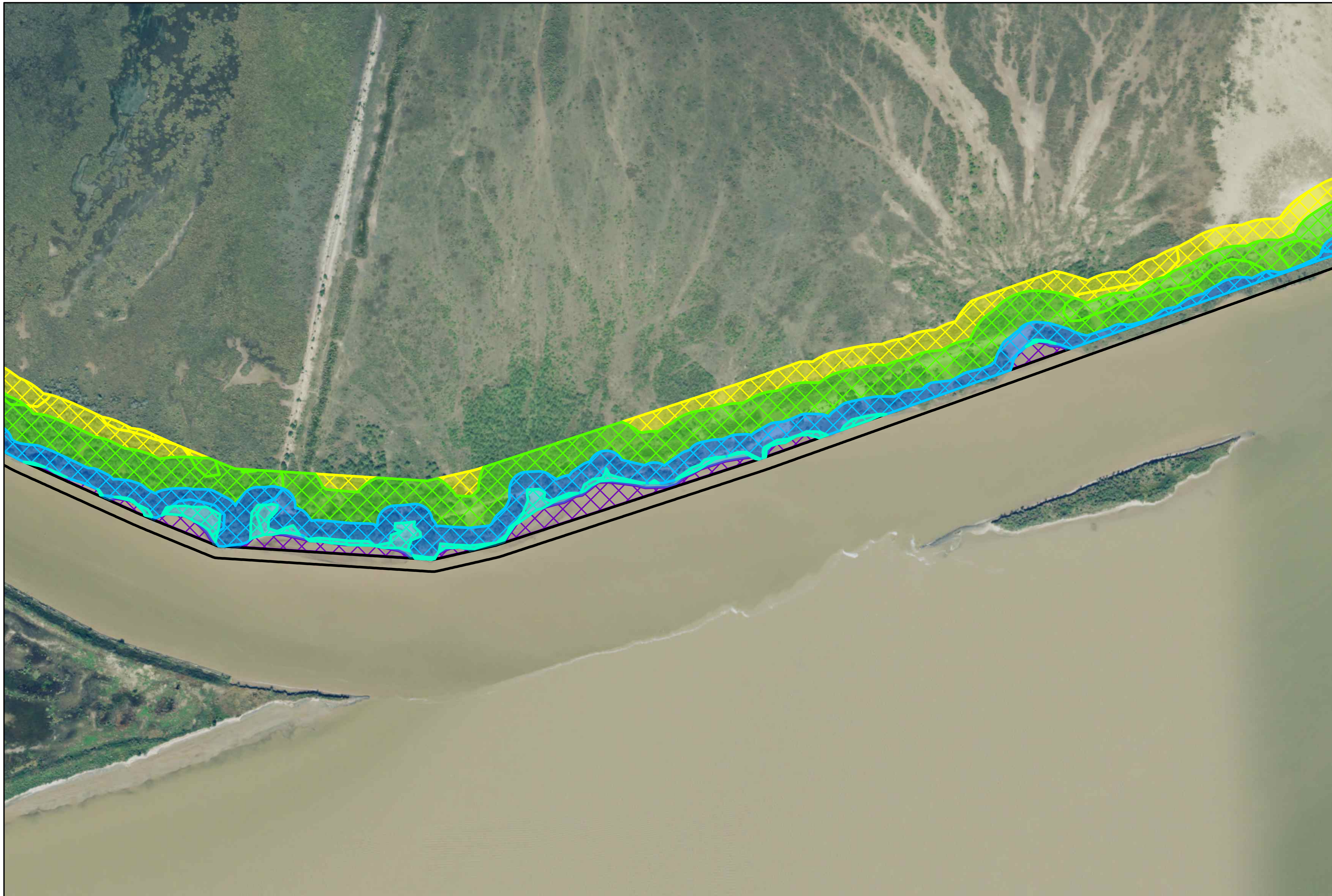

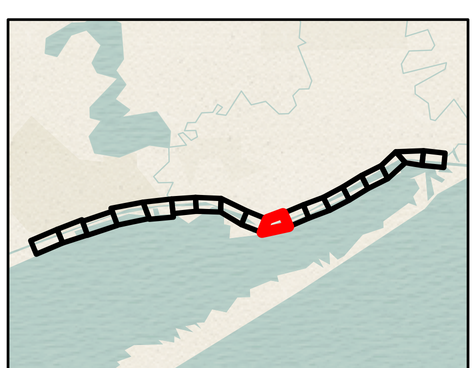

US Army Corps of Engineers ®
Galveston District

Coastal Texas Protection and Restoration Feasibility Study

Ecosystem Restoration Passive Benefits

DATUM: NAD 1983
PROJECTION: STATE PLANE
ZONE: TX-SC 4204

Basemap: 2018 NAIP

0 250 500 Feet

Date: 30 March 2021

ER Measure M8 East Matagorda Bay Shoreline Protection

Shoreline (2018)

NWI Polygon

2035 Interstitial Benefit Area

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NWI Polygon

2065 Benefit Area

NWI Polygon

2085 Benefit Area

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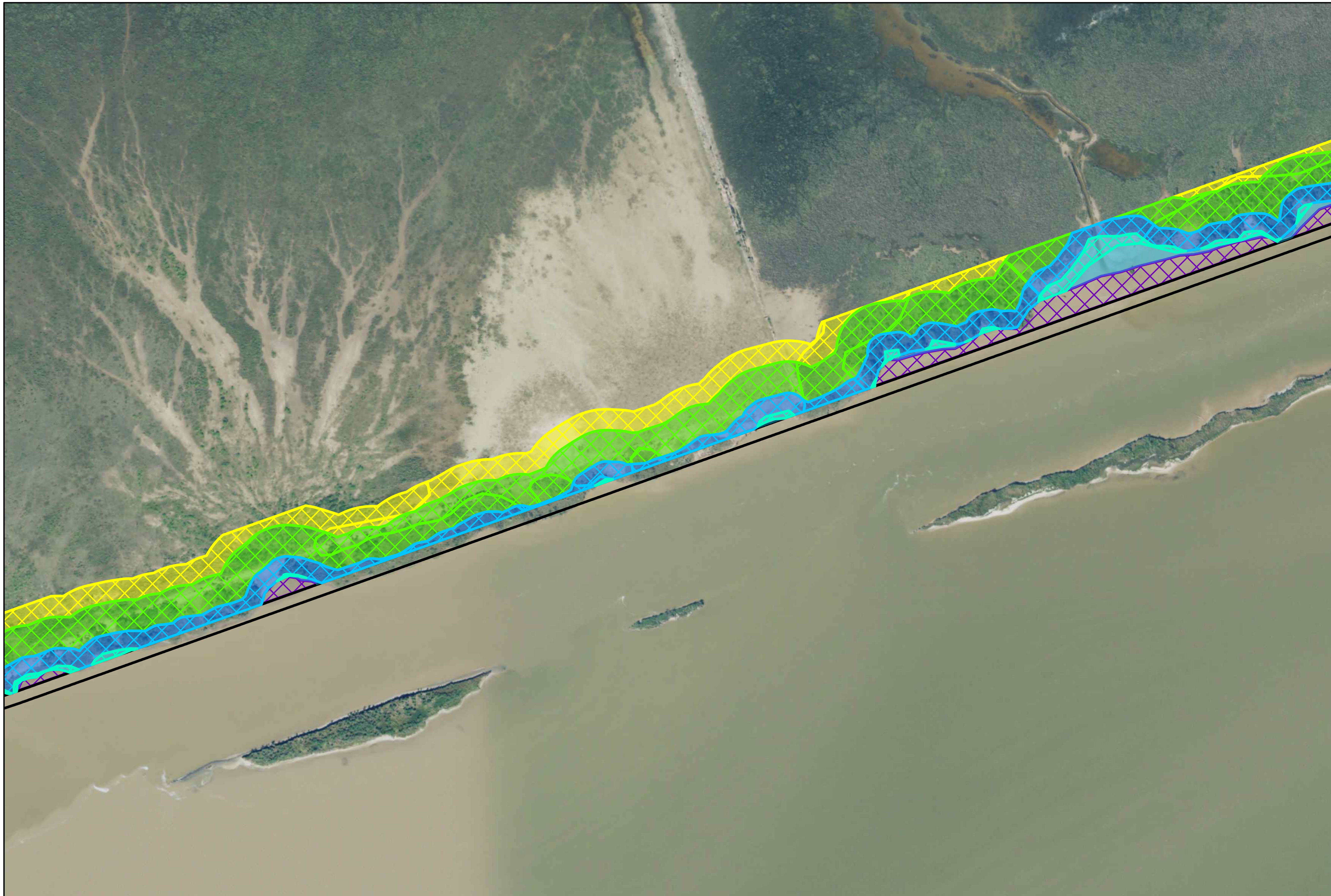
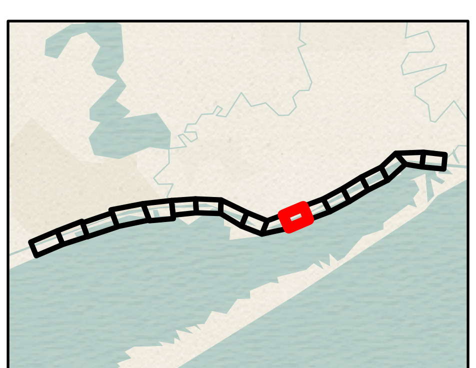




US Army Corps of Engineers ®
Galveston District

Coastal Texas Protection and Restoration Feasibility Study

Ecosystem Restoration Passive Benefits

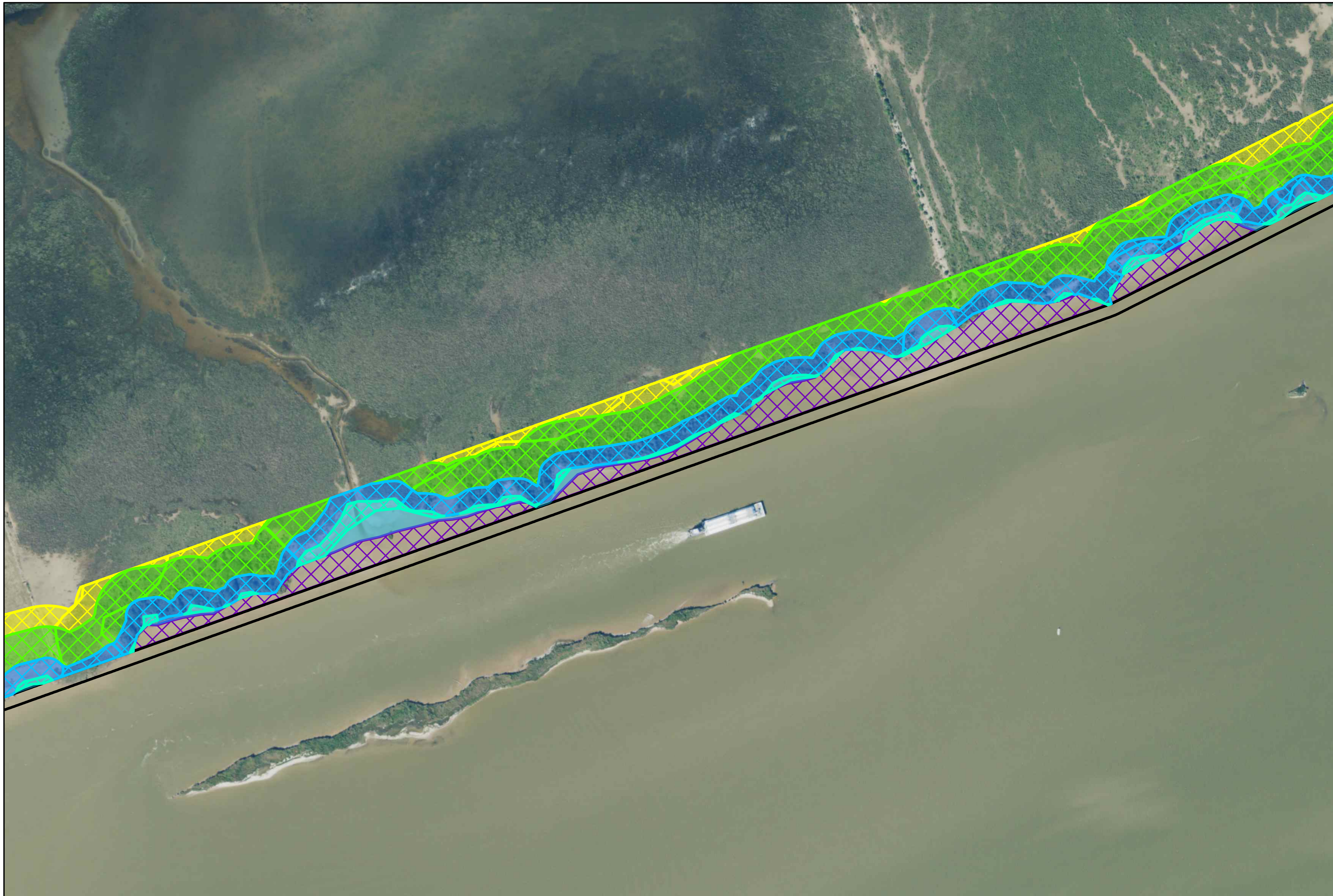
DATUM: NAD 1983
PROJECTION: STATE PLANE
ZONE: TX-SC 4204

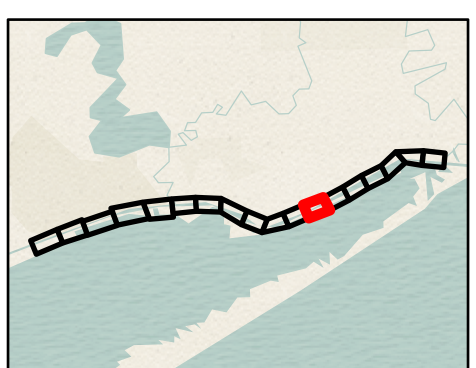
Basemap: 2018 NAIP

0 250 500 Feet

Date: 30 March 2021

ER Measure M8 East Matagorda Bay Shoreline Protection





US Army Corps of Engineers ® Galveston District

Coastal Texas Protection and Restoration Feasibility Study

Ecosystem Restoration Passive Benefits

DATUM: NAD 1983
PROJECTION: STATE PLANE
ZONE: TX-SC 4204

Basemap: 2018 NAIP

0 250 500 Feet

Date: 30 March 2021

ER Measure M8 East Matagorda Bay Shoreline Protection

Shoreline (2018)

NWI Polygon

2035 Interstitial Benefit Area

NWI Polygon

2035 Benefit Area

NWI Polygon

2065 Benefit Area

NWI Polygon

2085 Benefit Area

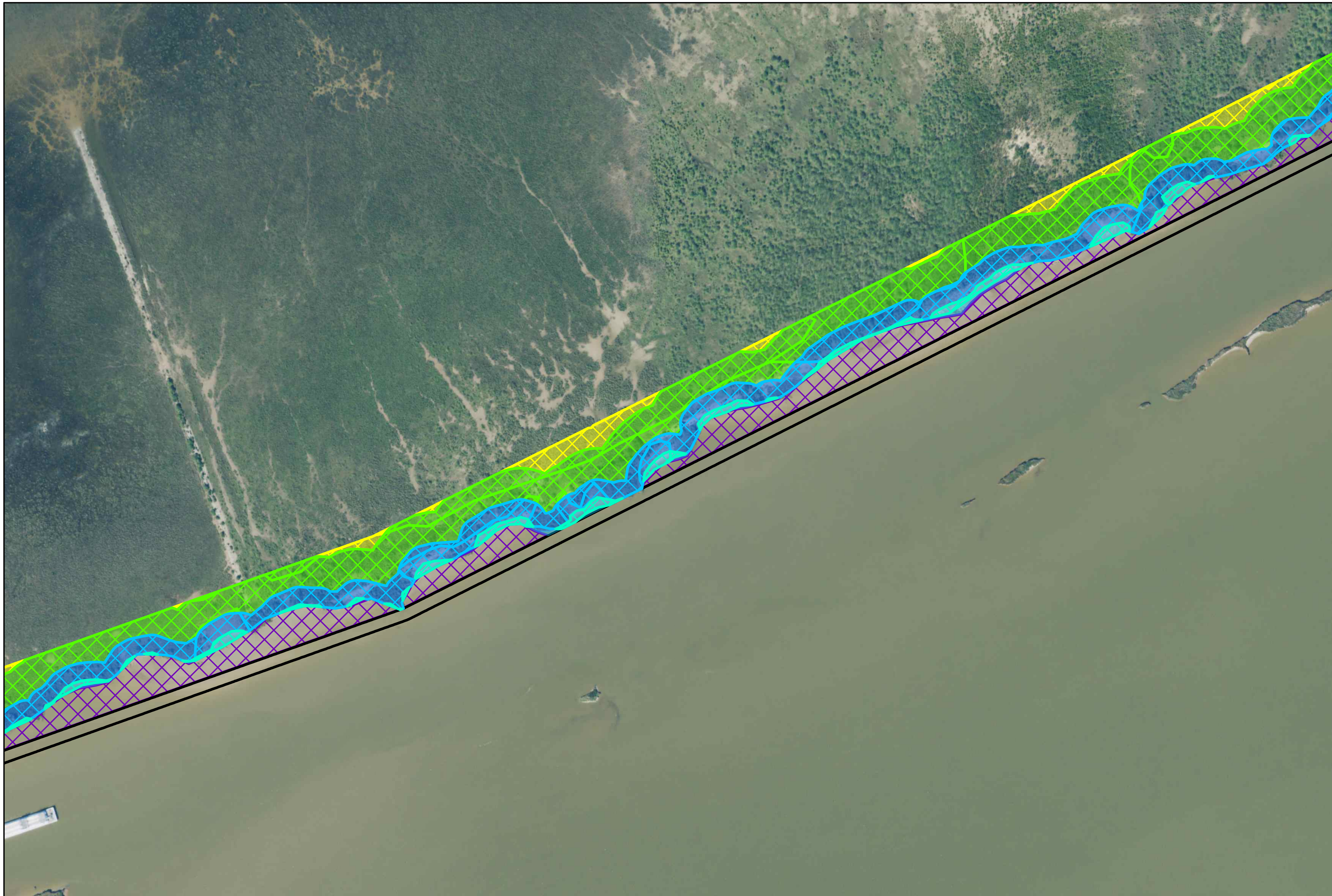
ER Measure

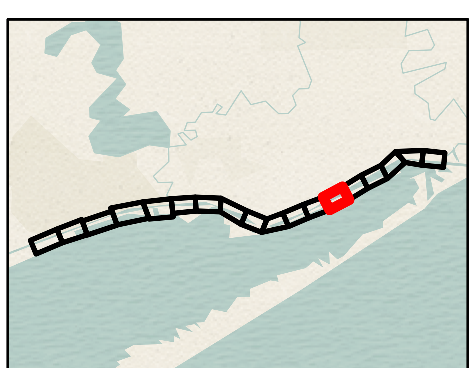
Breakwater

Island Restoration

Oyster Reef Scaling

Wetland / Marsh Restoration





US Army Corps of Engineers ®
Galveston District

Coastal Texas Protection and Restoration Feasibility Study

Ecosystem Restoration Passive Benefits

DATUM: NAD 1983
PROJECTION: STATE PLANE
ZONE: TX-SC 4204

Basemap: 2018 NAIP

0 250 500 Feet

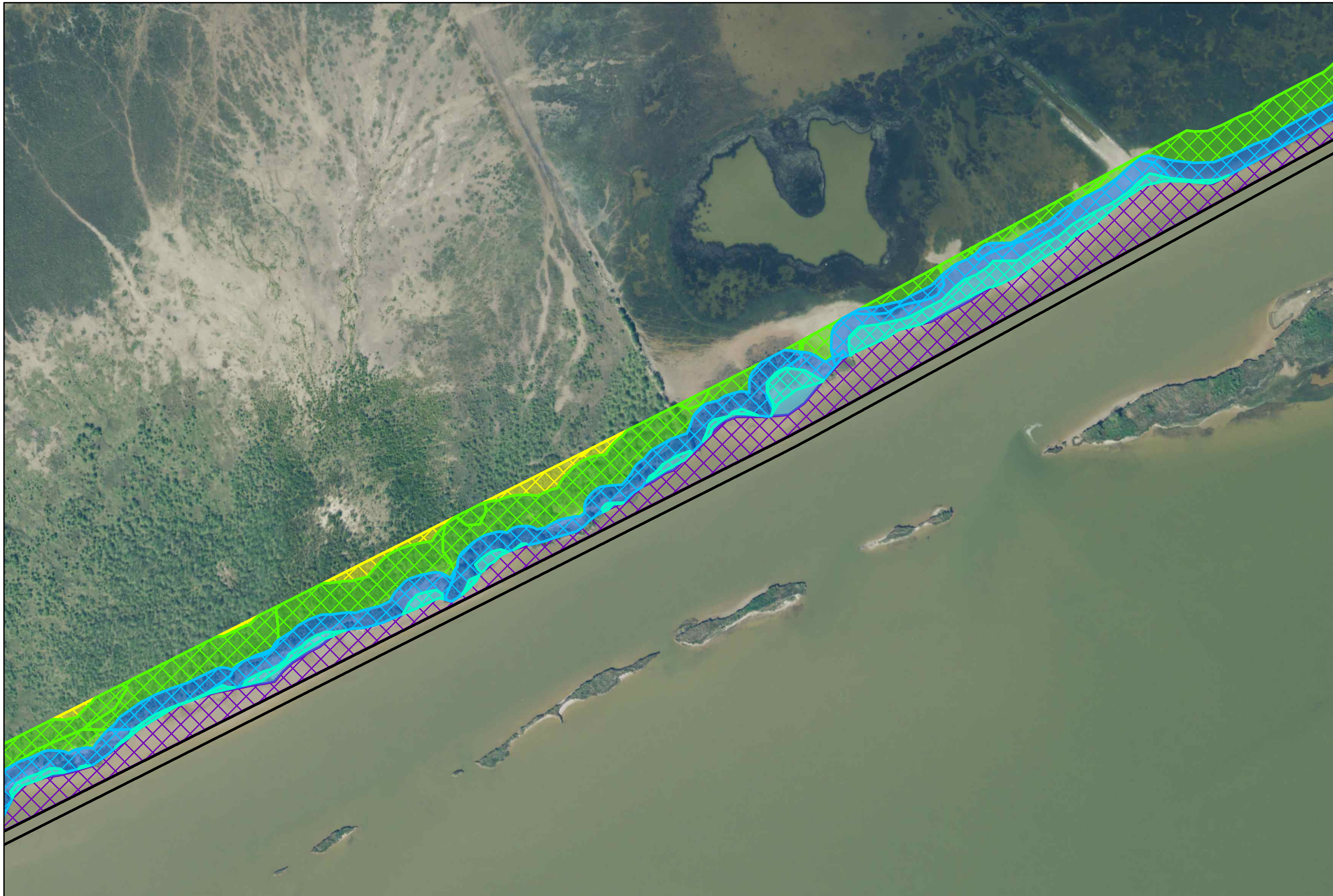
Date: 30 March 2021

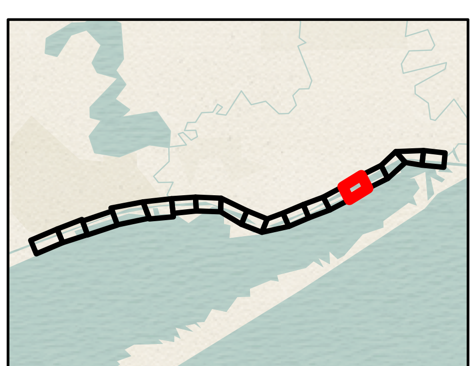
ER Measure M8
East Matagorda Bay
Shoreline Protection

- Shoreline (2018)
- NWI Polygon
- 2035 Interstitial Benefit Area
- NWI Polygon
- 2035 Benefit Area
- NWI Polygon
- 2065 Benefit Area
- NWI Polygon
- 2085 Benefit Area

ER Measure

- Breakwater
- Island Restoration
- Oyster Reef Scaling
- Wetland / Marsh Restoration





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Galveston District

TEXAS GENERAL LAND OFFICE
ESTABLISHED 1836

Coastal Texas Protection and Restoration Feasibility Study

Ecosystem Restoration Passive Benefits

μ

DATUM: NAD 1983
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ZONE: TX-SC 4204

Basemap: 2018 NAIP

0 250 500 Feet

Date: 30 March 2021

ER Measure M8
East Matagorda Bay
Shoreline Protection

Shoreline (2018)

NWI Polygon

2035 Interstitial Benefit Area

NWI Polygon

2035 Benefit Area

NWI Polygon

2065 Benefit Area

NWI Polygon

2085 Benefit Area

ER Measure

Breakwater

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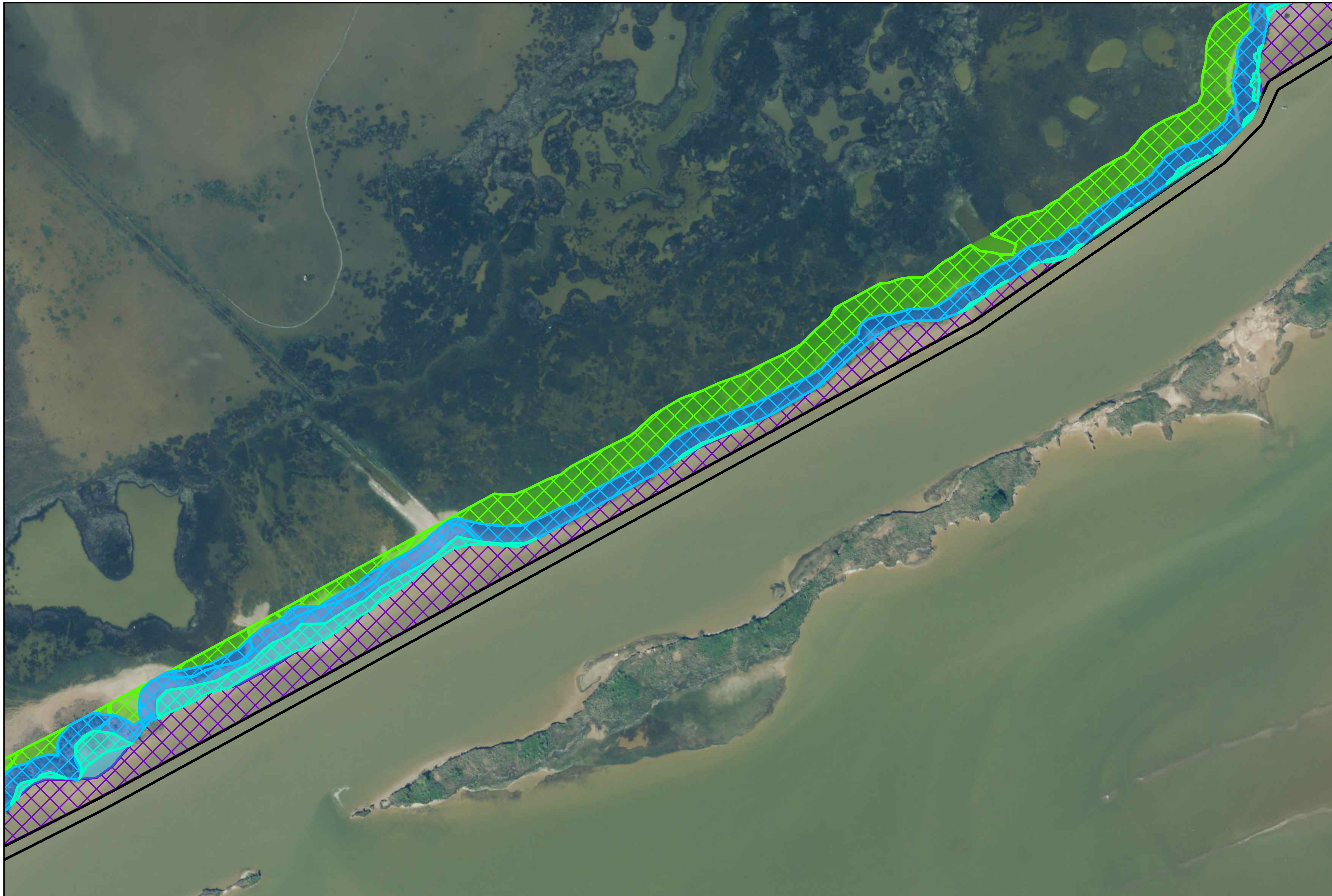
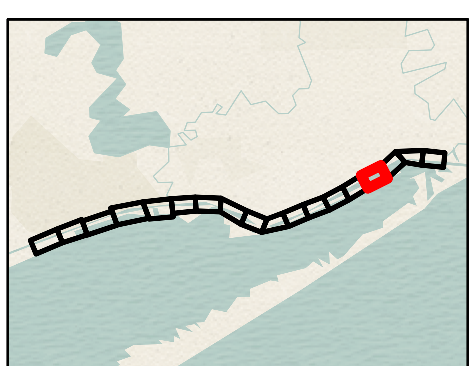
Oyster Reef Scaling

Wetland / Marsh Restoration





US Army Corps of Engineers ®
Galveston District

TEXAS GENERAL LAND OFFICE
ESTABLISHED 1836

Coastal Texas Protection and Restoration Feasibility Study

Ecosystem Restoration Passive Benefits

DATUM: NAD 1983
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ZONE: TX-SC 4204

Basemap: 2018 NAIP

0 250 500 Feet

Date: 30 March 2021

ER Measure M8
East Matagorda Bay
Shoreline Protection

Shoreline (2018)

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2065 Benefit Area

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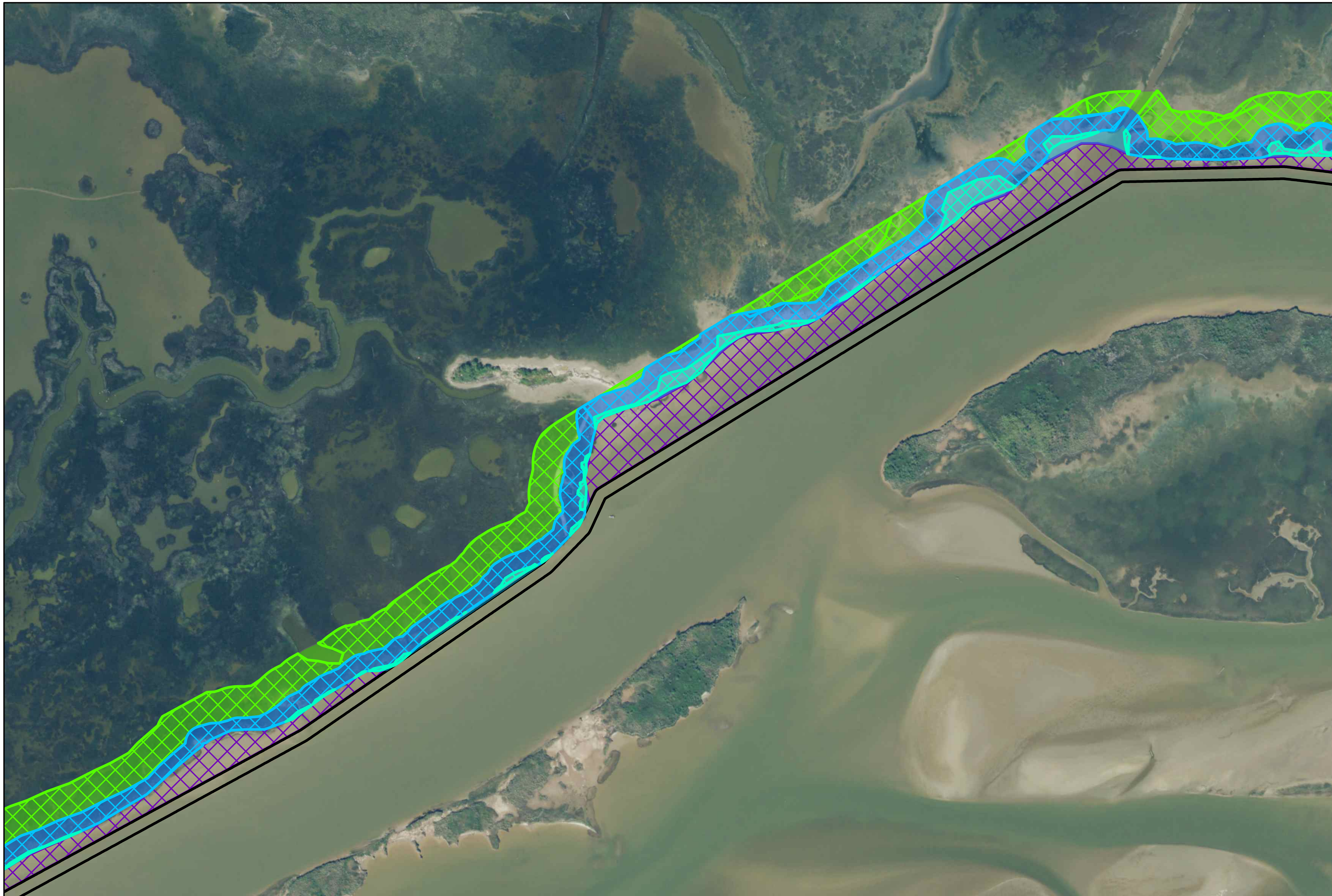
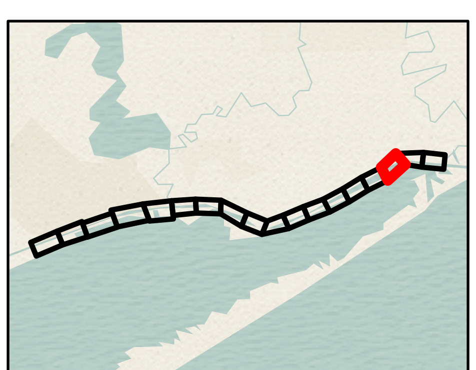
Oyster Reef Scaling

Wetland / Marsh Restoration





US Army Corps of Engineers ®
Galveston District

Coastal Texas Protection and Restoration Feasibility Study

Ecosystem Restoration Passive Benefits

DATUM: NAD 1983
PROJECTION: STATE PLANE
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East Matagorda Bay
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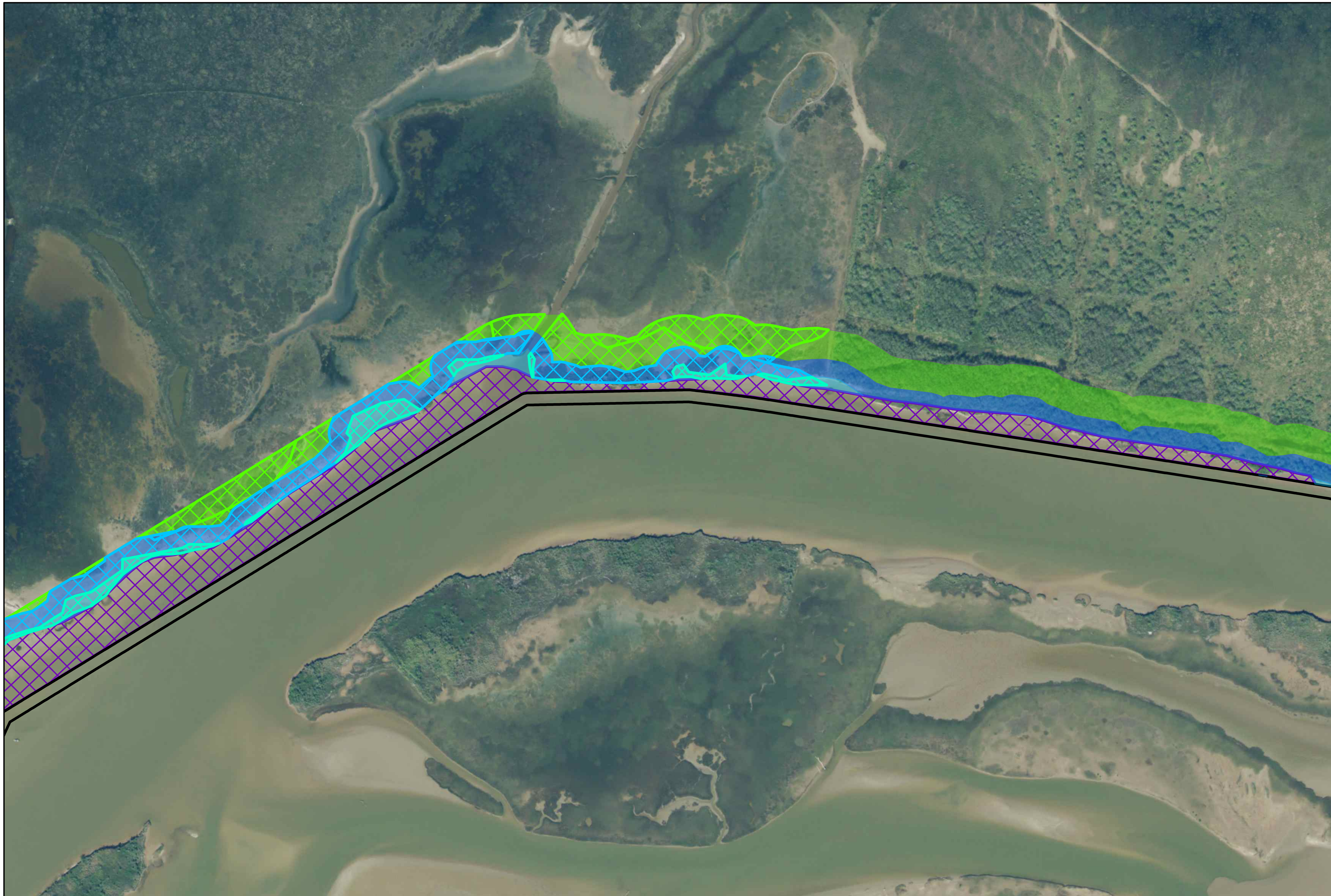

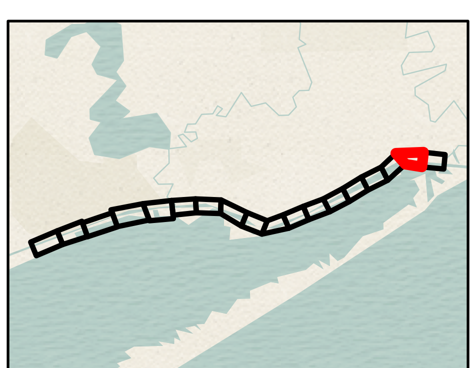

US Army Corps of Engineers ®
Galveston District

Coastal Texas Protection and Restoration Feasibility Study

Ecosystem Restoration Passive Benefits

DATUM: NAD 1983
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ER Measure M8
East Matagorda Bay
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NWI Polygon

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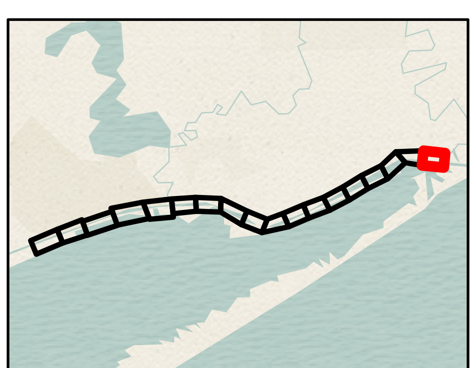
Oyster Reef Scaling

Wetland / Marsh Restoration



US Army Corps of Engineers ®
Galveston District

Coastal Texas Protection and Restoration Feasibility Study

Ecosystem Restoration Passive Benefits

DATUM: NAD 1983
PROJECTION: STATE PLANE
ZONE: TX-SC 4204

Basemap: 2018 NAIP

0 250 500 Feet

Date: 30 March 2021

CA-5

Habitat Modeling

CA-5 -- Seagrass Habitat

Project: CA-5 Spotted Seatrout

Condition: Future Without Project

Timeframe / Site Inputs		TY-1	TY-2	TY-3
TY	Target Year	0	1	31
Acres	Affected Acreage by Target Year	295.83	0	0
Function Inputs				
V1	Lowest monthly mean winter and spring salinity (ppt) (Range 0 to 50 ppt)	20	21	23
V2	Highest monthly mean summer salinity (ppt) (Range 0 to 50 ppt)	28	30	32
V3	Lowest monthly mean winter water temperature (°C) (Range 0 to 50 °C)	16	16	16
V4	HIghest monthly mean summer water temperature (°C) (Range 0 to 50 °C)	33	33	33
V5	Percent of area with submerged and/or emergent vegetation, submerged islands, shell reefs, or oyster beds. (Range 0 to 100 %)	50	0	0
HSI	Habitat Suitability Index	0.81	0.00	0.00

Condition: Future With Project

Timeframe / Site Inputs		TY-1	TY-2	TY-3
TY	Target Year	0	5	10
Acres	Affected Acreage by Target Year	295.83	295.83	295.83
Function Inputs				
V1	Lowest monthly mean winter and spring salinity (ppt) (Range 0 to 50 ppt)	20	21	23
V2	Highest monthly mean summer salinity (ppt) (Range 0 to 50 ppt)	28	30	32
V3	Lowest monthly mean winter water temperature (°C) (Range 0 to 50 °C)	16	16	16
V4	HIghest monthly mean summer water temperature (°C) (Range 0 to 50 °C)	33	33	33
V5	Percent of area with submerged and/or emergent vegetation, submerged islands, shell reefs, or oyster beds. (Range 0 to 100 %)	50	50	50
HSI	Habitat Suitability Index	0.81	0.81	0.81

Condition: Future Without Project

Timeframe / Site Inputs		TY-4	TY-5	TY-6
TY	Target Year	51	61	71
Acres	Affected Acreage by Target Year	0	10000	1000
Function Inputs				
V1	Lowest monthly mean winter and spring salinity (ppt) (Range 0 to 50 ppt)	24	0	0
V2	Highest monthly mean summer salinity (ppt) (Range 0 to 50 ppt)	34	0	0
V3	Lowest monthly mean winter water temperature (°C) (Range 0 to 50 °C)	16	0	0
V4	HIghest monthly mean summer water temperature (°C) (Range 0 to 50 °C)	33	0	0
V5	Percent of area with submerged and/or emergent vegetation, submerged islands, shell reefs, or oyster beds. (Range 0 to 100 %)	0	0	0
HSI	Habitat Suitability Index	0.00	0.00	0.00

Condition: Future With Project

Timeframe / Site Inputs		TY-4	TY-5	TY-6
TY	Target Year	51	61	71
Acres	Affected Acreage by Target Year	295.83	10000	1000
Function Inputs				
V1	Lowest monthly mean winter and spring salinity (ppt) (Range 0 to 50 ppt)	24	0	0
V2	Highest monthly mean summer salinity (ppt) (Range 0 to 50 ppt)	34	0	0
V3	Lowest monthly mean winter water temperature (°C) (Range 0 to 50 °C)	16	0	0
V4	HIghest monthly mean summer water temperature (°C) (Range 0 to 50 °C)	33	0	0
V5	Percent of area with submerged and/or emergent vegetation, submerged islands, shell reefs, or oyster beds. (Range 0 to 100 %)	50	0	0
HSI	Habitat Suitability Index	0.81	0.00	0.00

Condition: Future Without Project

Timeframe / Site Inputs		TY-7	TY-8	TY-9
TY	Target Year	81	91	100
Acres	Affected Acreage by Target Year	10000	10000	10000
Function Inputs				
V1	Lowest monthly mean winter and spring salinity (ppt) (Range 0 to 50 ppt)	0	0	0
V2	Highest monthly mean summer salinity (ppt) (Range 0 to 50 ppt)	0	0	0
V3	Lowest monthly mean winter water temperature (°C) (Range 0 to 50 °C)	0	0	0
V4	HIghest monthly mean summer water temperature (°C) (Range 0 to 50 °C)	0	0	0

Timeframe / Site Inputs		TY-7	TY-8	TY-9
TY	Target Year	81	91	100
Acres	Affected Acreage by Target Year	10000	10000	10000
Function Inputs				
V1	Lowest monthly mean winter and spring salinity (ppt) (Range 0 to 50 ppt)	0	0	0
V2	Highest monthly mean summer salinity (ppt) (Range 0 to 50 ppt)	0	0	0
V3	Lowest monthly mean winter water temperature (°C) (Range 0 to 50 °C)	0	0	0
V4	HIghest monthly mean summer water temperature (°C) (Range 0 to 50 °C)	0	0	0

V5	Percent of area with submerged and/or emergent vegetation, submerged islands, shell reefs, or oyster beds. (Range 0 to 100 %)	0	0	0
HSI	Habitat Suitability Index	0.00	0.00	0.00

V5	Percent of area with submerged and/or emergent vegetation, submerged islands, shell reefs, or oyster beds. (Range 0 to 100 %)	0	0	0
HSI	Habitat Suitability Index	0.00	0.00	0.00

Condition: Future Without Project

TY	Acres	HSI	Total HUs	Cumulative HUs
0	296	0.81	239.76	
1	0	0.00	0.00	79.92
31	0	0.00	0.00	0.00
51	0	0.00	0.00	0.00
Max TY=	**51**		AAHUs=	**1.6**

Condition: Future With Project

TY	Acres	HSI	Total HUs	Cumulative HUs
0	296	0.81	239.76	
1	296	0.81	239.76	239.76
31	296	0.81	239.76	7192.80
51	296	0.81	239.76	4795.20
Max TY=	**51**		AAHUs=	**239.8**

Net Change in AAHUs due to Alt1A

Future With Project AAHUs	239.8
Future Without Project AAHUs	1.6
Net Change	238.2

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USACE COASTAL TEXAS
PROTECTION AND RESTORATION STUDY

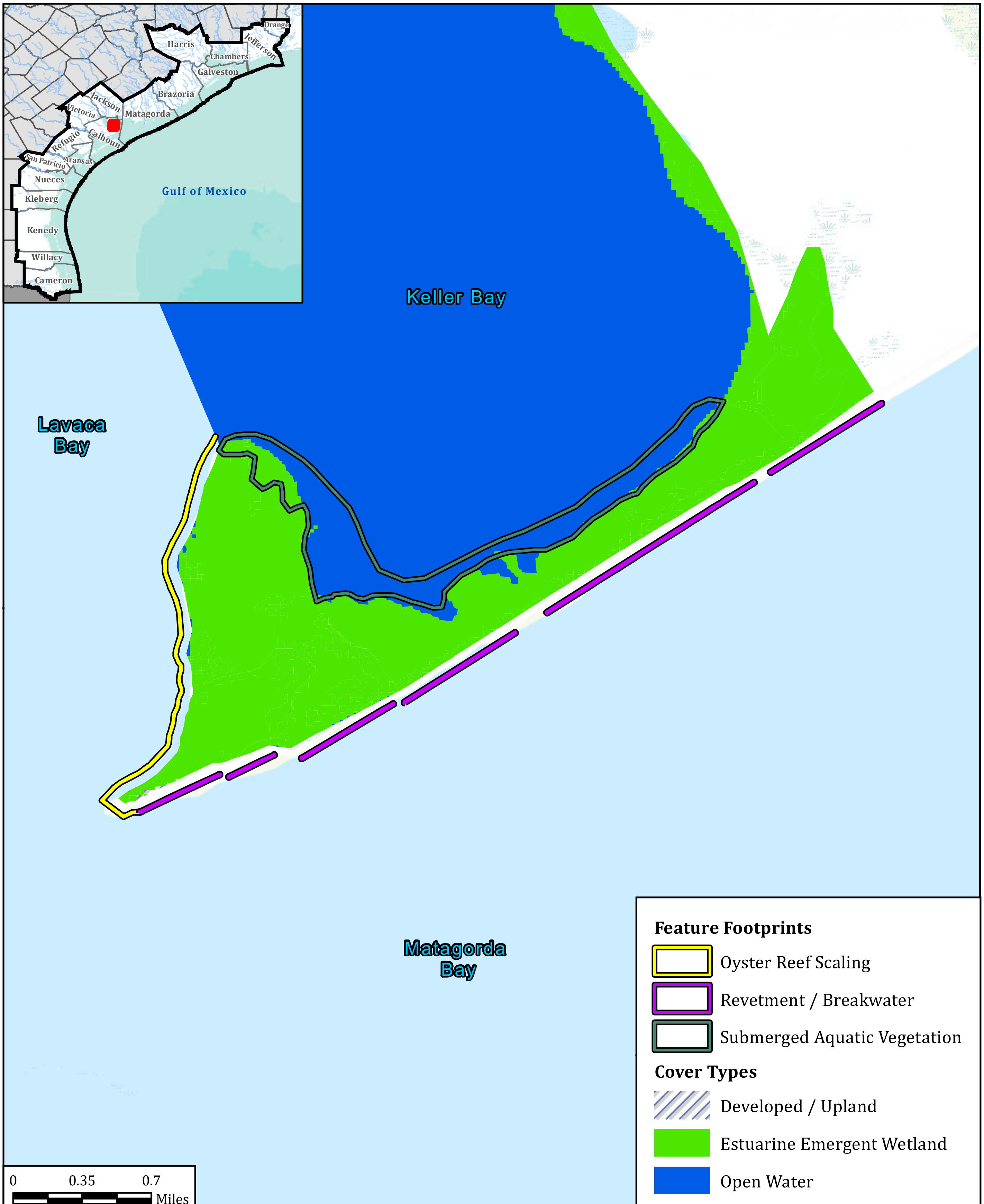
CA-5 - Keller Bay Restoration
Baseline Cover Types

FN JOB NO	TGL18185
FILE NAME	4_CA5_Mapbook.mxd
DATE	9/2/2020
SCALE	1:42,620
DESIGNED	KLC
DRAFTED	02588

4.0
FIGURE

Base Map: ESRI World Topographic Map Service

NAD 1983 StatePlane Texas Central FIPS 4203 Feet



N W E S

USACE COASTAL TEXAS
PROTECTION AND RESTORATION STUDY

CA-5 - Keller Bay Restoration
2035 FWOP Cover Types

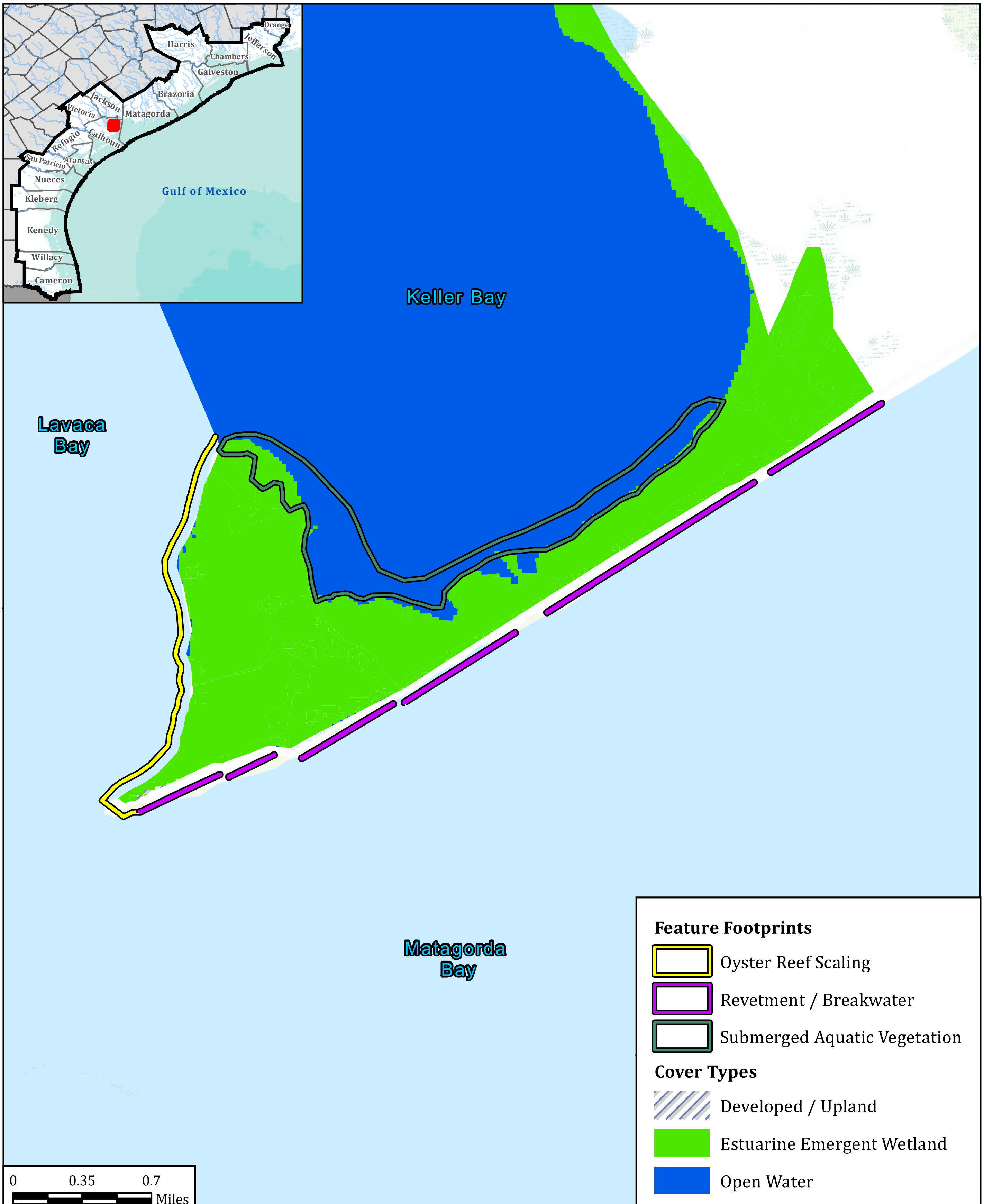
FN JOB NO	TGL18185
FILE NAME	4_CA5_Mapbook.mxd
DATE	9/2/2020
SCALE	1:42,620
DESIGNED	KLC
DRAFTED	02588

4.1

FIGURE

Base Map: ESRI World Topographic Map Service

NAD 1983 StatePlane Texas Central FIPS 4203 Feet



USACE COASTAL TEXAS
PROTECTION AND RESTORATION STUDY

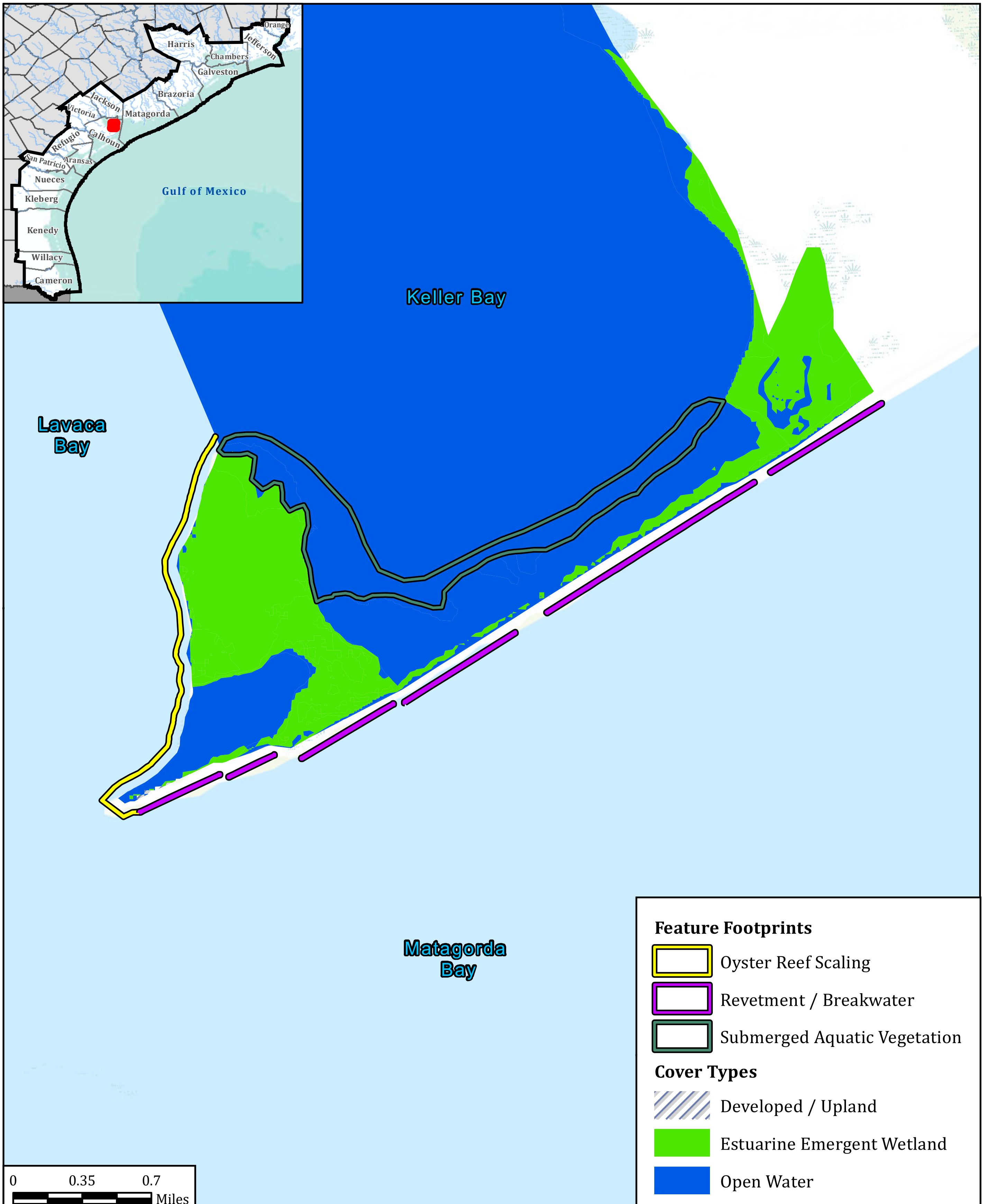
CA-5 - Keller Bay Restoration
2065 FWOP Cover Types

FN JOB NO	TGL18185
FILE NAME	4_CA5_Mapbook.mxd
DATE	9/2/2020
SCALE	1:42,620
DESIGNED	KLC
DRAFTED	02588

4.2
FIGURE

Base Map: ESRI World Topographic Map Service

NAD 1983 StatePlane Texas Central FIPS 4203 Feet



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USACE COASTAL TEXAS
PROTECTION AND RESTORATION STUDY

CA-5 - Keller Bay Restoration
2085 FWOP Cover Types

FN JOB NO	TGL18185
FILE NAME	4_CA5_Mapbook.mxd
DATE	9/2/2020
SCALE	1:42,620
DESIGNED	KLC
DRAFTED	02588

4.3

FIGURE

Base Map: ESRI World Topographic Map Service

NAD 1983 StatePlane Texas Central FIPS 4203 Feet

N W E S

USACE COASTAL TEXAS
PROTECTION AND RESTORATION STUDY

CA-5 - Keller Bay Restoration
2035 FWP Cover Types

FN JOB NO	TGL18185
FILE NAME	4_CA5_Mapbook.mxd
DATE	9/2/2020
SCALE	1:42,620
DESIGNED	KLC
DRAFTED	02588

4.4
FIGURE

Base Map: ESRI World Topographic Map Service

NAD 1983 StatePlane Texas Central FIPS 4203 Feet

USACE COASTAL TEXAS
PROTECTION AND RESTORATION STUDY

CA-5 - Keller Bay Restoration
2065 FWP Cover Types

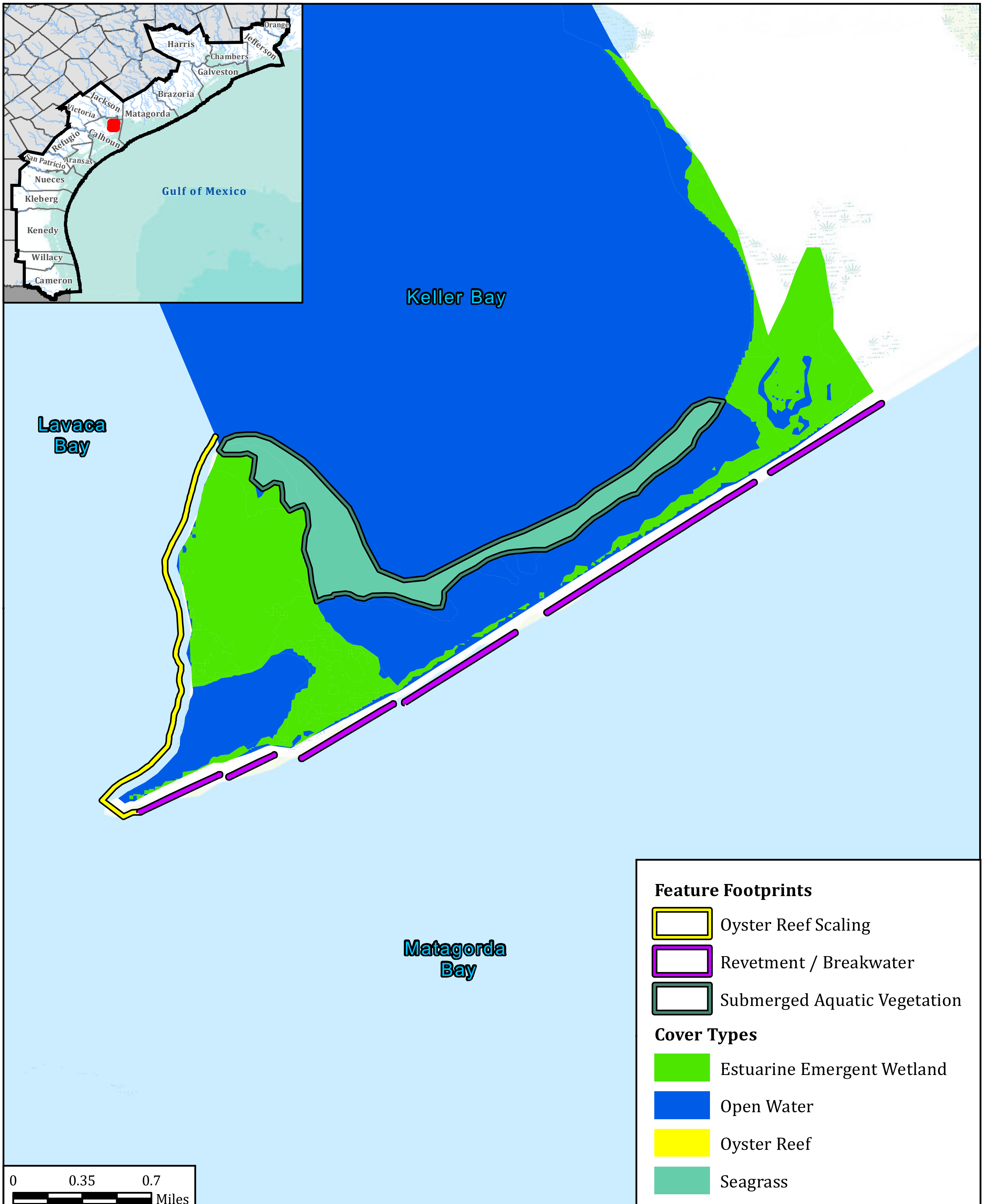
FN JOB NO	TGL18185
FILE NAME	4_CA5_Mapbook.mxd
DATE	9/2/2020
SCALE	1:42,620
DESIGNED	KLC
DRAFTED	02588

4.5

FIGURE

Base Map: ESRI World Topographic Map Service

NAD 1983 StatePlane Texas Central FIPS 4203 Feet



N W E S

USACE COASTAL TEXAS
PROTECTION AND RESTORATION STUDY

CA-5 - Keller Bay Restoration
2085 FWP Cover Types

FN JOB NO	TGL18185
FILE NAME	4_CA5_Mapbook.mxd
DATE	9/2/2020
SCALE	1:42,620
DESIGNED	KLC
DRAFTED	02588

4.6

FIGURE

Base Map: ESRI World Topographic Map Service

NAD 1983 StatePlane Texas Central FIPS 4203 Feet

CA-6

Habitat Modeling

Project: CA-6 Powderhorn Shoreline Protection and Wetland Restoration

Brown Shrimp HSI Model Spreadsheet

Condition: Future Without Project

Variable			SI		SI		SI
Acreage by TY		TY 0	1615	TY 1	2333	TY 31	2335
V1	% of estuary covered by vegetation (marsh and seagrass).	26	0.26	38	0.38	38	0.38
V2	Substrate Composition	muddy	0.80	muddy	0.80	muddy	0.80
V3	Mean salinity - spring	25	0.90	27	0.86	29	0.82
V4	Mean water temperature - spring	25	1	25	1	25	1
		HSI=	**0.38**	HSI=	**0.49**	HSI=	**0.49**
		vba fn	0.41		0.52		0.49

Condition: Future With Project

Variable			SI		SI		SI
Acreage by TY		TY 0	1615	TY 1	2416	TY 31	2335
V1	% of estuary covered by vegetation (marsh and seagrass).	26	0.26	39	0.39	38	0.38
V2	Substrate Composition	muddy	0.80	muddy	0.80	muddy	0.80
V3	Mean salinity - spring	25	0.90	27	0.86	29	0.82
V4	Mean water temperature - spring	25	1	25	1	25	1
		HSI=	**0.38**	HSI=	**0.50**	HSI=	**0.49**
		vba fn	0.41		0.31		0.52

Condition: Future Without Project

Variable			SI		SI		SI
		TY 51	620	TY		TY	
V1	% of estuary covered by vegetation (marsh and seagrass).	10	0.10				
V2	Substrate Composition	muddy	0.80				
V3	Mean salinity - spring	30	0.80				
V4	Mean water temperature - spring	25	1				
		HSI=	**0.20**	HSI=		HSI=	
		vba fn	0.22		V1_ENTRY		V1_ENTRY

Condition: Future With Project

Variable			SI		SI		SI
		TY 51	620	TY		TY	
V1	% of estuary covered by vegetation (marsh and seagrass).	10	0.10				
V2	Substrate Composition	muddy	0.80				
V3	Mean salinity - spring	30	0.80				
V4	Mean water temperature - spring	25	1				
		HSI=	**0.20**	HSI=		HSI=	
		vba fn	0.20		V1_ENTRY		V1_ENTRY

Condition: Future Without Project

Variable			SI		SI		SI
		TY		TY		TY	
V1	% of estuary covered by vegetation (marsh and seagrass).						
V2	Substrate Composition						
V3	Mean salinity - spring						
V4	Mean water temperature - spring						
		HSI=		HSI=		HSI=	
		vba fn	V1_ENTRY		V1_ENTRY		V1_ENTRY

Condition: Future With Project

Variable			SI		SI		SI
		TY		TY		TY	
V1	% of estuary covered by vegetation (marsh and seagrass).						
V2	Substrate Composition						
V3	Mean salinity - spring						
V4	Mean water temperature - spring						
		HSI=		HSI=		HSI=	
		vba fn	V1_ENTRY		V1_ENTRY		V1_ENTRY

Brown Shrimp HSI Model Spreadsheet

Condition: Future Without Project

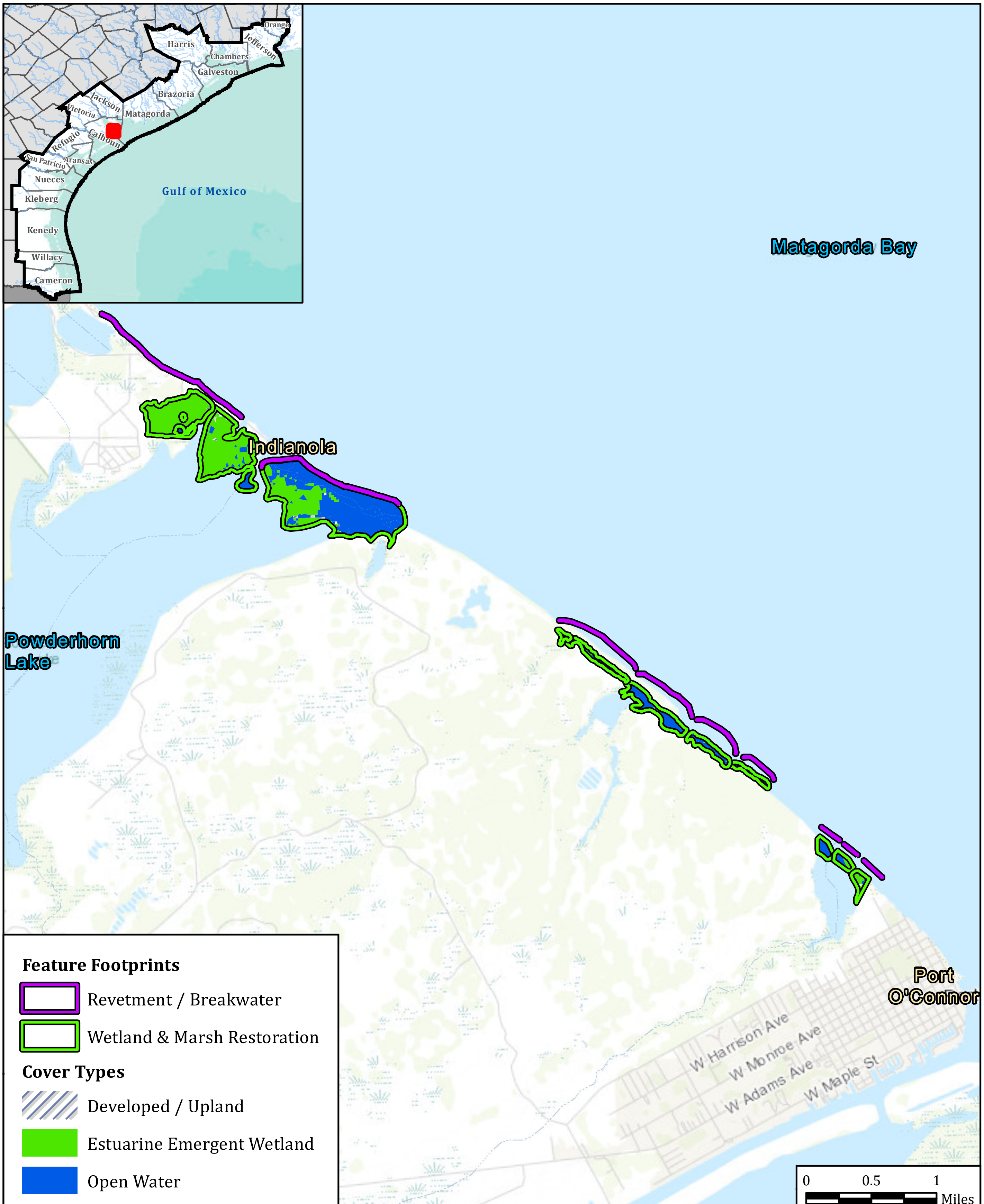
TY	Acres	HSI	Total HUs	Cumulative HUs
0	1615	0.38	610.73	
1	2333	0.49	1136.23	860.46
31	2335	0.49	1137.21	34101.58
51	620	0.20	124.00	10971.23
Max TY=	**51**		AAHUs=	**900.7**

Condition: Future With Project

TY	Acres	HSI	Total HUs	Cumulative HUs
0	1615	0.38	610.73	
1	2416	0.50	1197.21	888.30
31	2335	0.49	1137.21	35012.79
51	620	0.20	124.00	10971.23
Max TY=	**51**		AAHUs=	**919.1**

Net Change in AAHUs due to Project

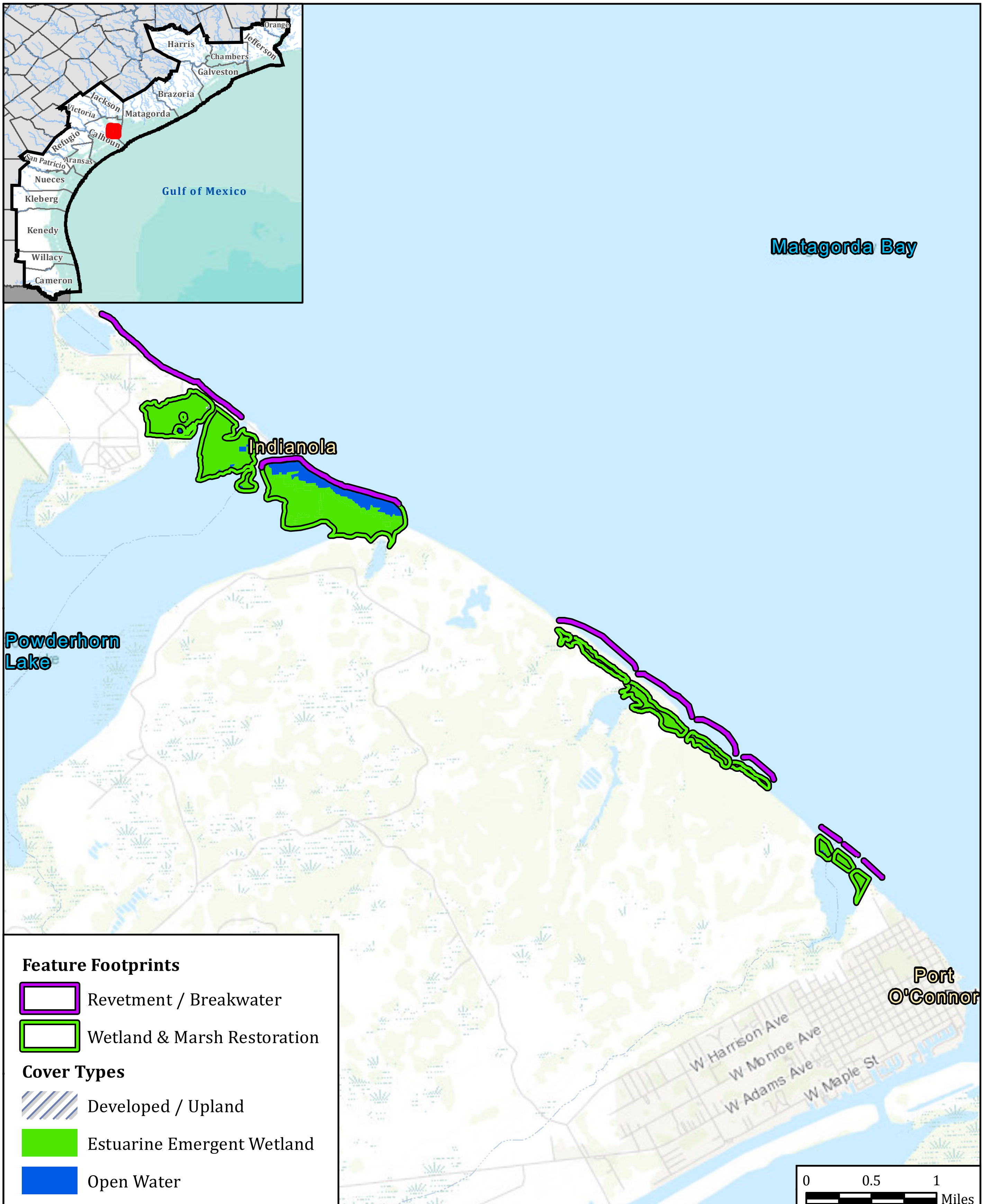
Future With Project AAHUs	919.1
Future Without Project AAHUs	900.7
Net Change	18.4



N W E S	USACE COASTAL TEXAS PROTECTION AND RESTORATION STUDY	FN JOB NO TGL18185 FILE NAME 5_CA6_Mapbook.mxd DATE 9/2/2020	5.0
	CA-6 - Powderhorn Shoreline Protection and Wetland Restoration Baseline Cover Types	SCALE 1:64,580 DESIGNED KLC DRAFTED 02588	**FIGURE**

Base Map: ESRI World Topographic Map Service

NAD 1983 StatePlane Texas Central FIPS 4203 Feet



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USACE COASTAL TEXAS
PROTECTION AND RESTORATION STUDY

CA-6 - Powderhorn Shoreline Protection and Wetland Restoration 2035 FWOP Cover Types

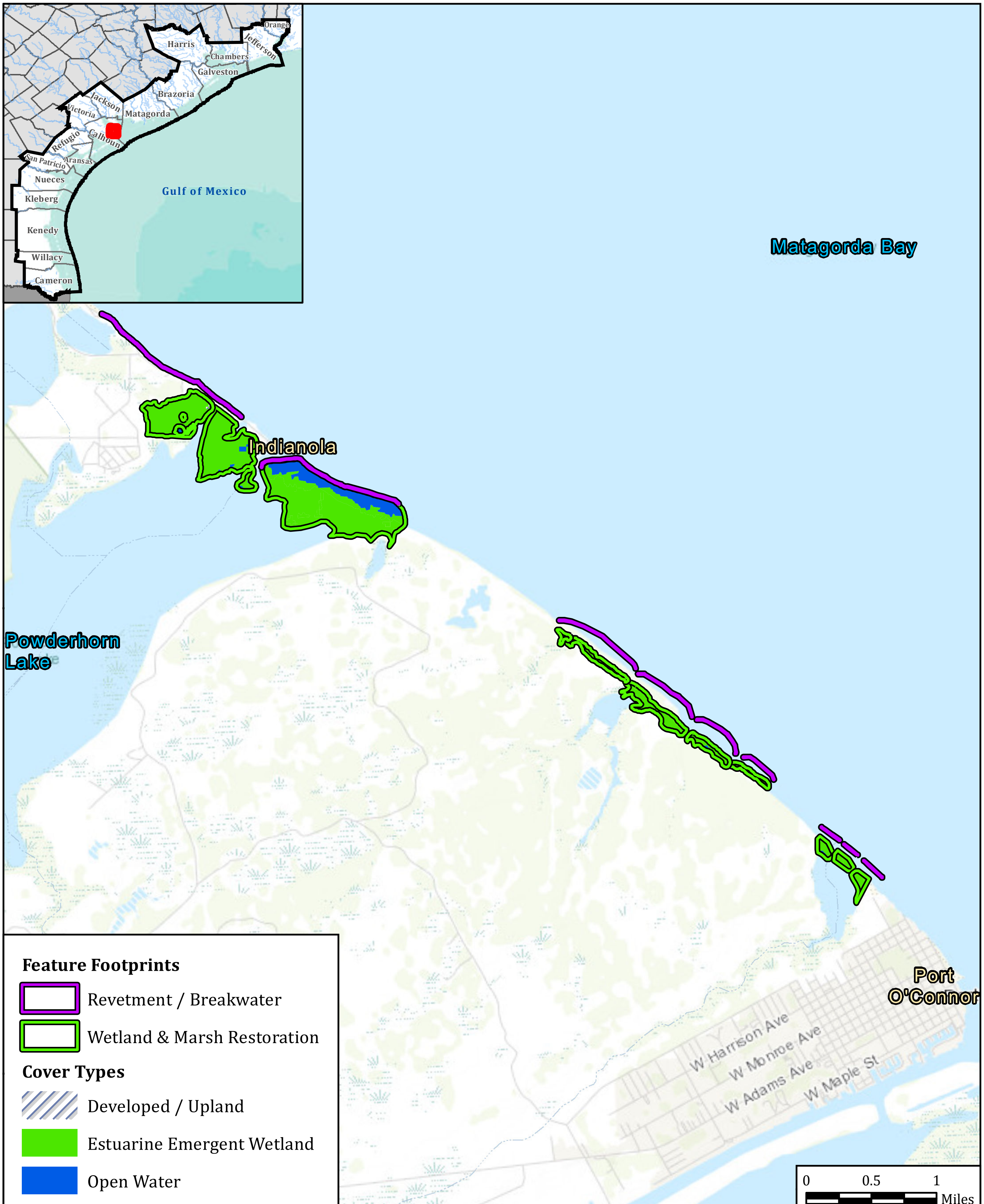
FN JOB NO	TGL18185
FILE NAME	5_CA6_Mapbook.mxd
DATE	9/2/2020
SCALE	1:64,580
DESIGNED	KLC
DRAFTED	02588

5.1

FIGURE

Base Map: ESRI World Topographic Map Service

NAD 1983 StatePlane Texas Central FIPS 4203 Feet



USACE COASTAL TEXAS
PROTECTION AND RESTORATION STUDY

CA-6 - Powderhorn Shoreline Protection and Wetland Restoration 2065 FWOP Cover Types

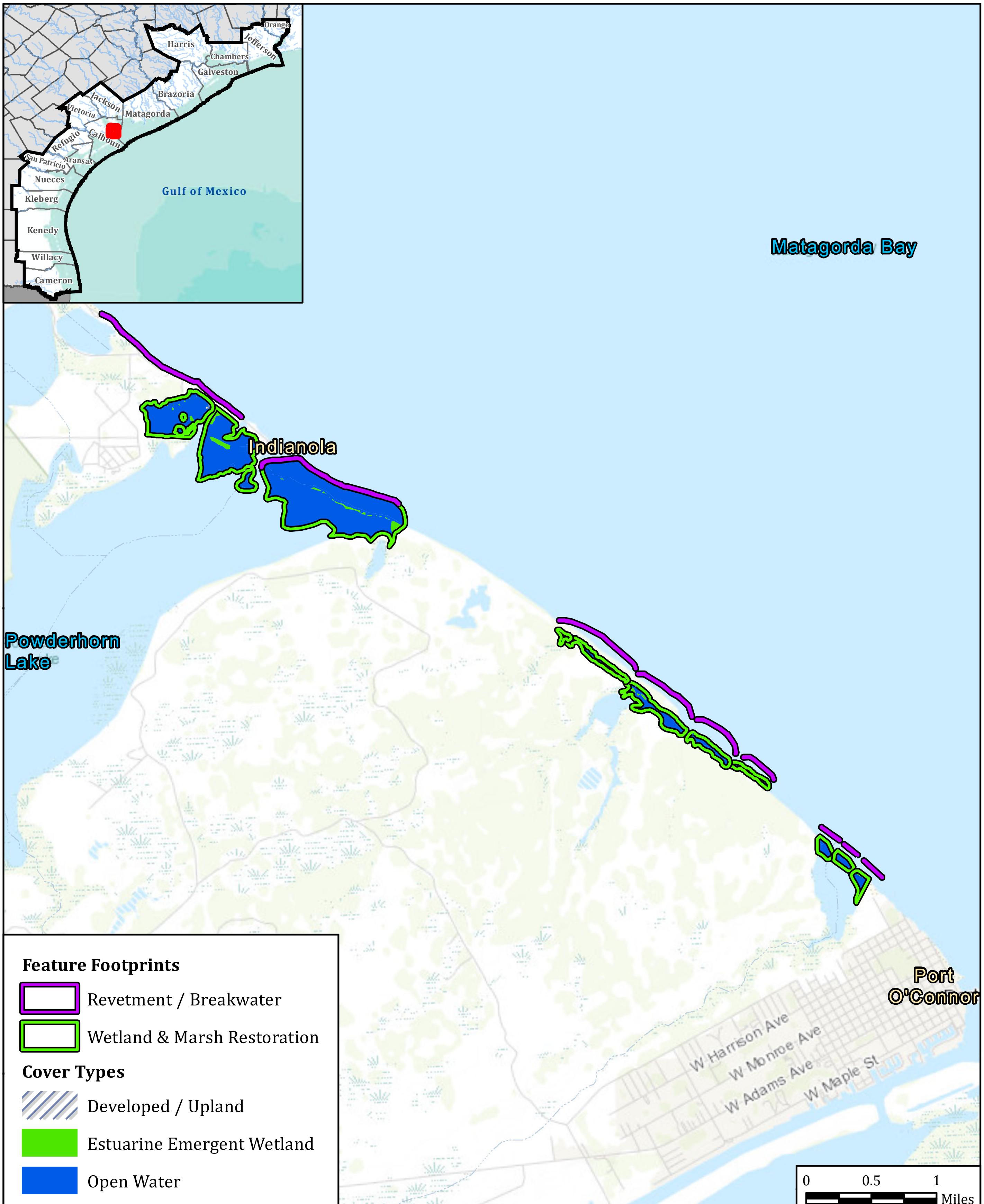
FN JOB NO	TGL18185
FILE NAME	5_CA6_Mapbook.mxd
DATE	9/2/2020
SCALE	1:64,580
DESIGNED	KLC
DRAFTED	02588

5.2

FIGURE

Base Map: ESRI World Topographic Map Service

NAD 1983 StatePlane Texas Central FIPS 4203 Feet



USACE COASTAL TEXAS
PROTECTION AND RESTORATION STUDY

CA-6 - Powderhorn Shoreline Protection and Wetland Restoration 2085 FWOP Cover Types

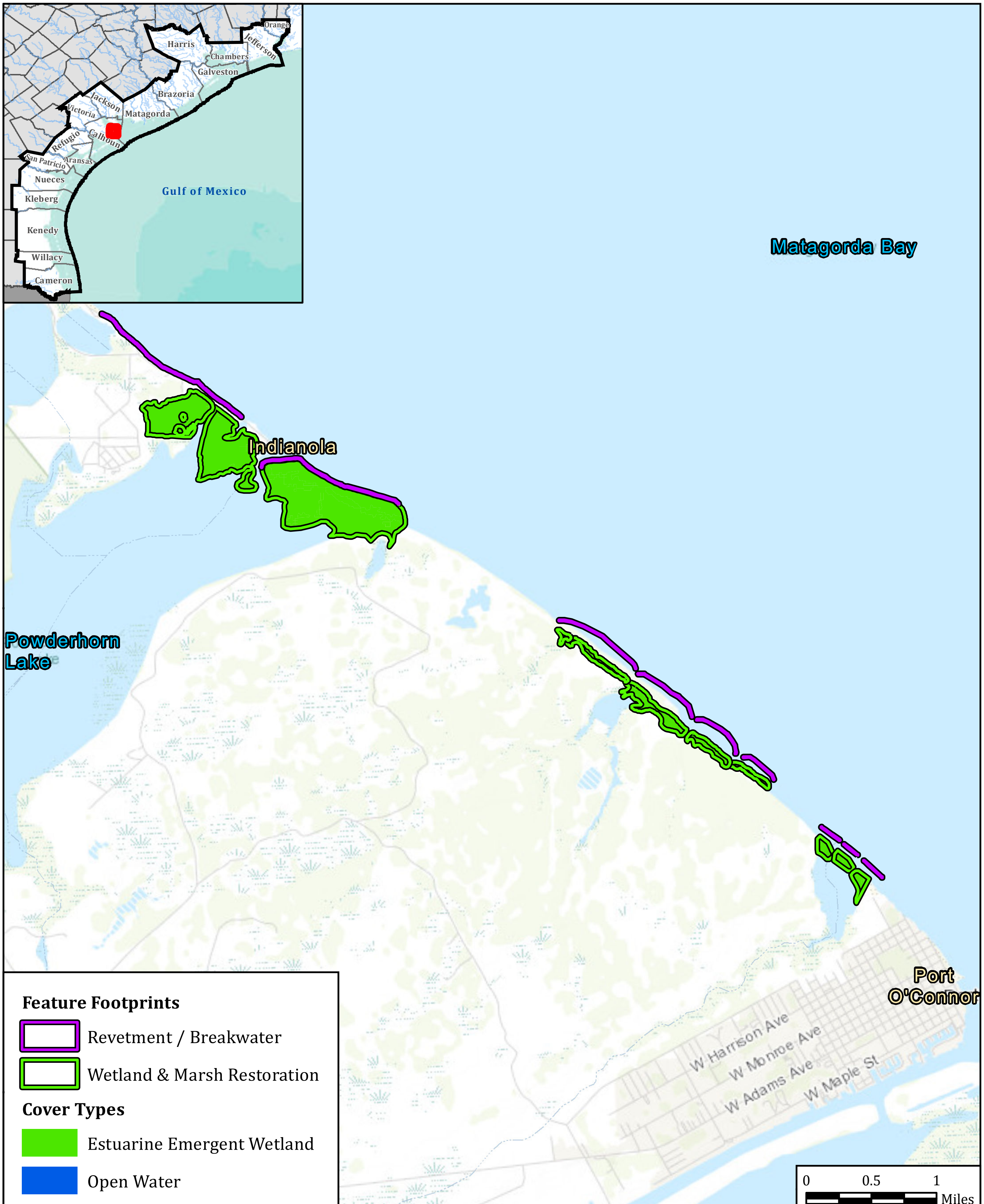
FN JOB NO	TGL18185
FILE NAME	5_CA6_Mapbook.mxd
DATE	9/2/2020
SCALE	1:64,580
DESIGNED	KLC
DRAFTED	02588

5.3

FIGURE

Base Map: ESRI World Topographic Map Service

NAD 1983 StatePlane Texas Central FIPS 4203 Feet



USACE COASTAL TEXAS

PROTECTION AND RESTORATION STUDY

CA-6 - Powderhorn Shoreline Protection and Wetland Restoration 2035 FWP Cover Types

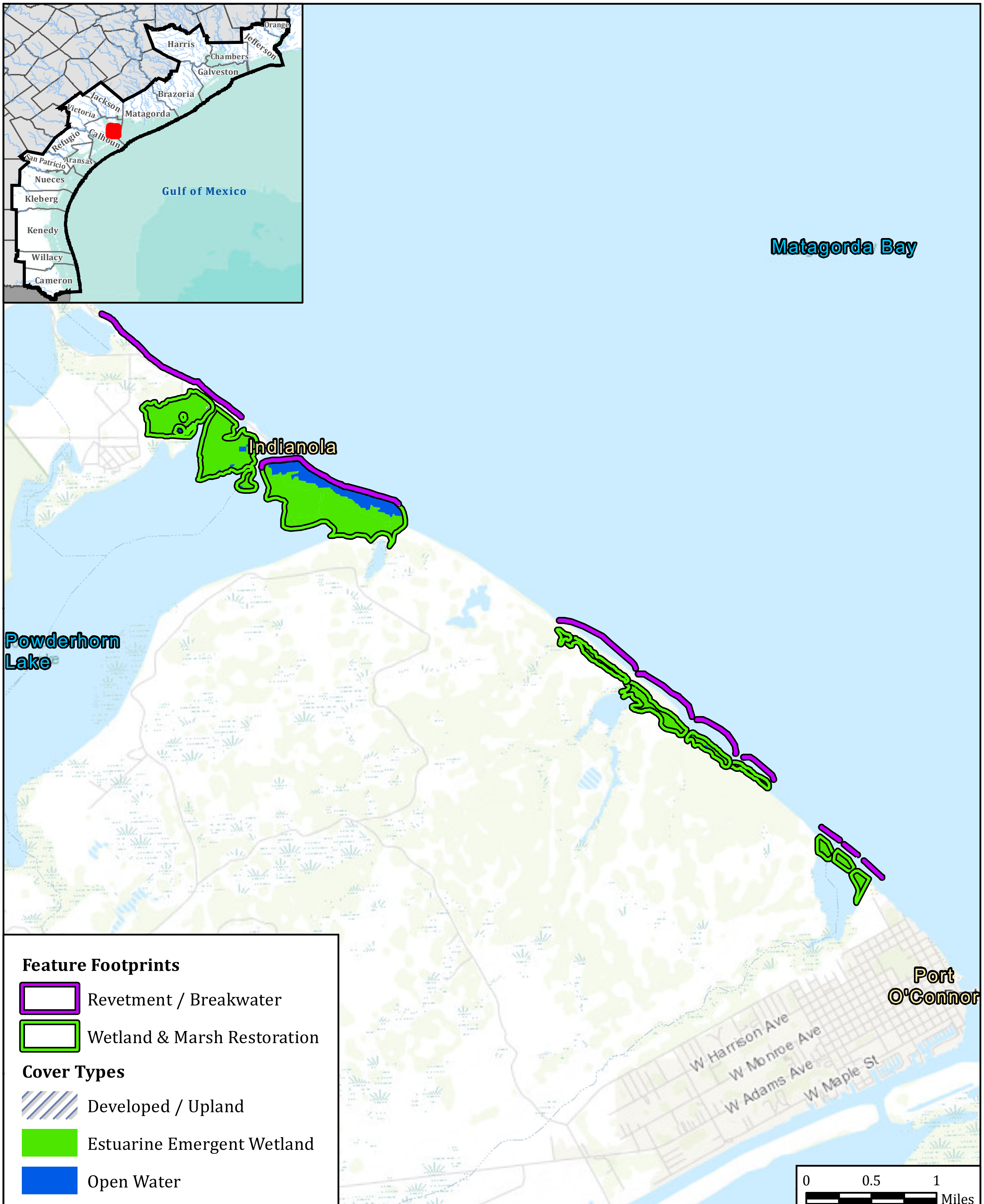
FN JOB NO	TGL18185
FILE NAME	5_CA6_Mapbook.mxd
DATE	9/2/2020
SCALE	1:64,580
DESIGNED	KLC
DRAFTED	02588

5.4

FIGURE

Base Map: ESRI World Topographic Map Service

NAD 1983 StatePlane Texas Central FIPS 4203 Feet



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USACE COASTAL TEXAS
PROTECTION AND RESTORATION STUDY

CA-6 - Powderhorn Shoreline Protection and Wetland Restoration 2065 FWP Cover Types

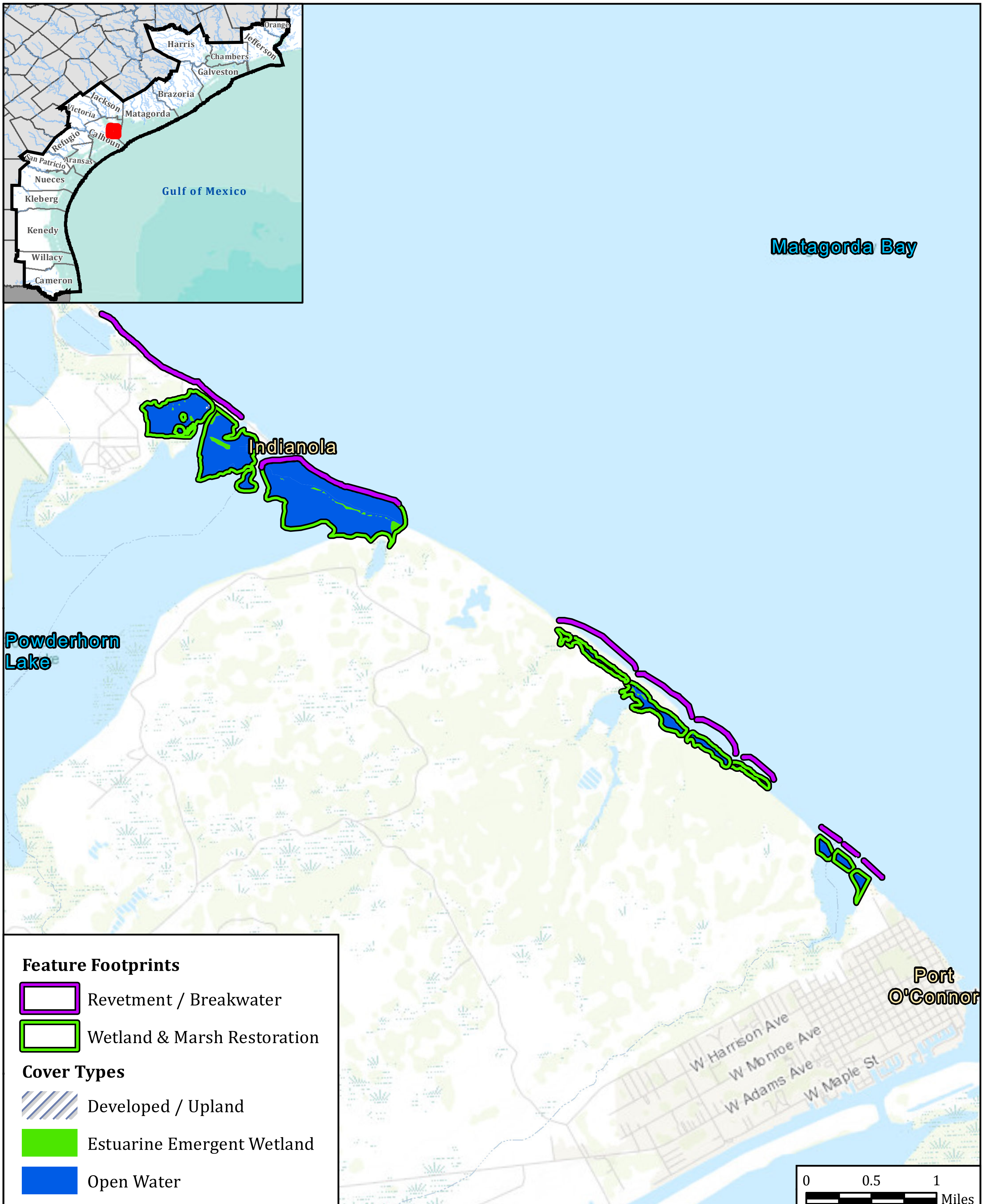
FN JOB NO	TGL18185
FILE NAME	5_CA6_Mapbook.mxd
DATE	9/2/2020
SCALE	1:64,580
DESIGNED	KLC
DRAFTED	02588

5.5

FIGURE

Base Map: ESRI World Topographic Map Service

NAD 1983 StatePlane Texas Central FIPS 4203 Feet



USACE COASTAL TEXAS
PROTECTION AND RESTORATION STUDY

CA-6 - Powderhorn Shoreline Protection and Wetland Restoration 2085 FWP Cover Types

FN JOB NO	TGL18185
FILE NAME	5_CA6_Mapbook.mxd
DATE	9/2/2020
SCALE	1:64,580
DESIGNED	KLC
DRAFTED	02588

5.6

FIGURE

Base Map: ESRI World Topographic Map Service

NAD 1983 StatePlane Texas Central FIPS 4203 Feet

SP-1

Habitat Modeling

Project: SP-1 American Oyster

American Oyster HSI Model Spreadsheet

Acres 0

Condition: Future Without Project

Variable		TY 0	SI	TY 1	SI	TY 31	SI
V1	Percent cultch cover	0	0.00	0	0.00	0	0.00
V2	Mean salinity during spawning season	33	0.18	34	0.14	37	0.06
V3	Minimum annual salinity	20	1	21	1	23	1
V4	Annual mean salinity	29	0.13	31	0.09	33	0.07
		HSI=	**0.00**	HSI=	**0.00**	HSI=	**0.00**

Condition: Future Without Project

Variable		TY 51	SI	TY	SI	TY	SI
V1	Percent cultch cover	0	0.00				
V2	Mean salinity during spawning season	39	0.02				
V3	Minimum annual salinity	24	1				
V4	Annual mean salinity	35	0.05				
		HSI=	**0.00**	HSI=		HSI=	

Condition: Future Without Project

Variable		TY	SI	TY	SI	TY	SI
V1	Percent cultch cover						
V2	Mean salinity during spawning season						
V3	Minimum annual salinity						
V4	Annual mean salinity						
		HSI=		HSI=		HSI=	

Acres 2

Condition: Future With Project

Variable		TY 0	SI	TY 1	SI	TY 31	SI
V1	Percent cultch cover	0	0.00	100	1.00	100	1.00
V2	Mean salinity during spawning season	33	0.18	34	0.14	37	0.06
V3	Minimum annual salinity	20	1	21	1	23	1
V4	Annual mean salinity	29	0.13	31	0.09	33	0.07
		HSI=	**0.00**	HSI=	**0.34**	HSI=	**0.25**

Condition: Future With Project

Variable		TY 51	SI	TY	SI	TY	SI
V1	Percent cultch cover	100	1.00				
V2	Mean salinity during spawning season	39	0.02				
V3	Minimum annual salinity	24	1				
V4	Annual mean salinity	35	0.05				
		HSI=	**0.18**	HSI=		HSI=	

Condition: Future With Project

Variable		TY	SI	TY	SI	TY	SI
V1	Percent cultch cover						
V2	Mean salinity during spawning season						
V3	Minimum annual salinity						
V4	Annual mean salinity						
		HSI=		HSI=		HSI=	

American Oyster HSI Model Spreadsheet

Condition: Future Without Project

TY	Acres	HSI	Total HUs	Cumulative HUs
0	0	0.00	0.00	
1	0	0.00	0.00	0.00
31	0	0.00	0.00	0.00
51	0	0.00	0.00	0.00
Max TY=	51		**AAHUs=**	0.00

Condition: Future With Project

TY	Acres	HSI	Total HUs	Cumulative HUs
0	0	0.00	0.00	
1	2	0.34	0.67	0.22
31	2	0.25	0.51	17.69
51	2	0.18	0.36	8.65
Max TY=	51		**AAHUs=**	0.52

Net Change in AAHUs due to Project

Future With Project AAHUs	0.52
Future Without Project AAHUs	0.00
Net Change	**0.52**

Project: SP-1 Brown Pelican

What State is the Project Location TX

Acres

Brown Pelican HSI Model Spreadsheet

Condition: Future Without Project

Variable		TY 0	SI	TY 1	SI	TY 31	SI
V1	Island surface area	Greater than 8 ha (19.8 ac)	0.40	Less than 2 ha (4.9 ac)	0.40	Less than 2 ha (4.9 ac)	0.40
V2	Distance of island from mainland*	0.16	0.40	0.16	0.40	0.16	0.40
V3	Distance of island from nearest human activity center*	1	1.00	1	1.00	1	1.00
V4 (WDY)							
V4	Percent of Island surface area at least 0.6 m elevation	100	1.00	0	0.00	0	0.00
		HSI=	0.63	HSI=	0.00	HSI=	0.00

Acres

Condition: Future With Project

Variable		TY 0	SI	TY 1	SI	TY 31	SI
V1	Island surface area	Greater than 8 ha (19.8 ac)	0.40	Greater than 8 ha (19.8 ac)	0.40	Greater than 8 ha (19.8 ac)	0.40
V2	Distance of island from mainland*	0.16	0.40	0.16	0.40	0.16	0.40
V3	Distance of island from nearest human activity center*	1	1.00	1	1.00	1	1.00
V4 (WDY)							
V4	Percent of Island surface area at least 0.6 m elevation	100	1.00	96	1.00	94	1.00
		HSI=	0.63	HSI=	0.63	HSI=	0.63

Condition: Future Without Project

Variable		TY 51	SI	TY	SI	TY	SI
V1	Island surface area	Less than 2 ha (4.9 ac)	0.40				
V2	Distance of island from mainland*	0.16	0.40				
V3	Distance of island from nearest human activity center*	1	1.00				
V4 (WDY)							
V4	Percent of Island surface area at least 0.6 m elevation	0	0.00				
		HSI=	0.00	HSI=		HSI=	

Condition: Future With Project

Variable		TY 51	SI	TY	SI	TY	SI
V1	Island surface area	Greater than 8 ha (19.8 ac)	0.40				
V2	Distance of island from mainland*	0.16	0.40				
V3	Distance of island from nearest human activity center*	1	1.00				
V4 (WDY)							
V4	Percent of Island surface area at least 0.6 m elevation	96	1.00				
		HSI=	0.63	HSI=		HSI=	

Condition: Future Without Project

Variable		TY	SI	TY	SI	TY	SI
V1	Island surface area						
V2	Distance of island from mainland*						
V3	Distance of island from nearest human activity center*						
V4 (WDY)							
V4	Percent of Island surface area at least 0.6 m elevation						
		HSI=		HSI=		HSI=	

Condition: Future With Project

Variable		TY	SI	TY	SI	TY	SI
V1	Island surface area						
V2	Distance of island from mainland*						
V3	Distance of island from nearest human activity center*						
V4 (WDY)							
V4	Percent of Island surface area at least 0.6 m elevation						
		HSI=		HSI=		HSI=	

* Measured as a straight-line distance in km.

Brown Pelican HSI Model Spreadsheet

Condition: Future Without Project

TY	Acres	HSI	Total HUs	Cumulative HUs
0	118	0.63	74.48	
1	0	0.00	0.00	24.83
31	0	0.00	0.00	0.00
51	0	0.00	0.00	0.00
Max TY=	**51**		**AAHUs=**	0.49

Condition: Future With Project

TY	Acres	HSI	Total HUs	Cumulative HUs
0	118	0.63	74.48	
1	423	0.63	267.72	171.10
31	421	0.63	266.26	8009.83
51	419	0.63	264.96	5312.25
Max TY=	**51**		**AAHUs=**	264.57

Net Change in AAHUs due to Project

Future With Project AAHUs	264.57
Future Without Project AAHUs	0.49
Net Change	264.09

Project: SP-1 Spotted Seatrout

Condition: Future Without Project

Timeframe / Site Inputs		TY-1	TY-2	TY-3
TY	Target Year	0	1	31
Acres	Affected Acreage by Target Year	3027.89	0	0
Function Inputs				
V1	Lowest monthly mean winter and spring salinity (ppt) (Range 0 to 50 ppt)	20	21	22
V2	Highest monthly mean summer salinity (ppt) (Range 0 to 50 ppt)	30	31	34
V3	Lowest monthly mean winter water temperature (°C) (Range 0 to 50 °C)	24	24	24
V4	HIghest monthly mean summer water temperature (°C) (Range 0 to 50 °C)	25	25	25
V5	Percent of area with submerged and/or emergent vegetation, submerged islands, shell reefs, or oyster beds. (Range 0 to 100 %)	50	0	0
HSI	Habitat Suitability Index	1.00	0.00	0.00

Condition: Future With Project

Timeframe / Site Inputs		TY-1	TY-2	TY-3
TY	Target Year	0	1	31
Acres	Affected Acreage by Target Year	3027.89	3257.91	3257.91
Function Inputs				
V1	Lowest monthly mean winter and spring salinity (ppt) (Range 0 to 50 ppt)	20	21	22
V2	Highest monthly mean summer salinity (ppt) (Range 0 to 50 ppt)	30	31	34
V3	Lowest monthly mean winter water temperature (°C) (Range 0 to 50 °C)	24	24	24
V4	HIghest monthly mean summer water temperature (°C) (Range 0 to 50 °C)	25	25	25
V5	Percent of area with submerged and/or emergent vegetation, submerged islands, shell reefs, or oyster beds. (Range 0 to 100 %)	50	55	55
HSI	Habitat Suitability Index	1.00	1.00	1.00

Condition: Future Without Project

Timeframe / Site Inputs		TY-4	TY-5	TY-6
TY	Target Year	51	61	71
Acres	Affected Acreage by Target Year	0	10000	10000
Function Inputs				
V1	Lowest monthly mean winter and spring salinity (ppt) (Range 0 to 50 ppt)	24	0	0
V2	Highest monthly mean summer salinity (ppt) (Range 0 to 50 ppt)	36	0	0
V3	Lowest monthly mean winter water temperature (°C) (Range 0 to 50 °C)	24	0	0
V4	HIghest monthly mean summer water temperature (°C) (Range 0 to 50 °C)	25	0	0
V5	Percent of area with submerged and/or emergent vegetation, submerged islands, shell reefs, or oyster beds. (Range 0 to 100 %)	0	0	0
HSI	Habitat Suitability Index	0.00	0.00	0.00

Condition: Future With Project

Timeframe / Site Inputs		TY-4	TY-5	TY-6
TY	Target Year	51	61	71
Acres	Affected Acreage by Target Year	3257.91	10000	10000
Function Inputs				
V1	Lowest monthly mean winter and spring salinity (ppt) (Range 0 to 50 ppt)	24	0	0
V2	Highest monthly mean summer salinity (ppt) (Range 0 to 50 ppt)	36	0	0
V3	Lowest monthly mean winter water temperature (°C) (Range 0 to 50 °C)	24	0	0
V4	HIghest monthly mean summer water temperature (°C) (Range 0 to 50 °C)	25	0	0
V5	Percent of area with submerged and/or emergent vegetation, submerged islands, shell reefs, or oyster beds. (Range 0 to 100 %)	55	0	0
HSI	Habitat Suitability Index	1.00	0.00	0.00

Condition: Future Without Project

Timeframe / Site Inputs		TY-7	TY-8	TY-9
TY	Target Year	81	91	100
Acres	Affected Acreage by Target Year	10000	10000	10000
Function Inputs				
V1	Lowest monthly mean winter and spring salinity (ppt) (Range 0 to 50 ppt)	0	0	0
V2	Highest monthly mean summer salinity (ppt) (Range 0 to 50 ppt)	0	0	0
V3	Lowest monthly mean winter water temperature (°C) (Range 0 to 50 °C)	0	0	0
V4	HIghest monthly mean summer water temperature (°C) (Range 0 to 50 °C)	0	0	0

Timeframe / Site Inputs		TY-7	TY-8	TY-9
TY	Target Year	81	91	100
Acres	Affected Acreage by Target Year	10000	10000	10000
Function Inputs				
V1	Lowest monthly mean winter and spring salinity (ppt) (Range 0 to 50 ppt)	0	0	0
V2	Highest monthly mean summer salinity (ppt) (Range 0 to 50 ppt)	0	0	0
V3	Lowest monthly mean winter water temperature (°C) (Range 0 to 50 °C)	0	0	0
V4	HIghest monthly mean summer water temperature (°C) (Range 0 to 50 °C)	0	0	0

V5	Percent of area with submerged and/or emergent vegetation, submerged islands, shell reefs, or oyster beds. (Range 0 to 100 %)	0	0	0
HSI	Habitat Suitability Index	0.00	0.00	0.00

V5	Percent of area with submerged and/or emergent vegetation, submerged islands, shell reefs, or oyster beds. (Range 0 to 100 %)	0	0	0
HSI	Habitat Suitability Index	0.00	0.00	0.00

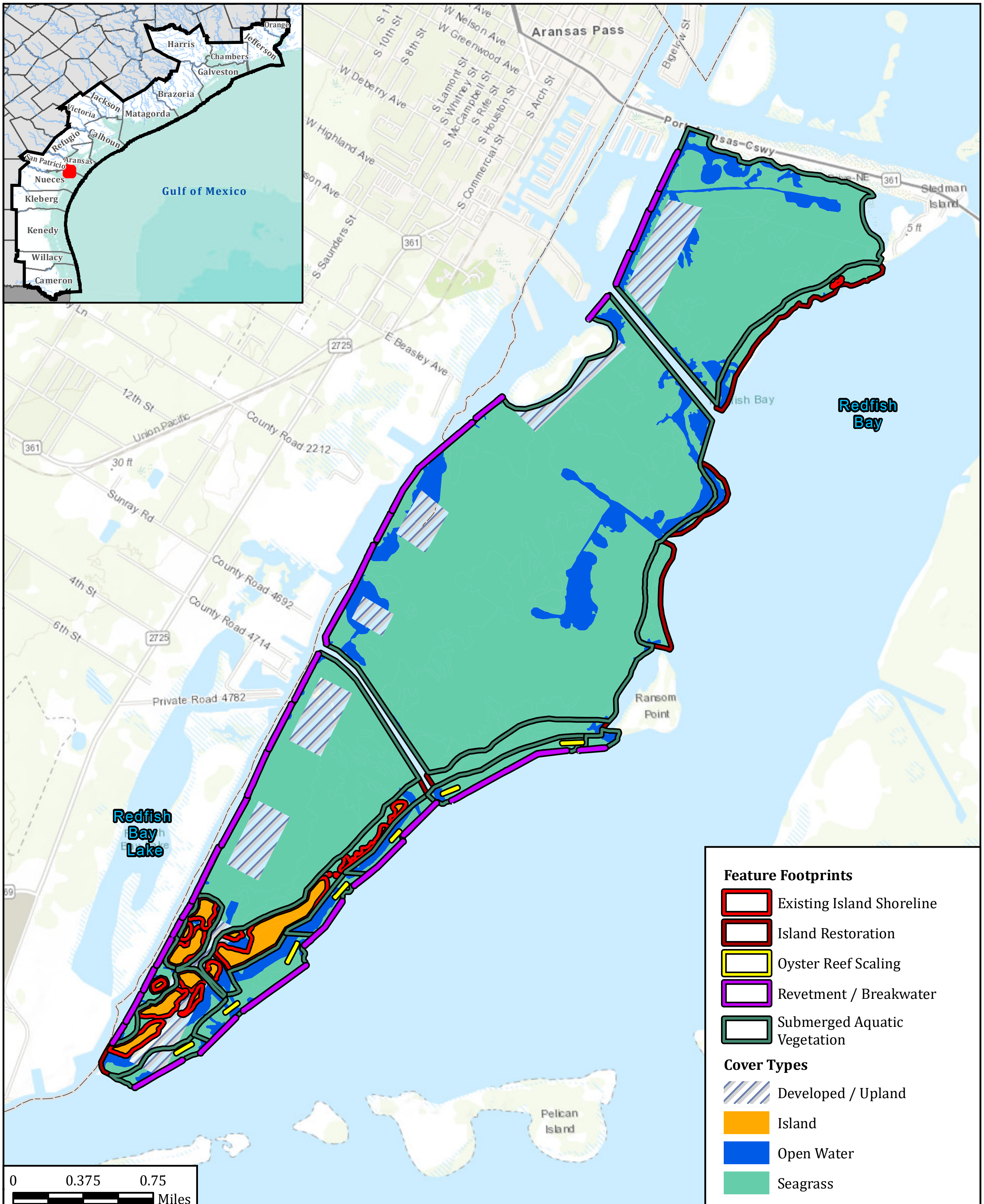
Condition: Future Without Project

TY	Acres	HSI	Total HUs	Cumulative HUs
0	3028	1.00	3028.00	
1	0	0.00	0.00	1009.33
31	0	0.00	0.00	0.00
51	0	0.00	0.00	0.00
Max TY=	**51**		**AAHUs=**	**19.8**

Condition: Future With Project

TY	Acres	HSI	Total HUs	Cumulative HUs
0	3028	1.00	3028.00	
1	3258	1.00	3258.00	3143.00
31	3258	1.00	3258.00	97740.00
51	3258	1.00	3258.00	65160.00
Max TY=	**51**		**AAHUs=**	**3255.7**

Net Change in AAHUs due to Alt1A	
Future With Project AAHUs	3255.7
Future Without Project AAHUs	19.8
Net Change	3236.0



USACE COASTAL TEXAS
PROTECTION AND RESTORATION STUDY

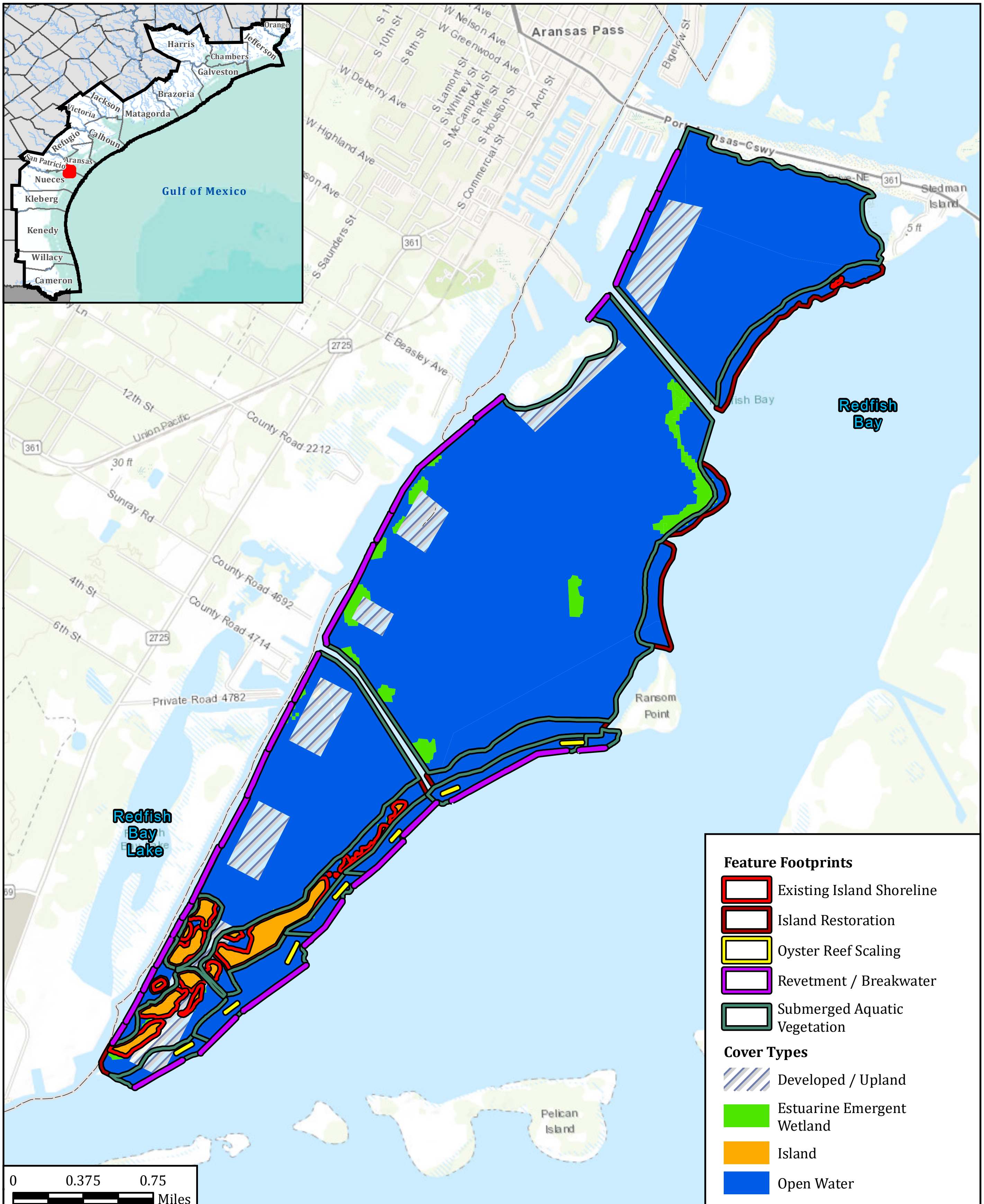
SP-1 - Redfish Bay Protection and Enhancement
Baseline Cover Types

FN JOB NO	TGL18185
FILE NAME	6_SP1_Mapbook.mxd
DATE	9/2/2020
SCALE	1:45,110
DESIGNED	KLC
DRAFTED	02588

6.0
FIGURE

Base Map: ESRI World Topographic Map Service

NAD 1983 StatePlane Texas Central FIPS 4203 Feet



N W E S

USACE COASTAL TEXAS
PROTECTION AND RESTORATION STUDY

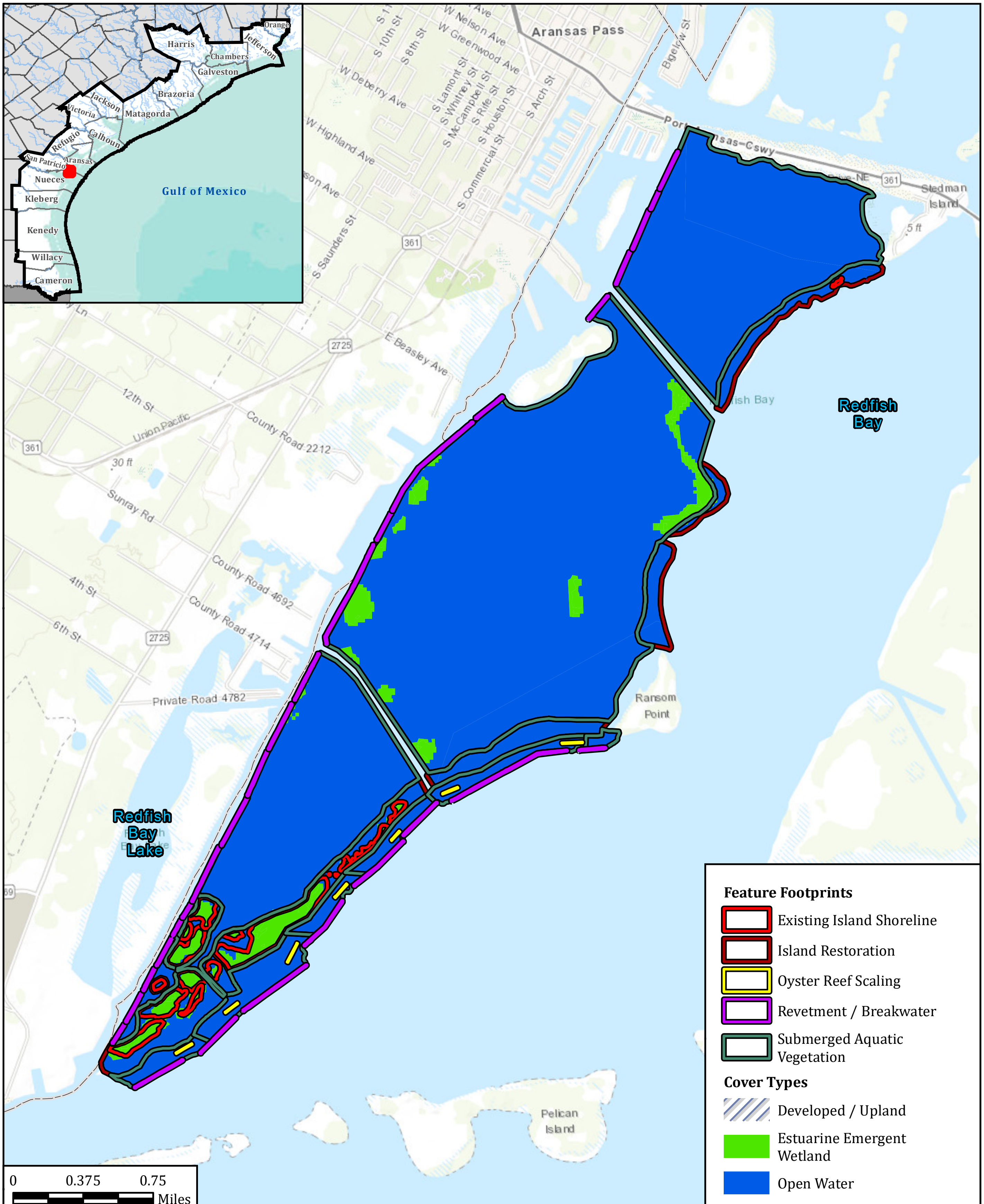
SP-1 - Redfish Bay Protection and Enhancement
2035 FWOP Cover Types

FN JOB NO	TGL18185
FILE NAME	6_SP1_Mapbook.mxd
DATE	9/2/2020
SCALE	1:45,110
DESIGNED	KLC
DRAFTED	02588

6.1
FIGURE

Base Map: ESRI World Topographic Map Service

NAD 1983 StatePlane Texas Central FIPS 4203 Feet



USACE COASTAL TEXAS
PROTECTION AND RESTORATION STUDY

SP-1 - Redfish Bay Protection and Enhancement
2065 FWOP Cover Types

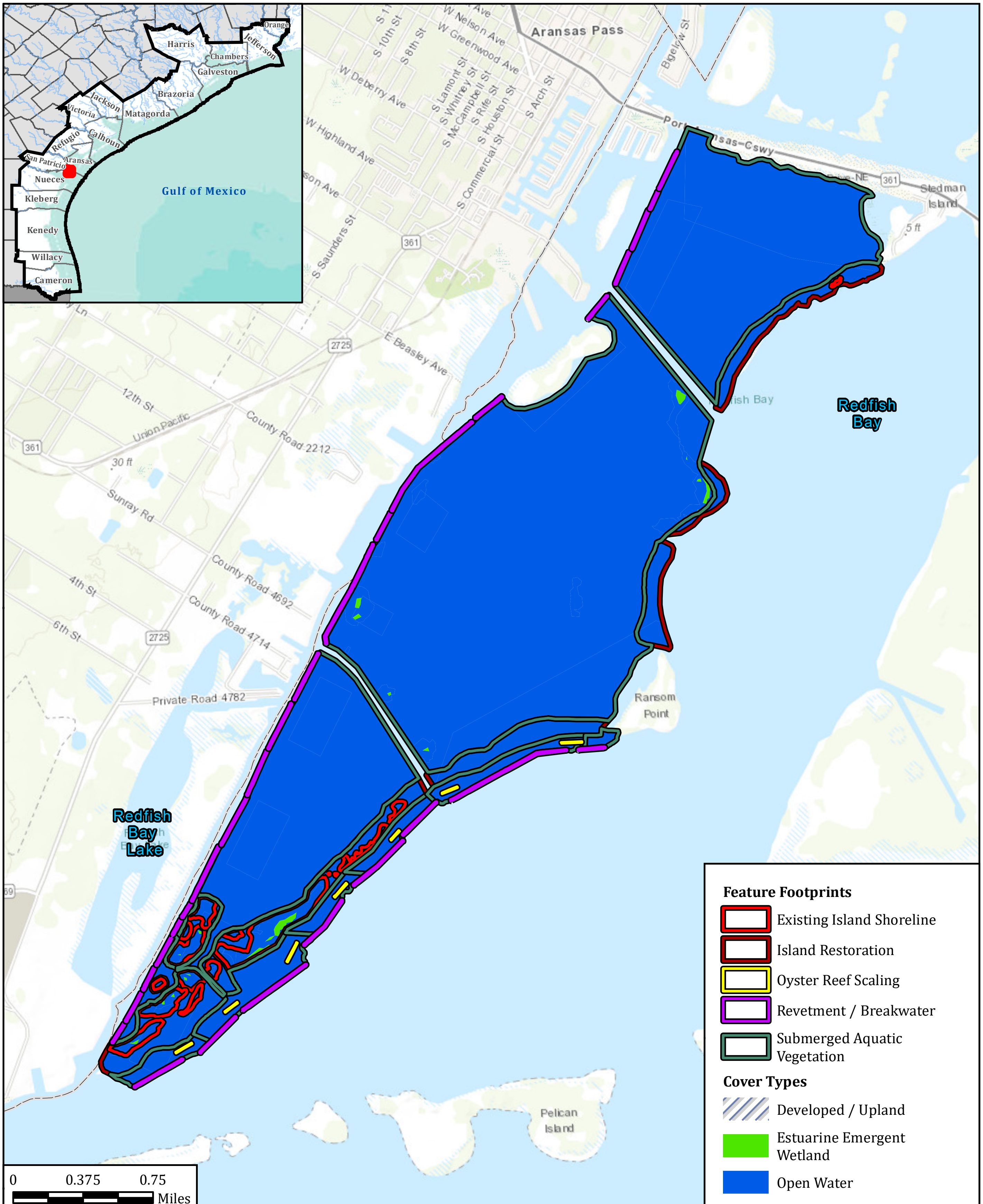
FN JOB NO	TGL18185
FILE NAME	6_SP1_Mapbook.mxd
DATE	9/2/2020
SCALE	1:45,110
DESIGNED	KLC
DRAFTED	02588

6.2

FIGURE

Base Map: ESRI World Topographic Map Service

NAD 1983 StatePlane Texas Central FIPS 4203 Feet



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USACE COASTAL TEXAS
PROTECTION AND RESTORATION STUDY

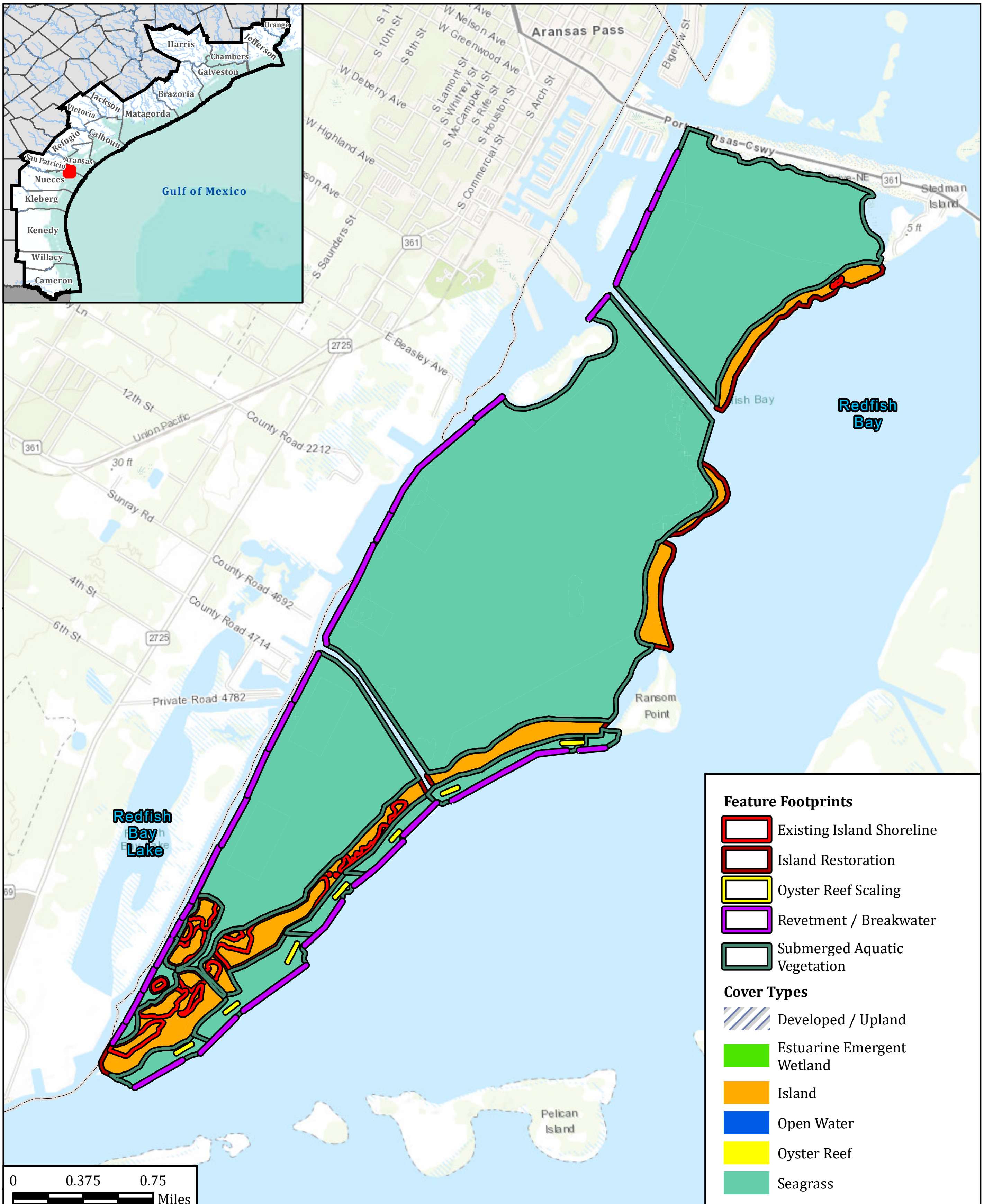
SP-1 - Redfish Bay Protection and Enhancement
2085 FWOP Cover Types

FN JOB NO	TGL18185
FILE NAME	6_SP1_Mapbook.mxd
DATE	9/2/2020
SCALE	1:45,110
DESIGNED	KLC
DRAFTED	02588

6.3
FIGURE

Base Map: ESRI World Topographic Map Service

NAD 1983 StatePlane Texas Central FIPS 4203 Feet



USACE COASTAL TEXAS
PROTECTION AND RESTORATION STUDY

SP-1 - Redfish Bay Protection and Enhancement
2035 FWP Cover Types

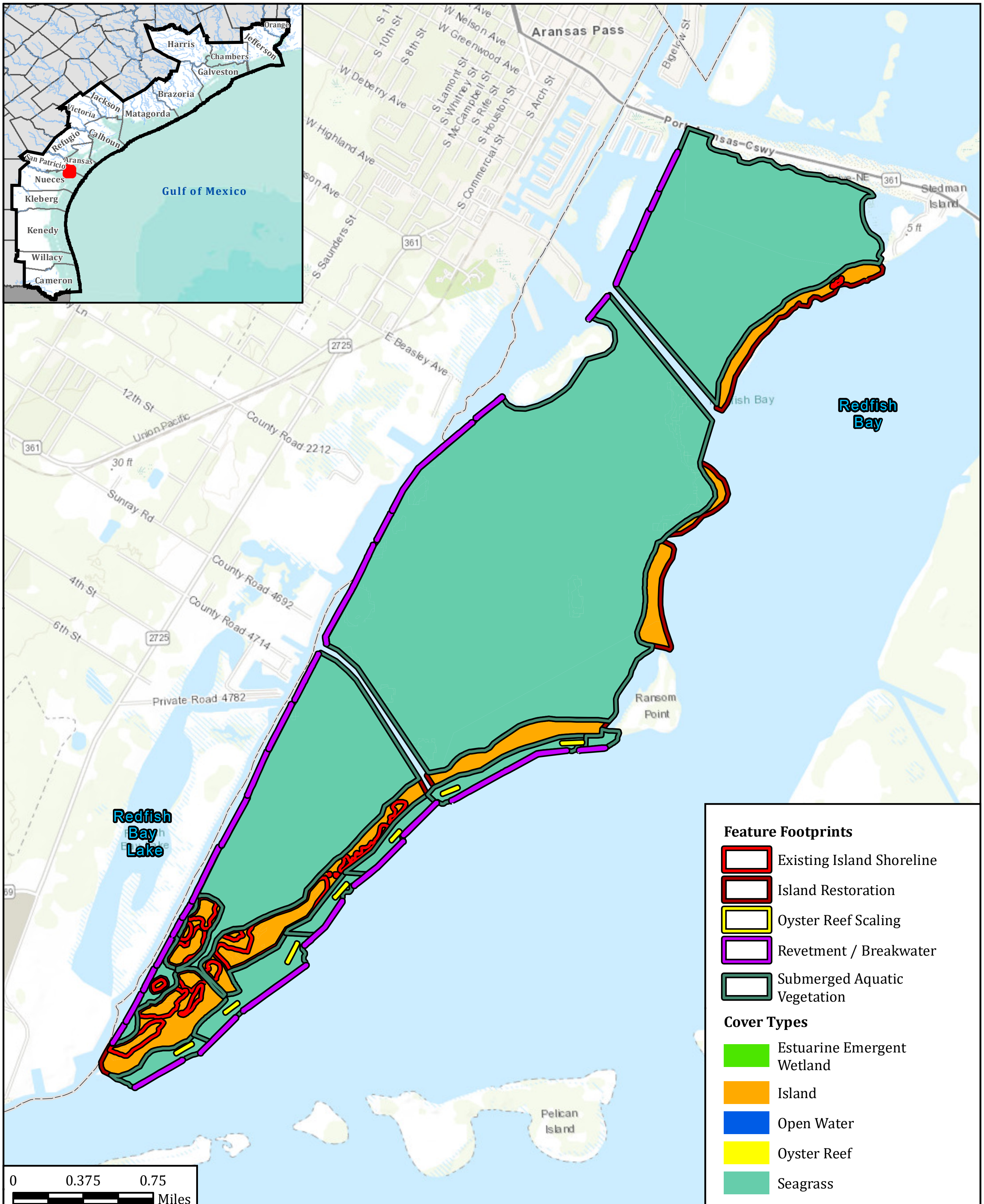
FN JOB NO	TGL18185
FILE NAME	6_SP1_Mapbook.mxd
DATE	9/2/2020
SCALE	1:45,110
DESIGNED	KLC
DRAFTED	02588

6.4

FIGURE

Base Map: ESRI World Topographic Map Service

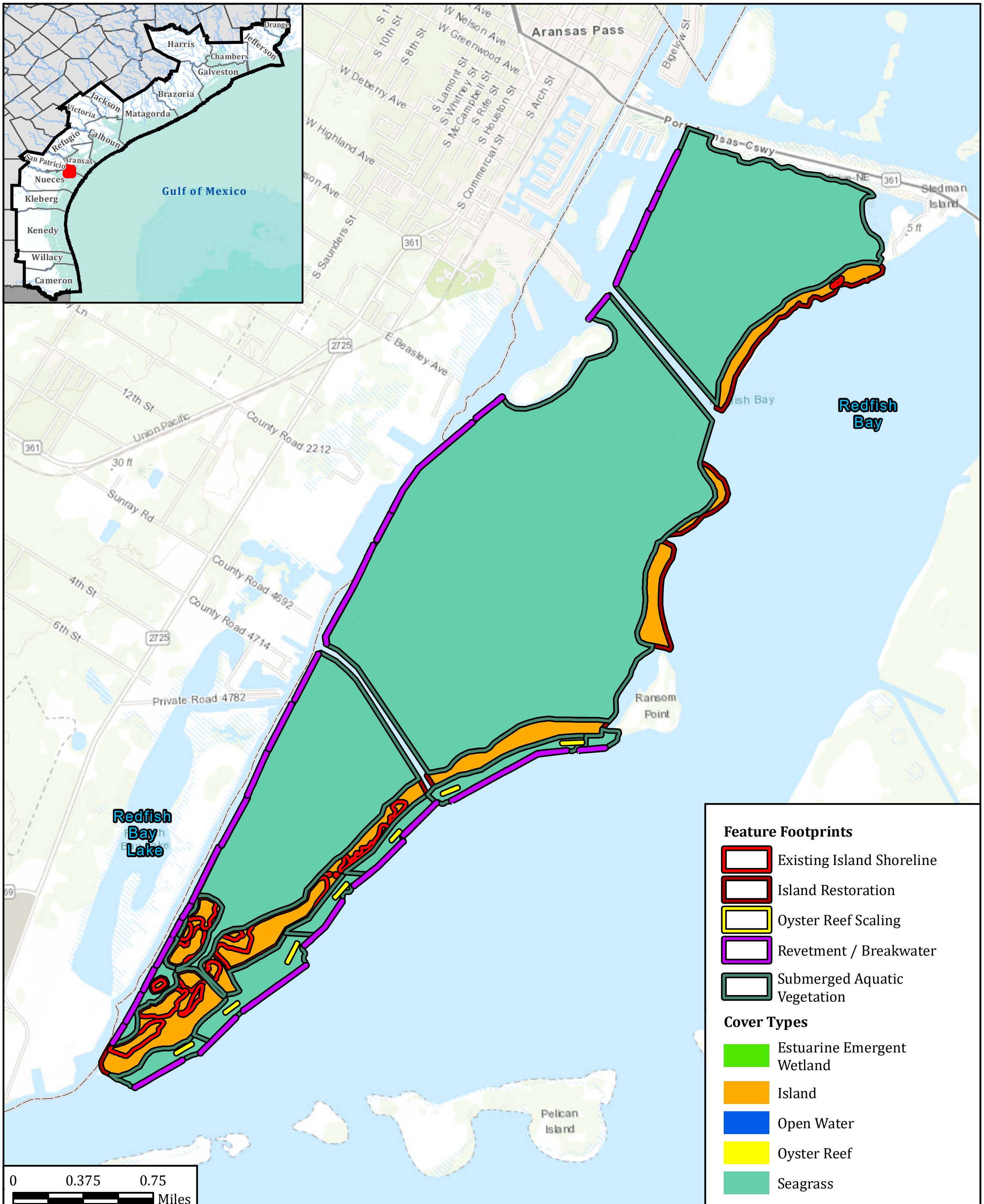
NAD 1983 StatePlane Texas Central FIPS 4203 Feet



N W E S	USACE COASTAL TEXAS PROTECTION AND RESTORATION STUDY	FN JOB NO TGL18185 FILE NAME 6_SP1_Mapbook.mxd DATE 9/2/2020	6.5
	SP-1 - Redfish Bay Protection and Enhancement **2065 FWP Cover Types**	SCALE 1:45,110 DESIGNED KLC DRAFTED 02588	**FIGURE**

Base Map: ESRI World Topographic Map Service

NAD 1983 StatePlane Texas Central FIPS 4203 Feet



USACE COASTAL TEXAS
PROTECTION AND RESTORATION STUDY

SP-1 - Redfish Bay Protection and Enhancement
2085 FWP Cover Types

FN JOB NO	TGL18185
FILE NAME	6_SP1_Mapbook.mxd
DATE	9/2/2020
SCALE	1:45,110
DESIGNED	KLC
DRAFTED	02588

6.6
FIGURE

Base Map: ESRI World Topographic Map Service

NAD 1983 StatePlane Texas Central FIPS 4203 Feet

W-3

Habitat Modeling

Project: W-3 Spotted Seatrout

Condition: Future Without Project

Timeframe / Site Inputs		TY-1	TY-2	TY-3
TY	Target Year	0	1	31
Acres	Affected Acreage by Target Year	46810	46081	37405
Function Inputs				
V1	Lowest monthly mean winter and spring salinity (ppt) (Range 0 to 50 ppt)	30	32	34
V2	Highest monthly mean summer salinity (ppt) (Range 0 to 50 ppt)	29	31	33
V3	Lowest monthly mean winter water temperature (°C) (Range 0 to 50 °C)	15	15	15
V4	HIghest monthly mean summer water temperature (°C) (Range 0 to 50 °C)	31	31	31
V5	Percent of area with submerged and/or emergent vegetation, submerged islands, shell reefs, or oyster beds. (Range 0 to 100 %)	41	40.9	33.2
HSI	Habitat Suitability Index	#NAME?	#NAME?	#NAME?

Condition: Future With Project

Timeframe / Site Inputs		TY-1	TY-2	TY-3
TY	Target Year	0	1	31
Acres	Affected Acreage by Target Year	46810	56333	47320
Function Inputs				
V1	Lowest monthly mean winter and spring salinity (ppt) (Range 0 to 50 ppt)	30	27	31
V2	Highest monthly mean summer salinity (ppt) (Range 0 to 50 ppt)	29	26	30
V3	Lowest monthly mean winter water temperature (°C) (Range 0 to 50 °C)	15	15	15
V4	HIghest monthly mean summer water temperature (°C) (Range 0 to 50 °C)	31	31	31
V5	Percent of area with submerged and/or emergent vegetation, submerged islands, shell reefs, or oyster beds. (Range 0 to 100 %)	41	50	42.2
HSI	Habitat Suitability Index	#NAME?	#NAME?	#NAME?

Condition: Future Without Project

Timeframe / Site Inputs		TY-4	TY-5	TY-6
TY	Target Year	51		
Acres	Affected Acreage by Target Year	21547		
Function Inputs				
V1	Lowest monthly mean winter and spring salinity (ppt) (Range 0 to 50 ppt)	36		
V2	Highest monthly mean summer salinity (ppt) (Range 0 to 50 ppt)	35		
V3	Lowest monthly mean winter water temperature (°C) (Range 0 to 50 °C)	15		
V4	HIghest monthly mean summer water temperature (°C) (Range 0 to 50 °C)	31		
V5	Percent of area with submerged and/or emergent vegetation, submerged islands, shell reefs, or oyster beds. (Range 0 to 100 %)	28		
HSI	Habitat Suitability Index	#NAME?	#NAME?	#NAME?

Condition: Future With Project

Timeframe / Site Inputs		TY-4	TY-5	TY-6
TY	Target Year	51		
Acres	Affected Acreage by Target Year	41687		
Function Inputs				
V1	Lowest monthly mean winter and spring salinity (ppt) (Range 0 to 50 ppt)	32		
V2	Highest monthly mean summer salinity (ppt) (Range 0 to 50 ppt)	31		
V3	Lowest monthly mean winter water temperature (°C) (Range 0 to 50 °C)	15		
V4	HIghest monthly mean summer water temperature (°C) (Range 0 to 50 °C)	31		
V5	Percent of area with submerged and/or emergent vegetation, submerged islands, shell reefs, or oyster beds. (Range 0 to 100 %)	37		
HSI	Habitat Suitability Index	#NAME?	#NAME?	#NAME?

Condition: Future Without Project

TY	Acres	HSI	Total HUs	Cumulative HUs
0	46810	0.82	38384.20	
1	46081	0.82	37786.42	38085.31
31	37405	0.66	24687.30	930165.00
51	21547	0.56	12066.32	362250.20
Max TY=	**51**		AAHUs=	**26088.2**

Condition: Future With Project

TY	Acres	HSI	Total HUs	Cumulative HUs
0	46810	0.82	38384.20	
1	56333	0.83	46756.39	42554.42
31	47320	0.83	39275.60	1290479.85
51	41687	0.74	30848.38	699549.90
Max TY=	**51**		AAHUs=	**39854.6**

Net Change in AAHUs due to Alt1A	
Future With Project AAHUs	39854.6
Future Without Project AAHUs	26088.2
Net Change	13766.3

Project: W-3 Port Mansfield Channel, Island Rookery, and Hydrologic Restoration

Brown Pelican HSI Model Spreadsheet

What State is the Project Location TX

Acres 4

Condition: Future Without Project

Variable		TY 0	SI	TY 1	SI	TY 31	SI
V1	Island surface area	Less than 2 ha (4.9 ac)	0.40	Less than 2 ha (4.9 ac)	0.40	Less than 2 ha (4.9 ac)	0.40
V2	Distance of island from mainland*	2.5	1.00	2.5	1.00	2.5	1.00
V3	Distance of island from nearest human activity center*	2.5	1.00	2.5	1.00	2.5	1.00
V4 (WDY)							
V4	Percent of Island surface area at least 0.6 m elevation	7	0.14	0	0.00	0	0.00
		HSI=	0.49	HSI=	0.00	HSI=	0.00

Acres 28

Condition: Future With Project

Variable		TY 0	SI	TY 1	SI	TY 31	SI
V1	Island surface area	Less than 2 ha (4.9 ac)	0.40	Greater than 8 ha (19.8 ac)	0.40	Greater than 8 ha (19.8 ac)	0.40
V2	Distance of island from mainland*	2.5	1.00	2.5	1.00	2.5	1.00
V3	Distance of island from nearest human activity center*	2.5	1.00	2.5	1.00	2.5	1.00
V4 (WDY)							
V4	Percent of Island surface area at least 0.6 m elevation	7	0.14	97	1.00	97	1.00
		HSI=	0.49	HSI=	0.80	HSI=	0.80

Condition: Future Without Project

Variable		TY 51	SI	TY	SI	TY	SI
V1	Island surface area	Less than 2 ha (4.9 ac)	0.40				
V2	Distance of island from mainland*	2.5	1.00				
V3	Distance of island from nearest human activity center*	2.5	1.00				
V4 (WDY)							
V4	Percent of Island surface area at least 0.6 m elevation	0	0.00				
		HSI=	0.00	HSI=		HSI=	

Condition: Future With Project

Variable		TY 51	SI	TY	SI	TY	SI
V1	Island surface area	Greater than 8 ha (19.8 ac)	0.40				
V2	Distance of island from mainland*	2.5	1.00				
V3	Distance of island from nearest human activity center*	2.5	1.00				
V4 (WDY)							
V4	Percent of Island surface area at least 0.6 m elevation	97	1.00				
		HSI=	0.80	HSI=		HSI=	

Condition: Future Without Project

Variable		TY	SI	TY	SI	TY	SI
V1	Island surface area						
V2	Distance of island from mainland*						
V3	Distance of island from nearest human activity center*						
V4 (WDY)							
V4	Percent of Island surface area at least 0.6 m elevation						
		HSI=		HSI=		HSI=	

Condition: Future With Project

Variable		TY	SI	TY	SI	TY	SI
V1	Island surface area						
V2	Distance of island from mainland*						
V3	Distance of island from nearest human activity center*						
V4 (WDY)							
V4	Percent of Island surface area at least 0.6 m elevation						
		HSI=		HSI=		HSI=	

* Measured as a straight-line distance in km.

Brown Pelican HSI Model Spreadsheet

Condition: Future Without Project

TY	Acres	HSI	Total HUs	Cumulative HUs
0	4	0.49	1.95	
1	0	0.00	0.00	0.65
31	0	0.00	0.00	0.00
51	0	0.00	0.00	0.00
Max TY=	51		AAHUs=	0.01

Condition: Future With Project

TY	Acres	HSI	Total HUs	Cumulative HUs
0	4	0.49	1.95	
1	28	0.80	22.27	10.87
31	28	0.80	22.27	668.03
51	28	0.80	22.27	445.35
Max TY=	51		AAHUs=	22.04

Net Change in AAHUs due to Project

Future With Project AAHUs	22.04
Future Without Project AAHUs	0.01
Net Change	22.03